ISSN 1880-7410

# KYB TECHNICAL REVIEW

OCT. 2017
No.55

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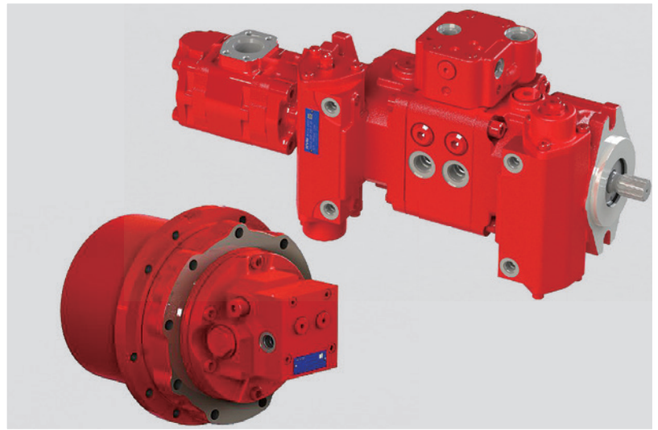

KYB Corporation

# KYB Corporation

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# KYB TECHNICAL REVIEW

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Foreword

# Quality over Quantity

OYAMA Osamu*

When the recruitment season comes, companies send their publications as reference for recruitment to universities. Such publications usually include articles written by their employees to introduce what they experienced in their work, probably hoping for students to learn what they do. I always read such articles. One day I noticed something. It was that I quite often found expressions like "I completed ○○ in a short time" or "I developed ○○ in a period half the time of the conventional development period" to describe their work. They expressed their satisfaction with their work by referring to time or quantity, rather than the importance or quality of it. I even felt sorry when I could not help but needlessly imagine that they might have been forced to finish with their work within a fixed time limit.

The terms "quantity" and "quality" are often used as a pair. People generally believe that quality is superior to quantity. The terms "you get what you pay for" and "buy cheap goods and you throw your money away" may be the antithesis of mass production or consumption at low prices. I think the feeling of happiness obtained from satisfaction with quantity of things will gradually change to longing for quality of things that cannot be replaced by anything else. I encountered an interesting story on this relationship between quantity and quality. It was "Biological Civilization" (the book I have was published by Shinchosha in 2011) written by Tatsuo Motokawa, who is famous for his book titled "The Elephant's Time and the Mouse's Time". Although being a biologist, he worked for a technical college at the time of writing the book and rolled out bitter criticism against science and technology based on his experience of working for the college in which he was surrounded by straightforward or rational people who were likely to think about everything in a mathematical or physical way. For example, against the fear that one fifth of the species of living organisms on the planet would become extinct and only 20 million species would survive in 30 years, many scientists may think that is no problem because as many as 20 million species will be still on the planet. Motokawa asserts that this way of thinking is thoughtless. Chains of individual species and living organisms support the environment, and none of these species can be replaced by any other. In other words, quality is essential. Scientists generally rely on Elementalism, where everything is decided simply by totalling the elements and concentrating attention to numerical formulas and data solely handling quantity, not trying to consider quality, according to Motokawa.

I do not think I'm qualified to speak out on large scale topics such as science and technology, but it reminds me that I may have something in mind. That is, various events that should be originally expressed in quality are often expressed in quantity or numeric values, and this way of expression is quite normally accepted. Speaking of economics, Gross National Product (GNP), Gross Domestic Product (GDP) and Gross National Income (GNI) are typical examples. These indexes are based on some type of assumption (or modeling) for quantification, but actually get out of control with the assumption itself never being closely examined. The engineering industry also digitizes individual objects with different characteristics and takes it for granted that they are arithmetically evaluated, which may be too strange in an intrinsic sense. For example, performance and cost are digitized, weighted quite at random and summed up together to be used as evaluation functions. What must be essentially evaluated in quality may be (unfairly?) evaluated in quantity.

Still, you may want to argue that science and technology have not solely pursued quantity. One of the first terms that include the word "quality" I remember is "product quality". Certainly digitized data may be widely used as a measure for quality management, but the thing on which prime importance is placed in the field is people's precious experiences, and ideas that can never be digitized. That is the "quality" aspect of the product. What about the hot topic of "artificial intelligence" (AI)? Some may condemn AI that deals with large amounts of data, namely quantity, but AI uses living organisms as a good model. In the process of cementing a fresh idea, it cannot be realized through learning based on large amounts of data if its quality is poor.

Currently AI has gained the spotlight, but they say it temporarily died down for a period a short while ago. In that period, computer-based intelligence was said to have limitations. The number of AI researchers perhaps drastically decreased after many of them gave up. Still, those who continued working with strong belief helped AI research make a come back. I heard that genetic algorithms (GA), which were revitalized a while ago, is what was achieved by a researcher who continued his study without fear, even if the utility could not gain attention. I think this is another stage on which the relationship "quality over quantity" exists.

* Professor, School of Science and Technology, Meiji University

Essay

# Report on Residence at KTS

NAGAE Tatsuhiko

## 1. Introduction

From July 2014 to January 2017, I was on an overseas assignment in KYB Trading Shanghai (hereafter referred to as KTS), a group company in Shanghai, China.

I was accompanied by my wife and three children in China. As the one-child policy has been applied there until recently, almost no families had three children (or rarely had two). When I walked around the town with my children, we were always in the center of attention and were spoken to by people. I'd like to explain some of the slightly difficult but fun and interesting expatriate life.

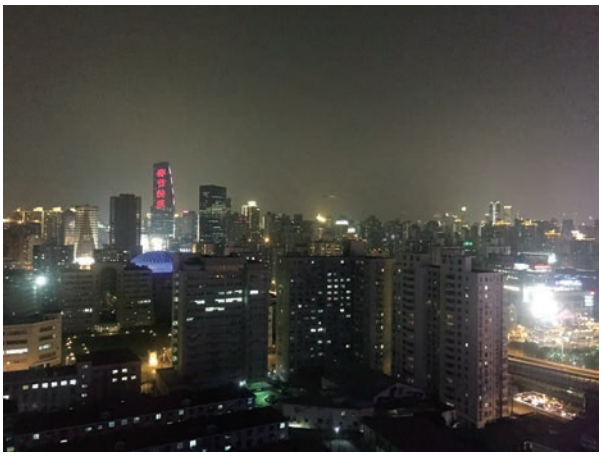

**Photo 1** View from home

## 2. Life in China

There are about 60,000 Japanese expatriates in Shanghai. The city always accommodates 100,000 Japanese, including those on a business trips, and many high-quality restaurants, department stores and supermarkets for Japanese. Public transportation is reasonable and runs throughout the city, which makes traveling easier with no trouble. As bus drivers are quite erratic here, people who are easy to get travel-sick and scared shouldn't travel on buses often.

Air pollution is very severe, as reported in Japan. Although Shanghai is relatively better compared to Beijing and Hebei in the north, it is not comparable to the clean air in Japan. At first, I was concerned and wore a mask outside. However, I rarely wore it in the end as I couldn't be bothered to wear it every day, and a mask that can completely block PM2.5 is expensive and looks ugly like a gas mask.

**Photo 2** PM2.5

Rent is as expensive as Tokyo but has many defects, no sound insulation and a poor hygienic environment. As for noise, although we were the ones who bothered others, many Chinese people like children and forgave as they knew we had three children.

Children went to a massive Japanese school which had over 2,000 students. The school had around 3,000 students before the Senkaku Islands issue occurred. The Japanese school with the largest number of students in the world at present is in Bangkok. However, Shanghai outstrips Bangkok in the total number of students as they have two schools with around 2,000 students. The first grade has the largest number of classes and the number decreases as the grade rises, as more accompanying family members (leaving the expatriate alone) will return to Japan for junior high school exams. I felt that the education level is high as highly motivated teaching staff have been selected from Japan and many parents have a fervor for education, which increases students' willingness to learn. However, there is little development in foreign language skills in Japanese schools. A certain number of children, therefore,

go to an international school rather than Japanese school.

I made several trips to Zhenjiang, where a group company KYB Industrial Machinery is located. Unlike Shanghai, the city has only 30 to 40 Japanese and I couldn't communicate in Japanese at all there. Although there are more than 10 Japanese restaurants as Japanese food is popular, many of them are not authentic and all the food tastes strange, without using stock, or using Chinese flavors instead. I mainly traveled by taxi in Zhenjiang. Unlike Shanghai, taxi drivers there had bad manners and took other customers to share a ride if they were going in the same direction, which often made me feel confused. In terms of experiencing a different culture, Zhenjiang is far superior to Shanghai. It is a good place for people who would like to improve their Chinese skills as locals don't speak Japanese, and you can experience China deeply.

**Photo 3** Sports day in Japanese school

## 3. Chinese language

Japanese can recognize 60 to 80% of Chinese characters without prior knowledge. On the other hand, pronunciation of Chinese is very difficult and I had some difficulties until I became used to communication with Chinese people. The pronunciation of one letter, for example "ma" has four types of intonations (four tones) and each tone has a completely different meaning. Therefore, you often can't make yourself understand in Chinese if you can't pronounce it correctly. Chinese people blatantly pull a face (without offense) if they can't understand what a person says. You could easily lose hope if you don't have a strong spirit.

## 4. Procurement in China

The business of KTS where I belonged was shock absorber sales. In many cases, manufacturers and trading companies of products related to raw materials (steel, aluminum, hydraulic oil), which are procured by KIMZ and Wuxi KYB Top Absorber (group companies), are based in Shanghai. As it is beneficial for collecting information, I took on the procurement service as a member of KTS as I was in the Procurement Department of the KYB (China) Investment (KCI), which is also a group company.

During the period I resided in Shanghai, prices of raw materials have continued to decrease due to the excessive production capability resulting from excess capital investment by the Chinese government. This was a harsh time for manufacturers of iron and steel and aluminum with continued deficit. I think it was an easy environment for me to work in as procurement personnel, as all manufacturers were desperate for trading (even with unreasonable prices).

I was often told previously that most of the iron and steel manufacturers in China are state-owned or semi-nationalized companies and it is difficult to control them, as they behave like customers. However, I had the impression that they were actually very positive and cooperative due partly to the above-mentioned situation. As technical capabilities were behind for the quality level which KYB expected, the situation remained a dilemma for them not being able to generate results despite their motivation, which led to bad reputations. Nevertheless, I believe that companies which are willing to learn will eventually catch up with Japan in technical capabilities.

**Photo 4** Authentic Sichuan dish I had during a business trip

## 5. Business with Chinese

Compared to the Japanese, Chinese people clearly say Yes or No. I personally like this character. On the contrary, they also tend to say Yes when they are not sure whether they can do something or not. I felt that it was necessary to judge whether it actually meant Yes in business situations. If they say No, it purely means No.

As a national character, Chinese people are kind once you become good friends with them. I think this implies the fact that people say building relationship is important in doing business in China. Although building a close relationship is best in private life, it is difficult to judge whether it is good to become closer with clients who have vested interests, as there is a risk and possibility of creating future constraints. It may be best if you completely understand Chinese culture and language, and

build a relationship beyond constraints. I felt it was not easy to build such relationship during the period of assignment.

I feel that Chinese people are better in negotiations than Japanese. While Japanese people tend to find a compromise immediately, Chinese people have a high tendency to be bitter-enders to the end. Nevertheless, they still have a smartness to prepare a compromise plan when they really have to give in.

Although it seems that I have only mentioned good points about Chinese people, there also have dangerous aspects such as collusions and failures from early decisions (excessive investment and orders). Basically, they tend to be cold toward others except for family members and close friends. As a result, many Japanese people feel that Chinese people are not kind.


**Photo 5** Crowded Hongqiao Station, Shanghai

## 6. Travels within China

I made some time to travel around China as I thought I will have no opportunities after I return to Japan, unless I really love China.

I visited most of the tourist sites where Japanese are likely to go (The Great Wall, Jiuzhaigou, Guilin, Emeishan, Leshan Giant Buddha, Huangshan, Xhangjiajie, Hainan, etc.) except for backlands such as Tibet and Mongol, and cold regions such as Harbin. After I learned to speak a little Chinese, I took my family to places where Japanese tourists would never go (Nanchang, Wuhan, etc.)

At first, I traveled with a Japanese tour group. After I realized the cost of these tours was extremely high and I had no free time, I mostly visited these places independently.

The largest problem of independent tours is transportation. It is easy to rent a car but it costs 30,000 to 40,000 yen per day, even in rural areas, if you use a reliable company. As we can't even communicate in Japanese in most cases, it is not worth paying that much. Except for when we went to remote regions, we took a taxi to go to our destinations from the station or airport. We had problems with transportation on the return trip. In many cases, it was difficult to find a taxi and public transportation was always very busy. I ended up often using private taxis. You may think private drivers are not safe, but if you use a popular car dispatch application, you can arrange a car in a safe and relatively reasonable manner. Although I had many problems when I didn't speak much Chinese, I could manage with a smattering of Chinese once I got used to it.

Over 15 million drivers are registered in this car dispatch application, and it has a 90% share in China, which is the biggest market in the world with over 300 million users. You can arrange a car with little trouble, even in rural areas where you often find it difficult to catch a driver, if you pay extra for a tip. The car dispatch market is hardly developed in Japan as the push-back of the taxi industry and legal restrictions are strong. I hope it will develop as it is a very convenient system.

Back to the travel story, sightseeing spots in China are ranked from 1 to 5 stars. Although we have a negative image of China as being unhygienic, inconvenient, unkind, crowded, no toilets, etc., we can visit places with 5 stars comfortably without those problems, except for too many people and being noisy.

**Photo 6** The Great Wall of China

## 7. Dialects and Food Culture in China

There are countless numbers of different dialects and foods in China, which even the Chinese can't keep track of.

You can basically communicate anywhere in China in Beijingese (standard language), but each place has its own local dialect other than Beijingese. For example, Shanghainese is used in Shanghai. You can hear Shanghainese frequently if you are in Shanghai, I was unable to understand what they were saying. Beijingese and Shanghainese are completely different in words and pronunciation. A certain number of elderly people in Shanghai can understand only Shanghainese, in which

case only people from Shanghai who understand the language can communicate with them.

These dialects are everywhere in China and Wuxi has its own dialect, although the city is located only one-hour drive from Shanghai. Like Shanghainese, there are words only people from Wuxi can understand.

There are as many different types of food as dialects. I tried various local dishes when I went on business trips, and I can still find new food ingredients, flavors and dishes.

## 8. In Closing

I would like to express my gratitude to local staff and expatriates who worked together in KTS, KCI and KIMX, and to the company which provided me with an opportunity to have valuable life experience for myself and my family by assigning overseas work to me.

Thank you very much.

**Photo 7** Panda, a national treasure of China (Shanghai Zoo)

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Essay

# Experience of ACTIVE Training (England, Spain)

OHMORI Yusuke

## 1. Introduction

I experienced a language training during the 6 months from March 2015 to August 2015 in England and on-the-job training in Spain for 1 year in 2016. Since I joined the company, I had been interested in working overseas. I was given the opportunity in the ACTIVE (Ambitious & challenging Traineeship for International Value-added Experience, an overseas training program) and had valuable experience through this training. As this program was a language training, I will explain my experience regarding language.

## 2. Language School

First, I stayed in Bournemouth for 3 months to learn general English. Bournemouth is a town located on the southern coast of England.

I arrived at Heathrow Airport, was picked up by an English taxi driver, and then traveled around 2 hours to Bournemouth. Only me and the English driver were in the car, so I remember I felt anxious as I didn't know what he was saying.

I arrived at the house where I was supposed to stay and met my host family. An English couple who were kind and welcomed me (Photo 1).

Their son had already left home so they accepted me and let me use his room.

**Photo 1** Host family

They were enthusiastic rugby fans. When they watched a rugby match on TV, I heard cheering from their room, which surprised me wonder until I got used to it. A Korean student also stayed in their house.

Upon arrival, the host explained to me how to go to school, how to take a bus, meal times, etc. Although I could only understand them a little, I got away with saying "OK, OK" because of nervousness.

I started going to school from the next day. Luckily, the Korean student attended the same school and took me there, so I could keep out of trouble.

At first, the school held an orientation and we took a placement test to determine class levels. They told us to chat with students sitting next to we during break time. I turned around to find a South American student and tried to speak using a few words I knew, but it was far from a conversation.

I was the only Japanese in the school and I had to count on my poor English.

Many university and high school students attended this school with different purposes for learning English: studying English during a holiday, government-aided English learning, preparation to go to university and so on. Some were soldiers.

My classmates were from Korea, Mexico, Oman, Turkey, Kuwait, Cote d'lvoire, Colombia, etc. (Photo 2).

As classes were determined based on the results of the placement test, I was put in a level higher than my speakry ability (judged from my written results) and felt very confused. Of course, all lessons were carried out in English and I had to ask questions in English. I was very nervous when I was told to introduce myself in front of more than 10 students.

Although I had received English education, the learning content was significantly different and focused on speaking, which surprised me. In schools in Japan, we listen to English, read and choose answers from A to D, or fill in the blanks. Here, we were expected to summarize and tell what you listened to and read, and talk to your classmates what you thought about it. We were always expected to output what we learned.

I was also simply surprised to see everyone scramble

**Photo 2** Classmates

to speak by raising their hands straight away, as we generally answer to teacher's questions after being called by name in Japan. I was strongly influenced by the attitude of everyone who spoke out what she/he wanted to say using words and grammar they knew regardless of ability.

Students who speak assertively improve more quickly. In this environment, you will rarely have a chance to speak unless you speak spontaneously and your English level will be slow to improve. I tried to speak assertively, keeping in mind not to care about making mistakes in the same way as the other students.

However, I had never experienced such environment as speaking English around foreigners before I studied overseas. I was afraid of speaking at first and it took me about one and a half months before I could think like this. Since then, I found myself feeling that my conversations became longer. I gradually gained confidence and started to enjoy conversations in English.

When I think back, I think I started to have longer conversations after having learned a technique of using other expressions when I couldn't make myself understood to get through the situation.

We talked about the differences of each culture during the class. Students from the Middle East said they like Ramadan because they can understand the feelings of poor people. I felt that it is a strange custom.

Once a week, we played soccer as an after-school activity. I could make friends outside the class through soccer which was my hobby. In particular, I enjoyed playing soccer more than ever in the beginning, probably because of stress from not being able to speak English. While playing soccer, I didn't know how to ask a favor and I couldn't understand when someone asked me a favor. I now know how much effort professional sport athletes playing overseas are making. At the same time, seeing them speak English with confidence, I gained motivation to learn (Photo 3).

**Photo 3** After-school activity (soccer)

Though only gradually, I continued to use English all day and I acquired the English ability to order, shop, make reservations and travel. Just as I became used to the life in England, I moved to a different town to learn business English. The town was Cheltenham and it was in the countryside near the border with Wales.

My host family changed to a host mother from Morocco and I lived with a Saudi Arabian student.

Unlike the previous school, adult students from Europe, including France, Germany, Czech Republic, Italy, Sweden, etc. attended the new school to improve their English skills.

All of the students said they couldn't work if they didn't speak English. Some said that English is the common language in their company.

Unlike general English, we had to learn new, unfamiliar terms in Business English. The class consisted of a small group of around 5 students and the teaching speed was faster. The small confidence I acquired during the three months in the previous school immediately disappeared and I had to start from scratch. When I think back, I gained and lost confidence repeatedly.

Our class activities included practice for presentations, practice in explaining graphs and simulated meetings. I practiced explaining what KYB is using, what they are, and what they are used for.

Through learning in the language schools, I realized that we should "speak" foreign languages. Since then, I could understand how grammar and syntax are used in conversations. Honestly speaking, although it was a little hard until I began to have a certain level of conversations, this significantly changed my awareness towards foreign languages and made me think that leaning them is enjoyable.

## 3. Language Study

I think that pronunciation is a barrier everyone faces when studying a foreign language.

There are some sounds that can be a problem for Japanese (R, TH, V, etc.). I couldn't make myself

understood with these sounds unless I pronounced them clearly with correct month movements. Before I went overseas, I honestly thought it wasn't a big problem, but it actually was.

I asked the host family, "can I borrow a DVD?" but they didn't understand at all even though I said it repeatedly. After that, they made me say "DVD" again and again during dinner time.

I had to move my mouth strongly when I spoke English. At first, I had muscle pain in my cheeks. We can speak Japanese without opening our mouths widely. It is important to speak out as you will not find what you are not good at until you speak, whether you are able to communicate or not.

A video site showing an approach to the barrier Japanese people may face in learning language was very helpful. For example, in order to pronounce the "R" sound, we can make a "Woo" sound in Japanese before saying "R." When I tried this, everyone was surprised and asked me "how did you improve so quickly?" Although I myself didn't notice so much difference, it seemed a big difference to native speakers. The grandson of the first host family was called Regan. When I saw him for the first time, I called him "Legan" and he corrected me "not Legan, woo-Regan." I thought it was the same, and pronouncing the "R" sound was a problem for me.

Although various ways to study English are introduced on the Internet, I think it is best to learn from your favorite things. Some recommend watching action movies and others say dramas. But if you are looking for learning materials, I think the best way to learn is to watch what you would like to watch as you are unable to continue learning unless you think it is fun. If you would like to get used to the language, you can read comics or anything. I think you should absorb the language from various things, not only from reference books. Learning a language is like muscle training. If you continue to speak, listen, read or write, you will gain these abilities.

The Korean student who stayed with me went on a trip and had his passport and wallet stolen. He couldn't return to England immediately. As he made same explanations in English at the embassy and school, he explained the situation better as he spoke.

You can never improve language skills in a short period and the only way to learn a language is to gain ability little by little.

## 4. KYB Steering Spain, S.A. (hereafter referred to as KSS)

After the 6-month language training in England, I started an internship training in KSS Quality Management Department in January 2016.

KSS's clients and suppliers are from the U.K., Germany, France, Spain, etc., and we communicated in each of their languages. To my biggest surprise, we used different languages (English, Spanish and French) in a single meeting for our clients from different countries. Materials of past results were also prepared in English, German, etc. and local staff working there use two to four languages at a high level. I felt as if I was knocked over as I struggled with English alone.

You need to communicate what you think accurately in practical English. As I was not good at practical English, I couldn't get information how I imagined. I was often in a position of communicating between Japan and the local site. It was rather difficult to transmit what the Japan side intended to say to the local site and vice versa.

As not all the local employees spoke English, I sometimes had to speak in Spanish. I started from not knowing how to read letters and numbers, I learned a few words every day by communicating in Spanish, just like I learned English.

Japanese expatriates require English or local language ability, although it depends on their position and location of work. The local language is used in internal meetings and English for clients. We spoke in Japanese when we communicated with the Japanese and interpreted to Japanese as needed.

## 5. Camino de Santiago

During my stay in Spain, I walked the paths in Camino de Santiago (meaning "the way to Santiago") on weekends and holidays. These are like pilgrim paths in Japan and the paths are registered as a World Heritage site. They are also pilgrimage routes for Christians and they walk about 800 km to the cathedral in Santiago de Compostela, located between western France and western Spain. Basically, you can always follow the arrows on the routes to the destination without getting lost (Photo 4).

The reason that I challenged this walk is because KSS is in Pamplona, a town located on one of these paths, and I found out during research that I could speak with people from various countries. It is impossible to walk all the routes, I walked when time allowed and headed to the destination using trains and buses.

I started walking at around 6:30 every morning and walked 25 to 35 km a day. Loaded with around 20 kg in a backpack, I walked through fields with grazing cattle, vineyards and barley fields, and sometimes through dark forests using a head light.

As heavy luggage can be a burden when walking a long distance, people threw away unnecessary goods on the way as a common sense. Some even ripped and threw away pages of novels and guidebooks.

Pilgrims who don't usually walk so much had many blisters on their feet. Walking in sweltering midsummer heat sometimes made me wonder why I was walking there.

I arrived at an Albergue, an accommodation for pilgrims by evening. I had dinner and went to bed around

8 pm, exhausted, and continued to walk the next morning. This was my daily routine during the pilgrimage.

Albergue is run by volunteers and you can stay reasonably for less than 10 Euros. This is one of the reasons why these routes are popular among tourists. However, I needed ear plugs to block snoring as we shared a room with others. I even stayed in a room with 100 people at the most.

In the final destination of Compostela, pilgrims and tourists who completed the pilgrimage can participate in Mass every day (Photo 5). There, they held a ceremony called botafumeiro, where eight adults pull ropes and swing about a large censer (53 kg, 1.5 m long) hanging on a pulley on the ceiling at a maximum speed of 68 km per hour. This was amazing. Originally, the ceremony began for the prevention of plagues and epidemics.

As people gather on these routes from all over the world, I could meet and speak to new people every day during breakfast, walking, lunch and dinner time. I chatted with a group of Irish people and spoke Spanish with Spanish people without using a dictionary. Actually, conversations between natives were so fast that it was difficult to understand, though I improved my language abilities during the journey. I recommend visiting this place for people who would like to learn foreign languages.

## 6. In Closing

I greatly appreciate all the people who gave me this valuable training opportunity and the local staff and expatriates who I worked with in KSS. I would like to utilize the experience I gained during the training program in future work.

**Photo 4** Camino de Santiago (arrow sign)

**Photo 5** Santiago de Compostela Cathedral

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Technology Explanation

# Analytical Technology for Axial Piston Pumps and Motors

SATO Naoto


## Abstract

Axial piston pumps and motors are key products of our company, and are subject to various requirements from vehicle manufacturers such as greater speed, higher pressure, higher efficiency, smaller size and lower cost. In order to meet these requirements, various techniques are being devised such as reducing pressure loss by optimizing pump or motor part shape, reducing loss torque by improving rotating and sliding sections, and changing the oil path structure.

In analysis technology for pump and motor characteristics, on the other hand, progress has been made for some time in improving prediction technology by carrying out analysis taking into account the movement of rotary parts. This analysis technology is used to predict torque when starting and in the low speed range. However, for the prediction of pump and motor efficiency in the high speed range, there are points where verification of the detailed analysis model has not been sufficient. Also, conventional analysis technology has had issues with greater complexity of the sliding section structure (spherical surface) and switching to a two-segment structure of the outlet port (split flow type).

In this paper, analysis technology for piston pump and motor characteristics, effective for the high-speed range, was developed to support various product specifications. In addition, validity was confirmed through experimental verification. This analysis technology has been deployed as a standard tool for design inside our company, and is routinely utilized for pump and motor development.


## 1 Introduction

Axial piston pumps and motors (hereinafter referred to as "piston pumps and motors" or independently "pumps" and "motors") are the key products of KYB Corporation and widely used in construction machinery, industrial vehicles and agricultural machinery. Manufacturers of these vehicles or machinery demand various requirements for piston pumps and motors, such as higher speed, higher pressure, higher efficiency, smaller size and lower cost. In order to meet these requirements, KYB has conducted many different improvements, including making the sliding sections of the valve plate spherical and switching into a two-segment structure of the outlet port (split flow type).

In analysis technology for the piston pumps and motors, on the other hand, design of the rotary part consisting of a cylinder block (hereinafter C/B), which forms the basis of the product, and pistons is the key issue. The rotary part has three major sliding sections between:

① C/B and valve plate
② C/B and piston
③ Swash plate and piston shoe

The characteristics of these three sections affect the pump and motor performance. Particularly the C/B is substantially affected by all the three sliding sections above. Establishing behavior prediction technology in implementing the optimal design of the rotary part is indispensable.

KYB has conventionally conducted analyses on C/B behavior (hereinafter "C/B hydraulic balance analysis") and calculation of cylinder internal pressure, and effectively used these results for development of pumps and motors. Particularly scenes arise in which prediction of the C/B behavior or efficiency in the high speed region is required with the recent demand for higher speed and higher efficiency. The conventional C/B hydraulic balance analysis, however, usually covered prediction of starting torque or driving torque at low speeds and was not sufficient enough to be applied to verification at the high speed region. In addition, improvements for implementing the spherical valve plate and split flow type stated above were also challenges.

Then KYB has established C/B hydraulic balance analysis technology to support various product specifications based on the conventional C/B hydraulic balance analysis calculation model. The following provides the overview and cases of analysis.

## 2 Analysis Target

### 2.1 Rotary Part

Fig. 1 shows the rotary part to be analyzed. The sliding section between the C/B and valve plate shown in Fig. 1 has a plane surface. It is generally possible to achieve higher speed, higher pressure and a more stable performance by modifying the sliding section into the spherical type [1]. The basic structure of the rotary part is shared by the pumps and motors. The pump rotates its drive shaft to cause the pistons to reciprocate, thereby enabling suction and discharge of oil. The motor, on the contrary, uses hydraulic power to rotate the drive shaft.

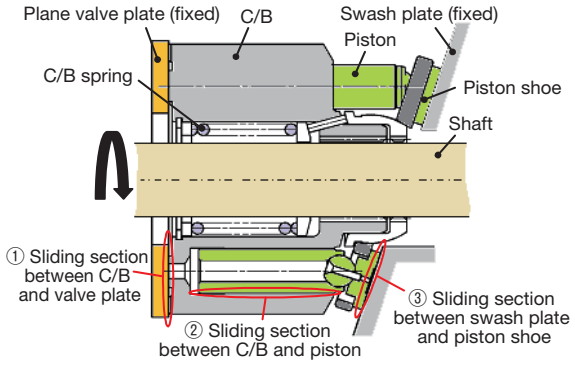
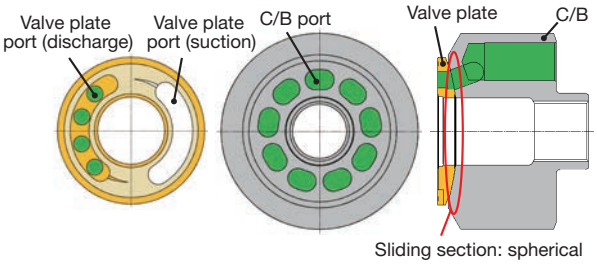


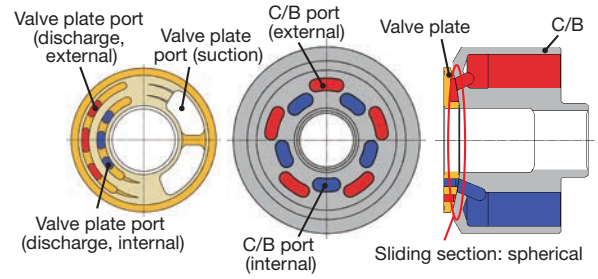

**Fig. 1** Rotary part

### 2.2 Supporting Various Product Specifications

The design has been modified to support not only the two types of valve plates (plane and spherical) but also two types of flow: single flow and split flow. The single flow type here refers to the general flow construction with one suction port and one discharge port as shown in Fig. 2 (a). The split flow type has internal and external C/B ports (internal: blue, external: red) as shown in Fig. 2 (b), enabling two independent discharges.




(a) Single flow type C/B, spherical valve plate port arrangement (for pumps)




(b) Split flow type C/B, spherical valve plate port arrangement (for pumps)

**Fig. 2** Construction of different flow types

## 3 C/B Hydraulic Balance

This chapter describes the hydraulic balance of the C/B, which is the basis of analysis.

The piston pump or motor contains the three major sliding sections as mentioned above. In particular, the sliding section between the C/B and valve plate is the critical part greatly affected by C/B behavior. It is necessary to minimize the leakage of hydraulic fluid from this sliding section and minimize friction and wear. To do so, C/B must be prevented from floating or inclining. It is also a must to avoid that C/B is pressed against the valve plate with excessive force. In other words, how to strike a dynamic balance of C/B is a critical issue.

To optimize the hydraulic balance of C/B, it is necessary to precisely identify the pressure distribution in the sliding section. Oil film pressure analysis is an effective approach to achieve this. The precision of the oil film pressure analysis depends on the precision of the modeling of the oil film profile in the sliding section. Therefore, how the oil film profile, which changes as C/B posture changes, can be modeled is important.

On the other hand, KYB has recently promoted development of a spherical valve plate, particularly that with a spherical diameter difference $C_L$, which is the difference between C/B spherical diameter $S_c$

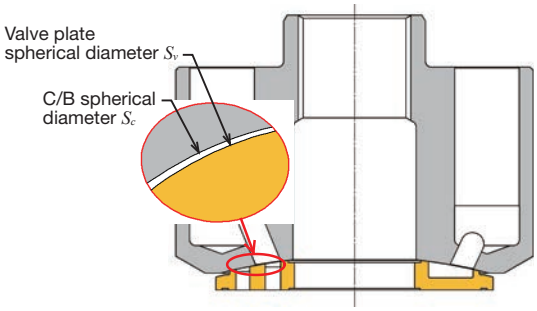
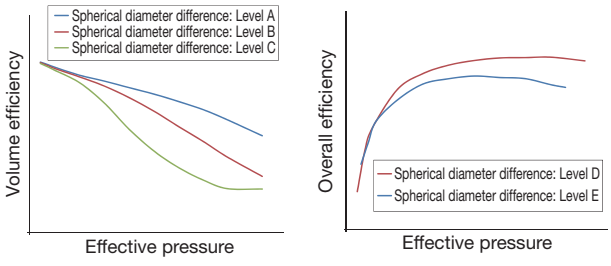



**Fig. 3** Spherical diameter difference $C_L$ ($=S_c-S_v$)




(a) Volume efficiency (b) Overall efficiency

**Fig. 4** Effect of spherical diameter difference $C_L$

and the valve plate spherical diameter $S_v$ ($C_L = S_c - S_v$, hereinafter "spherical diameter difference"). As an example, the results of tests on volume efficiency and overall efficiency on the effective pressure are shown in Fig. 4 (a) and (b) respectively. The findings that both the efficiencies greatly vary by the spherical diameter difference as shown in the figure imply how important the design of the spherical diameter difference is. However, the spherical diameter difference could not be taken into account in the conventional analysis approach based on the assumption that C/B and the valve plate had the same spherical diameter ($S_c = S_v$). This new analysis approach has introduced a modeling scheme for the oil film profile with the spherical diameter difference taken into account, thereby enabling evaluation of the possible effect of the difference.

## 4 Analysis Approach

### 4.1 Major Assumptions

This analysis approach uses the major assumptions:

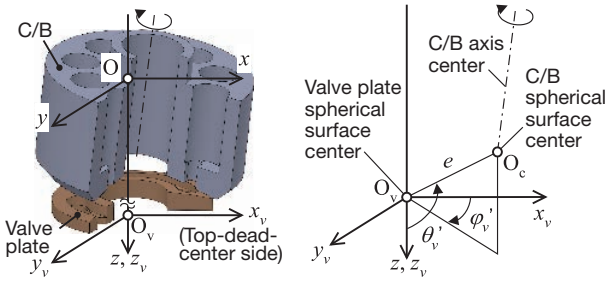
- Only the shaft is deformable and all the other parts are solid.
- Only the three sections listed below are considered as sliding sections:
  ① Between C/B and valve plate
  ② Between C/B and piston
  ③ Between swash plate and piston shoe.
  Wear in any other parts is ignored.
- The mass of all parts is ignored.

### 4.2 Oil Film Pressure Analysis

The profile of the oil film in the sliding sections (① Between C/B and valve plate, ② Between C/B and piston, and ③ Between swash plate and piston shoe) is determined from the posture of C/B, pistons and piston shoes. Each of the oil film profiles is applied with the Reynolds Equation and the oil film pressure distribution is calculated using the finite element method (or the finite difference method). From the obtained oil film pressure distribution, the force, moment and leak rate are calculated.

As an example of the oil film profile, the following explains the sliding section between C/B and spherical valve plate with a spherical diameter difference. Aside from the overall coordinate system with its origin point O located at the spline center of the spline coupling between C/B and shaft shown in Fig. 5 (a), another local spherical surface coordinate system with its origin point located at the spherical surface center $O_v$ of the spherical valve plate (spherical diameter $S_v$) is assumed. With the zenithal angle $\theta_v$ and the azimuthal angle $\varphi_v$, the spherical surface center $O_c$ of C/B (spherical diameter $S_c$) is set to ($e$, $\theta_v'$, $\varphi_v'$) as shown in Fig. 5 (b). This decides the geometry of C/B and the valve plate. Since $e \ll S_v/2$, oil film thickness $h$ can be approximately expressed in the equation [2]:

$$h = C_L + e\sin\theta_v \sin\theta_v' \cos(\varphi_v - \varphi_v') + e\cos\theta_v \cos\theta_v' \quad (1)$$

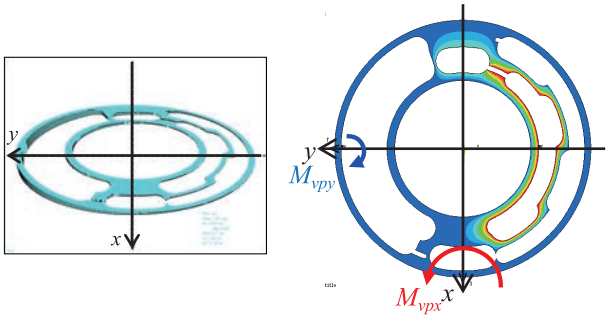



(a) Spherical surface coordinate system

(b) Spherical surface center of C/B and valve plate

**Fig. 5** Geometry of C/B and valve plate (for spherical valve plate)

The oil film profile of the split flow type determined from this analysis and the pressure distribution are shown in Fig. 6 (a) and Fig. 6 (b) respectively. According to Fig. 6 (a), oil film thickness $h$ varies by the position of the sliding surface, although the figure is somewhat exaggerated in the direction of thickness. Force $\overrightarrow{F_{vp}}$ and moment $\overrightarrow{M_{vp}}$, which both depend on the oil film pressure distribution in the sliding section, can be calculated from the pressure distribution shown in Fig. 6 (b). The arrows shown in the figure indicate the magnitude and direction of moments $M_{vpx}$ and $M_{vpy}$ around the $x$ and $y$ axes in red for a positive value, or in blue for a negative value.




(a) Example of oil film profile

(b) Example of pressure distribution

**Fig. 6** C/B-valve plate sliding section (for spherical valve plate)

### 4.3 Shaft Elastic Deformation Analysis

In the Cartesian coordinate system with its origin point O located at the spline center as shown in Fig. 7, the shaft

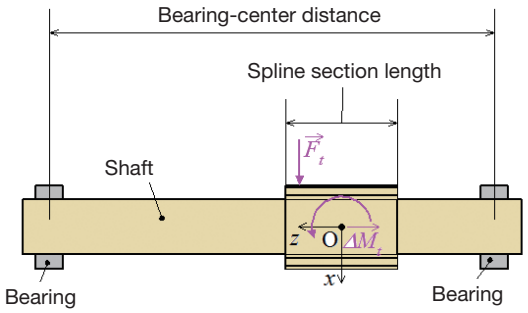



**Fig. 7** Forces applied to shaft

is assumed to be a beam supported by bearings. The shaft deflection is calculated from C/B reaction force at spline coupling $\overrightarrow{F_t}$ and reaction moment $\Delta\overrightarrow{M_t}$. The interface between C/B and the shaft includes a clearance for the spline coupling.

### 4.4 C/B Posture Analysis

The forces applied to C/B are shown in Fig. 8. These forces can be roughly divided into four groups: the resultant of forces applied to the C/B cylinder section ($\overrightarrow{F_{CB}}$), forces applied to the C/B valve plate section (force due to oil film pressure distribution $\overrightarrow{F_{vp}}$, contact force caused by unbalanced forces $\overrightarrow{F_{vm}}$, and force caused by friction $\overrightarrow{F_{\mu v}}$), forces applied by the shaft ($-\overrightarrow{F_t}$) and forces applied by C/B spring ($F_k$). The resultant of forces applied to C/B cylinder section $\overrightarrow{F_{CB}}$ is the total sum of the forces of all the pistons. With the inertia force applied to C/B ignored, the four groups of forces above and the moment balance around the origin point O can be expressed in the equations: [3].

$$\left.\begin{aligned} F_{CBx}+F_{vpx}+F_{vmx}+F_{\mu vx}-F_{tx}&=0\\ F_{CBy}+F_{vpy}+F_{vmy}+F_{\mu vy}-F_{ty}&=0\\ F_{CBz}+F_{vpz}+F_{vmz}+F_{\mu vz}-F_{tz}+F_k&=0 \end{aligned}\right\} \quad (2)$$

$$\left.\begin{aligned} M_{CBx}+M_{vpx}+M_{vmx}+M_{\mu vx}-M_{tx}&=0\\ M_{CBy}+M_{vpy}+M_{vmy}+M_{\mu vy}-M_{ty}&=0\\ M_{CBz}+M_{vpz}+M_{vmz}+M_{\mu vz}-M_{tz}&=0 \end{aligned}\right\} \quad (3)$$

where the terms in Equation (3) are the components around the axes of moment $\overrightarrow{M_{CB}}$, $\overrightarrow{M_{vp}}$, $\overrightarrow{M_{vm}}$, $\overrightarrow{M_{\mu v}}$ and $-\overrightarrow{M_t}$ generated by $\overrightarrow{F_{CB}}$, $\overrightarrow{F_{vp}}$, $\overrightarrow{F_{vm}}$, $\overrightarrow{F_{\mu v}}$, $-\overrightarrow{F_t}$ and $\Delta\overrightarrow{M_t}$.

C/B posture is calculated so as to satisfy Equations (2) and (3) above.

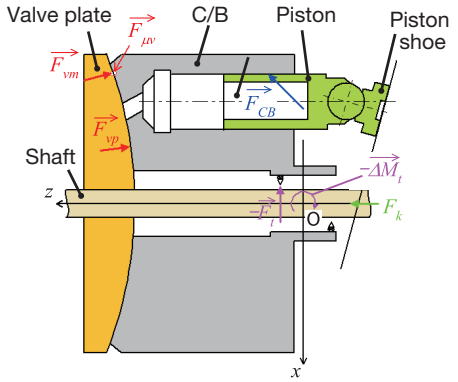



**Fig. 8** Forced applied to C/B

### 4.5 C/B Hydraulic Balance Analysis Procedure

Fig. 9 gives a flowchart of analysis on C/B hydraulic balance. After initial conditions are set, analysis on the oil film pressure for each C/B rotation angle, analysis on the shaft elastic deformation and analysis on C/B posture are repeated to provide convergent calculation of C/B posture. This set of calculations are conducted for each increase $\Delta\theta$ in C/B rotation angle until reaching one pitch (= result of 360 degrees divided by the number of pistons $n$). The various efficiencies are calculated from the leak rate for the pitch of C/B rotation angle and the average of lost torque.

## 5 Analysis Cases

### 5.1 Target Products

The target product of this analysis case is 1C/B piston pump PSVL2-42 for compact excavators [4] and is developed by using this analysis technology. Fig. 10 shows the appearance of PSVL2-42 and Table 1 provides the major specifications of PSVL2-42. This pump uses a spherical valve plate.

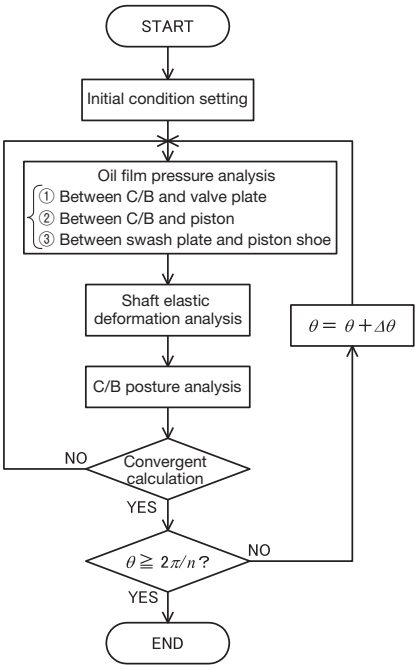



**Fig. 9** C/B hydraulic balance analysis flowchart

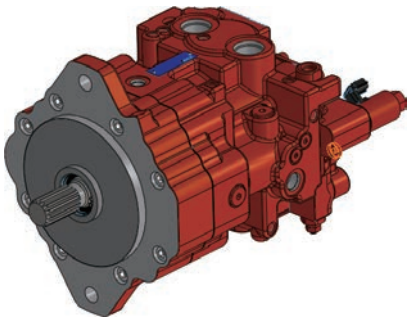


**Fig. 10** PSVL2-42

**Table 1** Major specifications of PSVL2-42

| Displacement [cm$^3$/rev] | Split flow: 42.3 + 42.3 |
|---|---|
| Max. pressure [MPa] | 32 |
| Max. speed [rpm] | 2,200 |

### 5.2 Analysis Condition

#### (1) Friction coefficient of each sliding section

The coefficient of friction is determined for each sliding section from the findings accumulated in the company and the results of newly conducted tests. The coefficient of friction in each sliding section is given according to the rotation speed.

#### (2) Minimum oil film thickness in each sliding section

Minimum oil film thickness in each sliding section is determined from the findings accumulated in the company and the results of newly conducted tests.

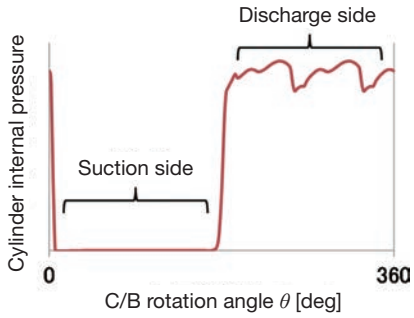



**Fig. 11** Cylinder internal pressure calculation result (example)

#### (3) Cylinder internal pressure

Calculation results of the cylinder internal pressure prediction program, which is KYB's design standard tool, are used for hydraulic balance analyses. The program can take into account the effects of swash plate vibration, discharge pulsation, notch profile and other factors. Fig. 11 gives an example of the result of cylinder internal pressure calculation for the external C/B ports of PSVL2-42. The horizontal axis represents C/B rotation angle $\theta$ and the vertical axis represents cylinder internal pressure. For analysis on C/B hydraulic balance, pressure pulsation on the discharge side may be considered as shown in Fig. 11.

### 5.3 Examples of Analysis Results

#### (1) Pressure distribution in C/B-valve plate sliding section

Figs. 12 and 13 show the pressure distribution in the sliding section between C/B and valve plate by 20 degrees of C/B rotation angle when the internal and external ports have high pressure respectively. The two figures show that, in either case of the high pressure internal or external port, the moment around $x$ axis $M_{vpx}$ is always stable with positive values, while the moment around $y$ axis $M_{vpy}$ shows negative and positive values that may be reversed depending on C/B rotation angle $\theta$. Since the internal and external ports have five pistons each, one pitch is 72 degrees.

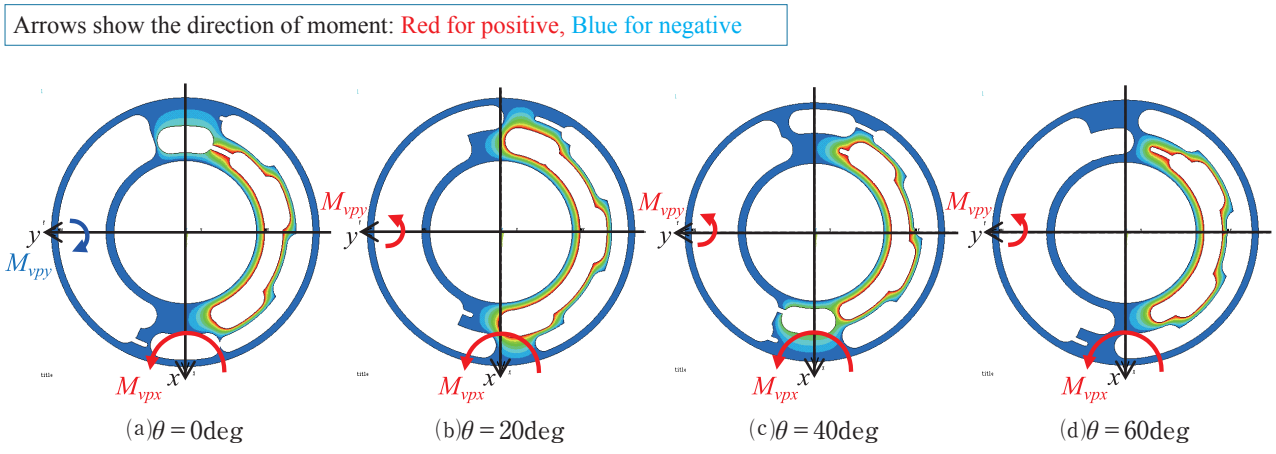



**Fig. 12** Pressure distribution in C/B-valve plate sliding section (spherical diameter difference ①, high pressure internal port)

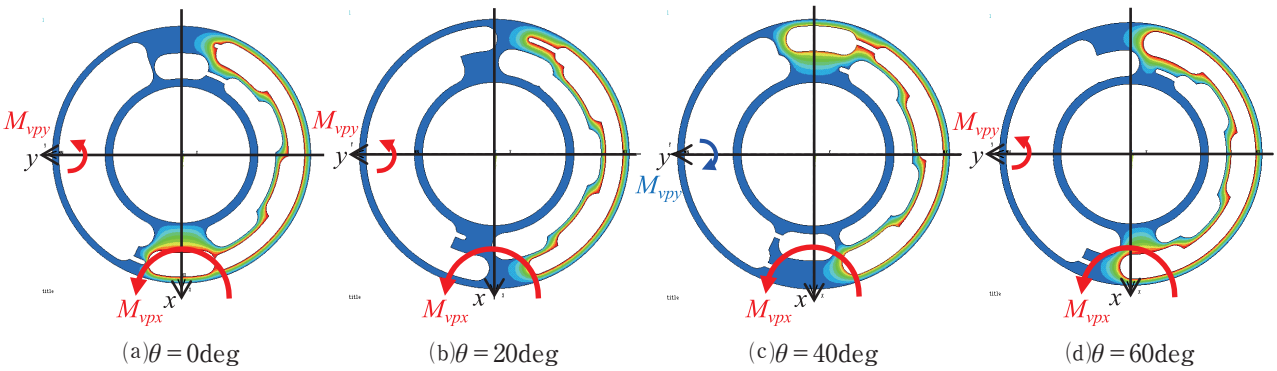
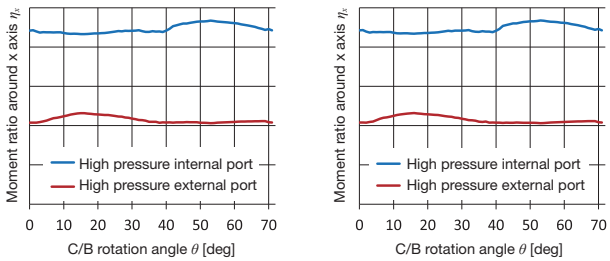
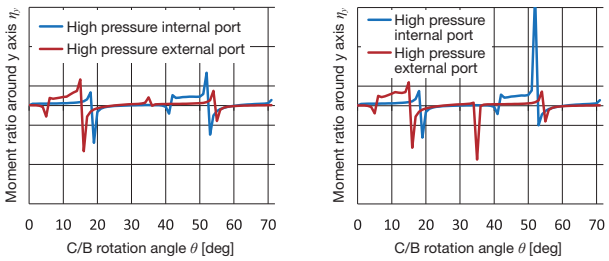



**Fig. 13** Pressure distribution in C/B-valve plate sliding section (spherical diameter difference ①, high pressure external port)




(a) Spherical diameter difference ①　(b) Spherical diameter difference ②

**Fig. 14** Moment ratio around $x$ axis $\eta_x$




(a) Spherical diameter difference ①　(b) Spherical diameter difference ②

**Fig. 15** Moment ratio around $y$ axis $\eta_y$

### (2) Moment ratio

Moment ratio is one of the hydraulic balance design indexes. Moment ratio around the $x$ and $y$ axes applied to C/B can be respectively expressed using the equation:

$$\eta_x = -\frac{M_{CBx}}{M_{vpx}},\ \eta_y = -\frac{M_{CBy}}{M_{vpy}} \tag{4}$$

Figs. 14 and 15 show the moment ratio around the $x$ and $y$ axes for one pitch for two levels of spherical diameter difference respectively. The effect of the spherical diameter difference on the moment ratio around the $x$ axis is small, while that on the moment ratio around the $y$ axis is substantial depending on C/B rotation angle $\theta$. This is probably because of the timing at which the moment around $y$ axis $M_{vpy}$ is switched between positive and negative values as stated in paragraph (1) above. Both moment ratios around the $x$ and $y$ axes should be designed so that the variation for one pitch can meet the design standard.

### (3) Pressing ratio

Pressing ratio is one of the hydraulic balance design indexes and can be expressed as the ratio of loads applied to the C/B in the direction of the $z$ axis using the equation:

$$\eta = -\frac{F_{CBz} + F_k}{F_{vpz}} \tag{5}$$

Fig. 16 shows the pressing ratio for a single pitch. In both the high pressure internal and external port cases, the pressing ratio substantially changes around C/B rotation angle $\theta$ = 0,40 degrees. These changes coincide with the timing of switching the number of high pressure pistons from two to three or three to two. Like the moment ratio, the pressing ratio should be designed so that the variation for one pitch can meet the design standard.

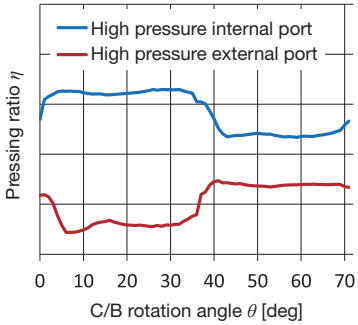



**Fig. 16** Pressing ratio

### 5.4 Experimental Verification of Analysis Precision

To verify the analysis precision, tests using actual machines were conducted for the two levels of the spherical diameter difference shown in Figs. 14 and 15. The relationship between the discharge pressure obtained from the actual machine tests and various efficiencies was compared to the analysis result as shown in Fig. 17. In the figure, a solid line indicates analysis results and a broken line indicates actual measurements. For volume efficiency, the high pressure external port case shows lower efficiency compared to the high pressure internal port case for both analysis and measurement, which is more obvious with spherical diameter difference ② than with spherical diameter difference ①. For mechanical efficiency, no substantial difference is seen between the high pressure external and internal port cases, or between the two levels of spherical diameter difference. As a result, the overall efficiency is dominantly affected by the volume efficiency for both analysis and measurements. From the results above, the analysis results have a very similar tendency to that of the actual measurements. It can be concluded that this analysis technology can be used for qualitative prediction of the various efficiencies as an effective tool for design development.

## 6 Concluding Remarks

Technology to analyze C/B hydraulic balance has been established to support various product specifications (plane and spherical valve plates, single and split flow types) of piston pumps and motors. In addition, the appropriateness of the calculation results on the various efficiencies at a high speed region has been verified. This analysis technology has been introduced as an in-house design standard tool and is effectively used for achieving higher efficiency in pump/motor development or optimal design of products.

From now on we will discuss application of the mixed lubrication theory or the elasto-hydrodynamic lubrication theory to the sliding sections that are currently applied

with the hydrodynamic lubrication theory, in order to address quality issues including seizure and wear.

Finally, I would like to show my deep appreciation to those who extended their full cooperation to the establishment of the analysis technology.

## Major symbols

$C_L$ : Spherical diameter difference ($= S_c - S_v$)
$h$ : Oil film thickness
$n$ : Number of pistons
$F_k$ : C/B spring force
$\overrightarrow{F_{CB}}$ : Resultant of forces applied to C/B cylinder section. Components in the direction of axes ($F_{CBx}$, $F_{CBy}$, $F_{CBz}$)
$\overrightarrow{F_t}$ : Force applied by C/B to shaft. Components in the direction of axes ($F_{tx}$, $F_{ty}$, $F_{tz}$)
$\overrightarrow{F_{vm}}$ : Contact force caused by unbalanced forces between C/B and valve plate. Components in the direction of axes ($F_{vmx}$, $F_{vmy}$, $F_{vmz}$)
$\overrightarrow{F_{vp}}$ : Force due to the oil film pressure distribution between C/B and valve plate. Components in the direction of axes ($F_{vpx}$, $F_{vpy}$, $F_{vpz}$)
$\overrightarrow{F_{\mu v}}$ : Friction force between C/B and valve plate. Components in the direction of axes ($F_{\mu vx}$, $F_{\mu vy}$, $F_{\mu vz}$)
$\overrightarrow{M_{CB}}$ : Combined moment related to the origin point O of forces applied to C/B cylinder section $\overrightarrow{F_{CB}}$. Components in the direction of axes ($M_{CBx}$, $M_{CBy}$, $M_{CBz}$)
$\overrightarrow{M_t}$ : Moment caused by force applied by C/B to shaft $\overrightarrow{F_t}$ and reaction moment $\overrightarrow{\Delta M_t}$. Components around axes ($M_{tx}$, $M_{ty}$, $M_{tz}$)
$\overrightarrow{M_{vp}}$ : Moment caused by force $\overrightarrow{F_{vp}}$ due to the oil film pressure distribution applied to C/B valve plate section. Components around axes ($M_{vpx}$, $M_{vpy}$, $M_{vpz}$)
$\overrightarrow{M_{vm}}$ : Moment caused by contact force $\overrightarrow{F_{vm}}$ resulting from unbalanced forces applied to C/B valve plate section. Components around axes ($M_{vmx}$, $M_{vmy}$, $M_{vmz}$)
$\overrightarrow{M_{\mu v}}$ : Moment caused by friction force $\overrightarrow{F_{\mu v}}$ applied to C/B valve plate section. Components in the direction of axes ($M_{\mu vx}$, $M_{\mu vy}$, $M_{\mu vz}$)
$\overrightarrow{\Delta M_t}$ : Reaction moment applied by C/B to shaft. Components in the direction of axes ($\Delta M_{tx}$, $\Delta M_{ty}$, $\Delta M_{tz}$)
$e$, $\theta_v$', $\varphi_v$': Coordinate of C/B spherical surface center
$O_c$ : C/B spherical surface center
$O_v$ : Spherical surface center of spherical valve plate
$S_c$ : C/B spherical diameter
$S_v$ : Valve plate spherical diameter
$\eta$ : Pressing ratio
$\eta_x$, $\eta_y$ : Moment ratio around x and y axes
$\theta$ : C/B rotation angle
$\Delta\theta$ : Increase in C/B rotation angle used during C/B hydraulic balance analysis
$\theta_v$ : Zenithal angle
$\varphi_v$ : Azimuthal angle

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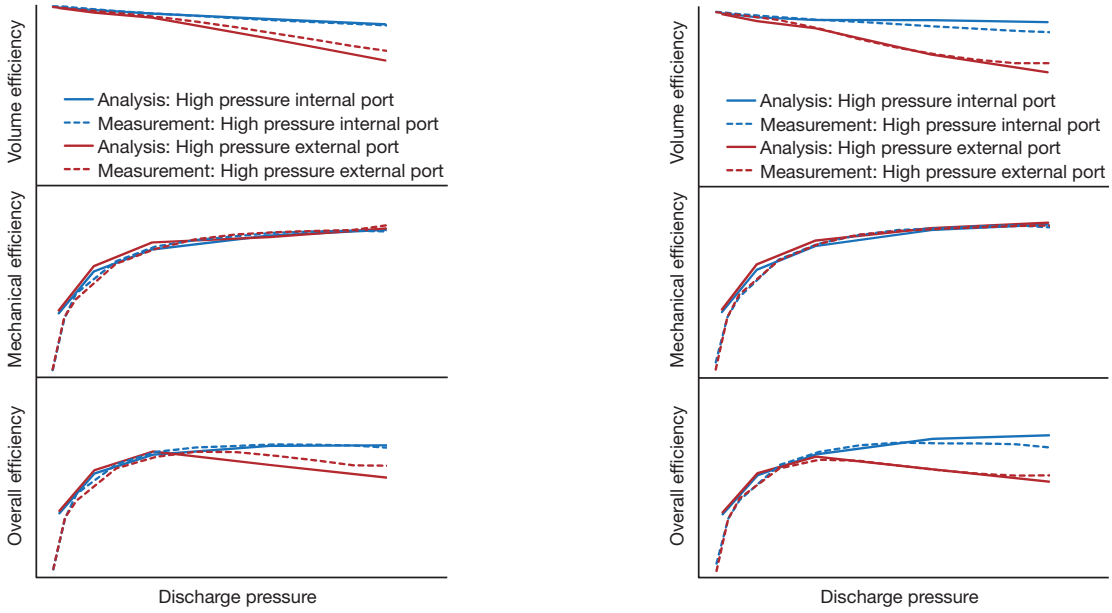


(a) Spherical diameter difference ①　　(b) Spherical diameter difference ②

**Fig. 17** Example of efficiency precision verification (piston pump)

3) YAMAGUCHI: Formation of a Fluid Film Between a Valve Plate and a Cylinder Block of Piston Pumps and Motors, 1st Report, Valve Plate with Dynamic Pad, Transactions of the Japan Society of Mechanical Engineers (JSME), Series B, Vol.51, No.469 (1985).
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Technology Explanation

# Surface Treatment of Aluminium Alloy for Tribological Applications

NAKASE Takuya ・ SAKURAGI Kenji

**Abstract**

Among various light-weight materials, aluminium alloy is the most typical material used for products at KYB. However, common aluminium alloys are not sufficiently wear resistant. This is problematic when such alloys are used for tribological application in mechanical parts.

Anodizing is typically used for surface treatment of aluminium. Plasma electrolytic oxidation (PEO) is more wear resistant than anodizing. The first step for designing machinery is to determine the substrate material. Therefore, the influence of substrate material on PEO film is discussed first in this report. The tribological properties of PEO films deposited on three different aluminium alloys are investigated.

In mechanical parts such as hydraulic shock absorbers, it is necessary to consider hydraulic oil. Our last report (KYB Technical Review, Vol. 51) described the tribological properties of PEO film lubricated with several hydraulic oils. In this report the tribological properties of the PEO film are further discussed using a wetting parameter from the view point of surface free energy.

## 1 Introduction

With recent increasing environmental awareness, the demand for lighter components has become even more obvious. As an example, shock absorbers for automobiles can be reduced in weight to provide possible effects:

- Improved fuel economy and higher maneuverability with a lighter vehicle body, and;
- Greater ride quality with lower unsprung mass.

Lower weight design may be implemented by making the structure smaller or replacing the materials with lighter ones for instance. Typical light-weight materials include aluminium, magnesium, titanium and other alloys, as well as carbon fiber reinforced plastics and other similar resins. In particular, aluminium alloy is the first option to be considered since it is generally superior in cost, specific strength, corrosion resistance and thermal conductivity compared to magnesium and titanium. With its relatively lower melting point, aluminium can also be easily remolten for recycling. This excellent recyclability makes aluminium a sustainable material.

However, aluminium as substrate material is likely to wear due to its lower hardness compared to steel, often presenting problems. Wear in mechanical parts in tribological interfaces leads to performance degradation or machinery failure. When sliding parts of a pump wear for instance, leakage through the interface between the contact part may increase, resulting in lower volume efficiency. Wear debris may also cause galling or seizure, leading to not only a pump problem but also system failure.

Therefore, what should be done first in order to use aluminium alloy for tribological applications is to improve the wear resistance of the alloy. It is also necessary to properly control the wear occurring in tribological applications since it always affects the mechanical efficiency and other performances. In other words, the tribological properties of the surface of aluminium alloy are very important. This report explains various tribological technologies related to surface treatment coating on aluminium alloy.

## 2 Surface Treatment of Aluminium Alloy

### 2.1 Anodizing

Although surface treatment of aluminium may be done by plating or chemical conversion coating, anodizing is known to be the most typical method. Anodizing has been used from long ago as a means to increase resistance to corrosion and wear of aluminium substrate materials. In particular, hard anodizing can create coating highly resistant to wear with a high hardness.

In the anodizing process, passing an electric current through an electrolytic solution of sulfuric, oxalic or chromic acid with the material to be treated, serving as the anode, will grow the aluminum oxide film over the material surface. The thickness and quality of the film depend on the current density, the concentration and temperature of the electrolytic solution, and the time of the process. The film produced by anodizing is certainly an oxide of aluminium, but does not have a specific crystal structure. It is different in structure and hardness from

crystalline aluminum oxides such as the film produced by plasma electrolytic oxidation ($\alpha$, $\gamma$-alumina) described later.

The anodized film has a microscopic structure as shown in Fig. 1 [1]. A dense oxide layer called a "barrier layer" is produced over the surface of the aluminium substrate material. On top of the layer grows a cellular oxide layer consisting of hexagonal pillars. Each cell has a micropore in its center that penetrates down to just above the barrier layer. Unlike plating, anodizing provides an oxide film that grows due to the reaction of the substrate material. The cell size is approximately 300 nm, the micropore size is 10 to 30 nm, and the barrier layer size is approx. 150 nm, although the film configuration varies by the electrolytic solution and electrolysis condition used [2].

As mentioned above, the anodized film has a porous structure consisting of unit cells with a micropore each. For this reason, the anodized film as it is normally provides poor resistance to corrosion. To solve the problem, sealing of anodic oxide coating is conducted to improve corrosion resistance. This process uses an electrochemical approach using water vapor, boiling water or nickel acetate to produce hydrate over the film surface, which covers the micropores. The sealing process, however, may slightly reduce wear resistance while improving corrosion resistance. It is thus needed to consider whether the sealing process should be selected or not and, if selected, discuss the process conditions, depending on the product application. Particularly for coating by hard anodizing with a focus placed on wear resistance, special consideration is needed in carrying out the sealing process.

The wear resistant anodized film may eventually cause failure originated in lower mechanical efficiency or higher friction when it is used for tribological applications, depending on the connecting part or tribological conditions. For the purpose of providing lubricity to the anodized film, an approach to composite molybdenum disulfide or fluorocarbon resin into the film is available. The composite film can thus have compatibility between wear resistance of the anodized film and lubricity. Still, the film hardness is normally around 400 to 500 HV. It cannot be said that the film is sufficiently resistant to wear compared to steel alloy.

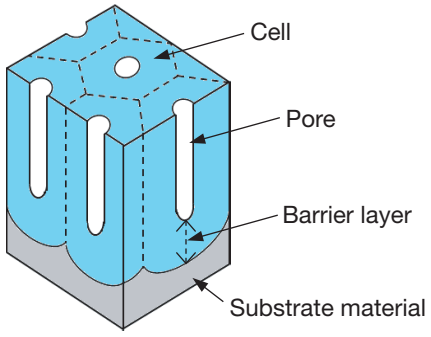


**Fig. 1** Microscopic model of anodized film [1]

### 2.2 Plasma Electrolytic Oxidation (PEO)

This report focuses on PEO, with which higher film hardness can be obtained than the anodized film, in order to improve wear resistance of aluminium alloy. The principle of PEO was invented in Russia over one century ago. Development of the process has been promoted mainly in Europe since the 2000s. Recently, PEO technology has been commercialized in Japan as well. Thus PEO is a relatively new surface treatment method. Like anodizing, PEO can be applied, not only to aluminium alloy, but also to light metal. It can also be applied even to material that is difficult to be anodized.

While the oxide film produced by the aforementioned anodizing is a porous film with less crystallinity [3], that made by PEO has a crystalline structure mainly consisting of $\gamma$-alumina [4]. The difference in processing method is that anodizing uses an oxidation reaction by normal electrolysis and PEO causes spark discharge in a process liquid with an even higher voltage to produce the oxide film. Furthermore, PEO creates a ceramic film with a dense, hard and stable structure, eliminating the sealing process needed for anodizing. Table 1 lists major differences between the two processes:

**Table 1** Difference between anodizing and PEO [3, 4]

| | Anodized film | PEO film |
|---|---|---|
| Electrolyte | Mainly acidic solution | Basic solution |
| Film composition | Amorphous alumina | Crystalline alumina (with variants depending on electrolyte) |
| Hardness | 200 to 600 HV | Max. approx. 2000 HV |
| Film formation speed | Approx. 1 $\mu$m/min | Max. approx. 4 $\mu$m/min |
| Sealing | Necessary depending on application | Unnecessary |

## 3 Tribological Properties of PEO Films

In consideration of using PEO films for tribological applications in mechanical parts, investigations were conducted on:

- Friction and wear characteristics of PEO films of different film thicknesses
- Wear characteristics of PEO films produced over different substrate materials

### 3.1 PEO Films with Different Film Thicknesses

The result of investigation on the friction and wear characteristics of PEO film samples with different film thicknesses (PEO_A, PEO_B and PEO_C films deposited on different processing times to be thinner in the order of PEO_A, PEO_B and PEO_C).

An X-ray diffraction (hereinafter "XRD") analysis revealed that PEO_B and PEO_C, which both have relatively thinner film thicknesses, mainly contain $\gamma$-alumina and PEO_A, which is the thickest, contains $\alpha$-alumina (Fig. 2). A film section sample was prepared from PEO_A and subjected to a Vickers hardness test. An optical microscope image and Vickers hardness distribution of the sample are shown in Fig. 3. In the figure, the hardest point appears in the film thickness region of several μm from the top surface.

The film hardness depends on the crystalline state of alumina. The hardest alumina is $\alpha$-alumina. Since only the thickest PEO_A contains $\alpha$-alumina, as revealed by the XRD analysis, the alumina crystalline state in the film is inclined. $\gamma$-alumina appears in the region close to the substrate material and $\alpha$-alumina, which is the hardest among the alumina crystalline components, exists in the film thickness region of 20 μm and more from the surface ($\alpha$-alumina has about 2000 HV hardness according to a literature [5]). Note that the Vickers hardness, which is measured by making an indentation of a depth of several μm, slightly decreases at a film thickness very close to the surface. This is probably because the thickness area is very porous.

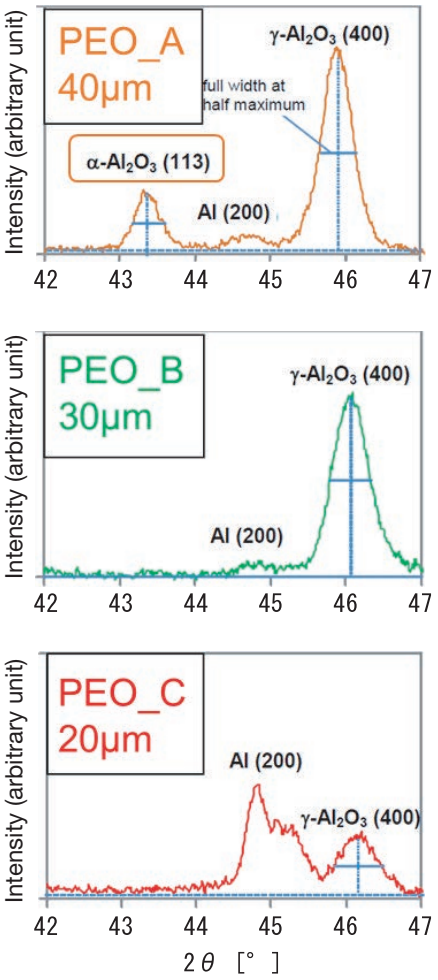


**Fig. 2** XRD spectrum of PEO films with different film thicknesses

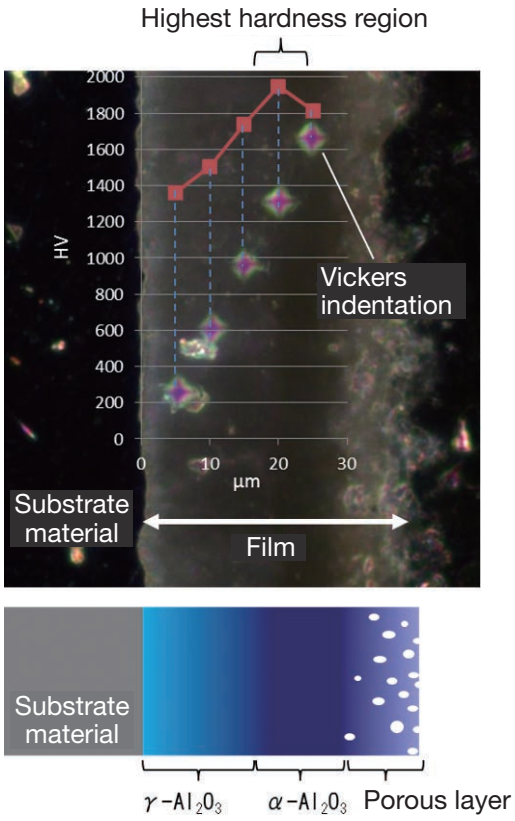


**Fig. 3** PEO film section and Vickers hardness distribution

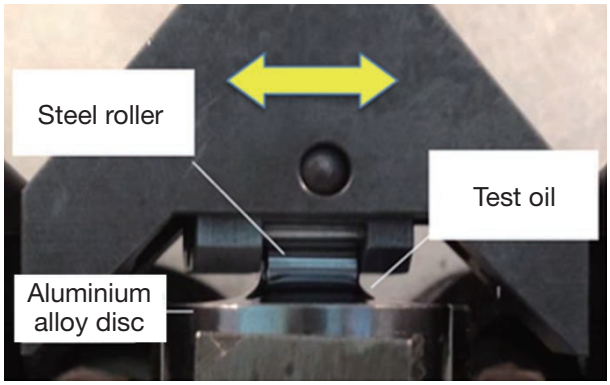


**Fig. 4** Sliding test system

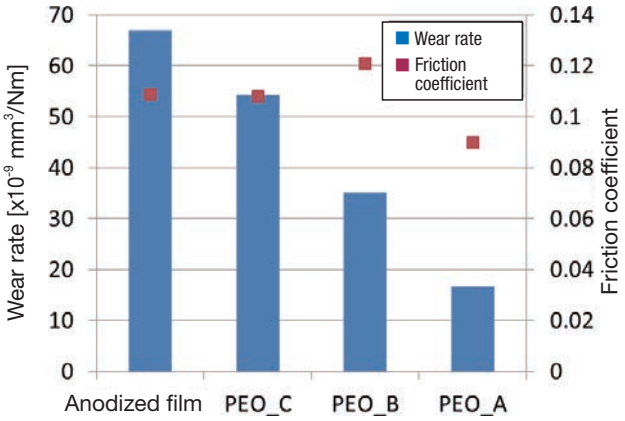


**Fig. 5** Friction and wear characteristics of PEO and anodized films

The friction and wear characteristics of these PEO films were evaluated using the oscillating friction and wear testing machine (SRV tester) shown in Fig. 4. PEO samples were polished to smooth the top porous layer. A bearing steel roller was used as the counter material in such a manner that the two parts had line contact, which is similar to the tribological mode of the actual parts, rather than point contact. Polypropylene glycol (PPG) based oil was used as the lubricant, and PPG with additive was used for the anodized film that was used for comparison with the PEO films. The test was conducted under the conditions of a load of 50N, amplitude of +/-1 mm, a frequency of 50 Hz, test temperature of 80°C and sliding time of 2 hours.

Fig. 5 shows the result of friction and wear evaluation. The anodized film for comparison showed the highest wear rate in spite of the lubricant with additive being used. All the PEO films showed a lower wear rate than that of the anodized film. Moreover, PEO_A containing $\alpha$-alumina particularly showed low friction and wear.

From the above, it has been verified that PEO films have different crystalline structures depending on the film thickness and the differences affect the friction and wear characteristics.

### 3.2 Influence of PEO films

In considering actual product design, the first step is to select a substrate material. The substrate material influences the properties of the surface treated film and, of course, the tribological properties. The following describes the results of investigation on the tribological properties of PEO processed samples deposited on three different substrate materials.

PEO_A is a sample produced on wrought aluminum alloy material. PEO_A' and PEO_A" are samples made on cast aluminium alloy materials with different chemical compositions (Fig. 6). The microstructure of these three substrate materials indicate that there is a difference in distribution of crystallized intermetallic compounds (particles scattered over the substrate materials) among the three samples.

For PEO, the film grows as the surface layer of the substrate material is dissolved into the electrolyte, as seen in anodizing. This is the reason why the film may have different compositions depending on the substrate material, thereby showing different mechanical and other physical properties. Particularly for castings, silicon (Si) contained in the substrate material is also distributed in the film. In Fig. 7 giving the results of component analysis by the Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy (SEM/EDX), slightly pale blue parts distributed in the film enclosed by a yellow line represent Si. The values appearing under the sample name indicate the Vickers hardness of the film section, representing the average hardness of the film including the distributed Si phase. This suggests that PEO_A with the highest film hardness is expected to be most resistant to wear.

For the purpose of determining the wear resistance of the films over different substrate materials in particular, a friction and abrasion test was conducted. To accurately evaluate the wear, an alumina ball was used as the counter material to accelerate the wear in the SRV test. Synthetic hydrocarbon poly-$\alpha$ olefin base oil was used as the lubricant. The test was conducted under the conditions of a load of 20N, amplitude of +/-0.5 mm, frequency of 50 Hz, test temperature of 25 +/-2°C, and sliding time of 20 minutes.

Fig. 8 shows the wear rate of the films. Contrary to the expectations, among the films subjected to the investigation, PEO_A", with the lowest film hardness, showed the highest resistance to wear. The sample showing the second highest wear resistance was PEO_A'. This is probably because the presence of Si in the film influenced resistance to wear. Since all the samples except PEO_A contain Si in their substrate materials, the deposited films may have a chemical composition, including Si, highly resistant to wear.

With the idea that microhardness around the contact surface influences wear resistance, nano-indentation hardness (hereinafter "nano-hardness") of the film surface was measured. With the indentation depth of the indenter during nano-hardness measurement fixed to 50 nm, the hardness in the submicroscopic contact projected area (indentation area) was determined. Fig. 9 shows the nano-hardness and the elastic modulus of the films. PEO_A" with the lowest film hardness is distributed in the highest nano-hardness region. The result for PEO_A' is also

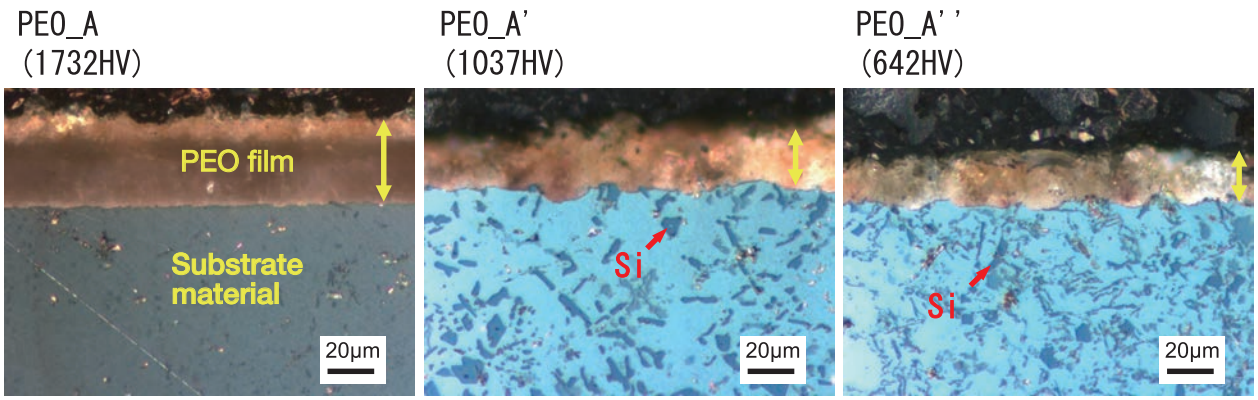


**Fig. 6** Sections of PEO films deposited on different substrate materials and their Vickers hardness (HV)

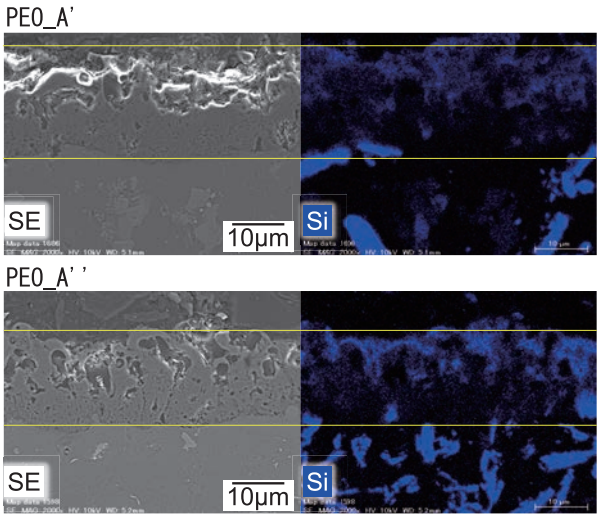


**Fig. 7** SEM/EDX analysis on cross section of PEO film deposited on cast materials (left: SEM image, right: EDX mapping image)

included in the figure for reference purposes, although the measurements are not necessarily accurate since the sample is relatively porous.

The investigation above has revealed that one of the reasons why PEO_A" showed the highest resistance to wear was the high nano-hardness of the surface. However, it is necessary to determine the reason for the high nano-hardness of PEO_A" in further film analysis in future.

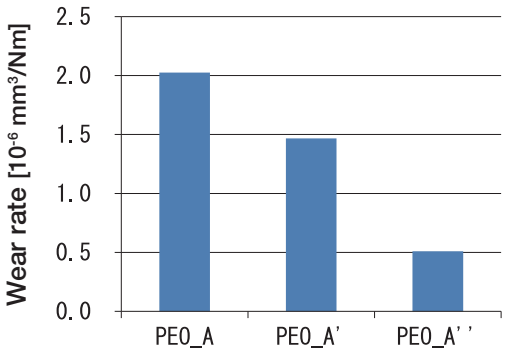


**Fig. 8** Wear resistance of various PEO films

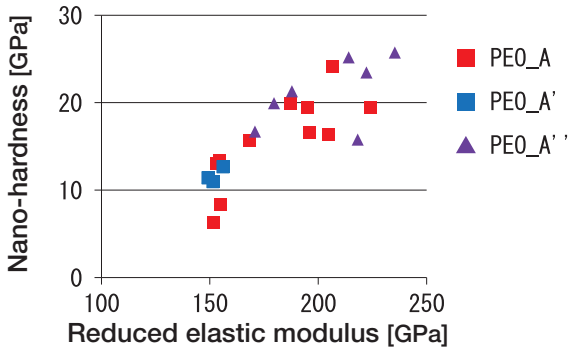


**Fig. 9** Nano-hardness and Reduced elastic modulus of various PEO films

## 4 Lubrication Parameter for PEO Films

In relation to the effect of lubricants as mentioned in the previous section, the use of environmentally acceptable lubricants has been recently expanding. The base oil of environmentally acceptable lubricants is biodegradable ester or polyglycol, rather than mineral oil as seen in conventional lubricants. The tribological properties of lubricants depend on the type of base oil and additives. Then the influence of hydraulic oil on friction and wear characteristics of PEO film has been investigated and reported in a previous KYB Technical Review [6].

It has been revealed by numerous studies on tribology that the tribological properties of lubricants are governed by the chemical structure of their base oil. Specifically, Van der Waals forces or hydrogen bonding strength by the functional group of molecules in the base oil decides the surface contact behavior, namely wetting (the ability of a liquid to maintain contact with a solid surface). Wettability is one of the factors of the tribological properties. Surface wettability is an intrinsic property of each combination of oil and surface that is decided by their own surface free energy. In other words, there should be an interrelation between the coefficient of friction and the wetting of lubricated interacted surfaces. Wetting is expected to be one of the effective indexes in selecting and designing lubricants.

As lubricant, synthetic hydrocarbon poly-$\alpha$ olefin base oil (PAO), polypropylene glycol (PPG) and unsaturated fatty acid trimethylolpropane ester (TMP) were used. All these oils have a viscosity of ISO-VG46. 1 wt% dibenzyldisulfide (DBDS) was added to these base oils as an extreme-pressure agent or anti-wear additive to make a blend oil each. Another blend oil, commercially available ester oil (hereinafter "commercial oil E") was used as well. These base oils and blend oils were dropped on the PEO_A film and evaluated through an SRV test. (The same test condition as that for 3.1 was applied).

The friction coefficient at test end is shown in Table 2. For base oil comparison, the friction coefficient was higher in the order of PAO, PPG and TMP. DBDS showed an effect of reducing the friction coefficient for all the base oils. It was verified that the commercial oil E showed

**Table 2** Friction coefficient of lubricants for PEO_A

| Lubricant | Friction coefficient | | |
|---|---|---|---|
| | Base oil | Base oil + DBDS | — |
| PAO | 0.113 | 0.089 | — |
| PPG | 0.090 | 0.081 | — |
| TMP | 0.079 | 0.062 | — |
| Commercial oil E | — | — | 0.080 |

a lower friction coefficient than any of the PAO or PPG oils.

For wettability evaluation, a Drop Shape Analyzer DSA100 made by Krüss in Germany was used to measure the contact angle of a droplet on a solid surface. The surface free energy of a liquid or solid has a relationship with the contact angle that can be expressed in the following Young's equation:

$$\cos\theta = \frac{\sigma_s - \sigma_{sl}}{\sigma_l} \quad (1)$$

where $\theta$ is the contact angle, $\sigma_s$ is the surface free energy of the solid, $\sigma_l$ is the surface free energy of the liquid, and $\sigma_{sl}$ is the interfacial energy of the solid and the liquid.

Now the focus has been placed on the work of adhesion $W_A$ as a wettability parameter. The work of adhesion $W_A$ represents work consumed by the liquid to form an interface over the solid surface. In other words, it may be recognized as necessary work to remove the liquid from the solid surface. The energy before adhesion is the sum of the surface free energy of the solid and that of the liquid ($\sigma_s + \sigma_l$). The energy after adhesion is the interfacial energy $\sigma_{sl}$ by the solid-liquid interaction. Therefore, Equation (2) holds:

$$W_A = \sigma_s + \sigma_l - \sigma_{sl} \quad (2)$$

The interfacial energy $\sigma_{sl}$ can be expressed in the equation:

$$\sigma_{sl} = \sigma_s + \sigma_l - 2\left(\sqrt{\sigma_s^d \sigma_l^d} + \sqrt{\sigma_s^p \sigma_l^p}\right) \quad (3)$$

where $\sigma_s^d$ indicates the surface free energy dispersion of the solid, $\sigma_s^p$ the surface free energy polarity of the solid, $\sigma_l^d$ the surface free energy dispersion of the liquid and $\sigma_l^p$ the surface free energy polarity of the liquid. For detailed calculation of the surface tension of the liquid and of the surface free energy of the solid, published works were referred to [7), 8)].

The surface tension of oils (surface free energy of liquids) $\sigma_l$ was determined using the pendant-drop method. The dispersion term $\sigma_l^d$ and polarity term $\sigma_l^p$ were determined using the sessile drop method on dimethyl polysiloxane.

The surface free energy of the solid $\sigma_s$ was determined using the Owens, Wendt, Rabel and Kaelble methods. Equations (1) and (3) can be modified to obtain the equations:

$$\frac{\sigma_l(\cos\theta + 1)}{2\sqrt{\sigma_l^d}} = \sqrt{\sigma_s^p}\frac{\sqrt{\sigma_l^p}}{\sqrt{\sigma_l^d}} + \sqrt{\sigma_s^d} \quad (4)$$

$$If\ y = a \cdot x + b$$

$$x = \frac{\sqrt{\sigma_l^p}}{\sqrt{\sigma_l^d}}, \quad y = \frac{\sigma_l(\cos\theta + 1)}{2\sqrt{\sigma_l^d}}$$

$$a = \sqrt{\sigma_s^p}, \quad b = \sqrt{\sigma_s^d}$$

Using three or more types of reference liquid with a known surface tension, the contact angle was measured to plot the measurements using the linear equation $y = a \cdot x + b$. $\sqrt{\sigma_s^p}$ and $\sqrt{\sigma_s^d}$ can be determined as slope $a$ and intercept $b$. Therefore, the solid surface free energy polarity and dispersion terms can be determined according to $\sigma_s^p = a^2$ and $\sigma_s^d = b^2$ respectively.

The resultant surface free energy of the PEO film (PEO_A) and lubricants are shown in Table 3. These values were used to calculate $W_A$ using Equations (1) and (2). Results are shown in Table 4.

**Table 3** Surface free energy (at 80°C)

| Solid | $\sigma_s$ | $\sigma_s^d$ | $\sigma_s^p$ |
|---|---|---|---|
| PEO_A | 40.65 | 38.08 | 2.57 |
| **Lubricant** | $\sigma_l$ | $\sigma_l^d$ | $\sigma_l^p$ |
| PAO base oil | 23.47 | 17.45 | 6.02 |
| PAO + DBDS | 24.26 | 20.48 | 3.78 |
| PPG base oil | 25.28 | 17.70 | 7.58 |
| PPG + DBDS | 25.43 | 19.23 | 6.20 |
| TMP base oil | 27.32 | 20.54 | 6.78 |
| TMP + DBDS | 27.30 | 22.51 | 4.79 |
| Commercial oil E | 25.87 | 21.09 | 4.78 |

**Table 4** Work of adhesion of lubricants and PEO films

| | $W_A$ | | |
|---|---|---|---|
| Lubricant | Base oil | Base oil + DBDS | — |
| PAO | 59.42 | 62.09 | — |
| PPG | 60.75 | 62.10 | — |
| TMP | 64.28 | 65.57 | — |
| Commercial oil E | — | — | 63.69 |

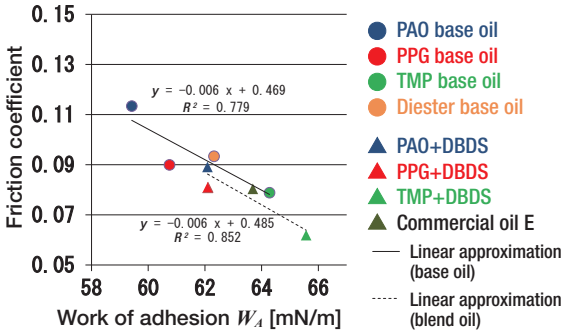


**Fig. 10** Correlation between work of adhesion and coefficient of friction of lubricants for PEO_A

Fig. 10 plots the correlation between the friction coefficient and work of adhesion $W_A$. With the focus placed on the base oils only, the figure indicates that the higher the work of adhesion $W_A$ is, the lower the friction coefficient is. (Another type of base oil (diester) has been added to increase reliability). On the other hand, the base oils with DBDS additives have a tendency of showing higher $W_A$ and lower friction coefficient.

Although it is still necessary to continue verification using more types of solids and liquids in future, the work of adhesion $W_A$, which is one of the wetting parameters derived from the surface free energy, is correlated with the friction coefficient and can be used as an effective measure in selecting lubricants for a solid surface.

## 5 Concluding Remarks

This report has introduced plasma electrolytic oxidation (PEO) as one of the possible breakthrough measures for applying aluminium alloy to tribological applications of mechanical parts. This Technology Explanation mainly covers tribological technologies related to surface treatment of aluminium alloy. KYB is committed to continuously addressing product application, contributing to implementation of lighter KYB products with higher added values.

## 6 Acknowledgements

We would like to thank Prof. SASAKI Shinya, Tokyo University of Science, and Dr. Mathias Woydt, Federal Institute for Materials Research and Testing (BAM) in Germany, for their guidance on part of the content introduced in this report.

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Product Introduction

# Development of Externally-Mounted Shock Absorber with Adjustable Solenoid Damping Force

KAMAKURA Ryosuke, FURUTA Yusuke, MORI Toshihiro, TOMITA Kohei

## 1 Introduction

The automotive industry has manufactured more and more vehicles equipped with semi-active suspension (refer to Glossary "Semi-active Suspension" on p.31) since 2000 to achieve compatibility between handling stability and ride comfort. The number of these vehicles is expected to rise in the future (Fig. 1).

Automotive adjustable shock absorbers (hereinafter adjustable SA") a shock absorber with a proportional solenoid valve, that can seamlessly control the damping force in response to the control current with high switching response (Fig. 2) in the mainstream of automotive adjustable shock absorbers.

Vehicles equipped with this damping force adjustable SA are used not only in segment C, but also even in segment B (Fig. 3).

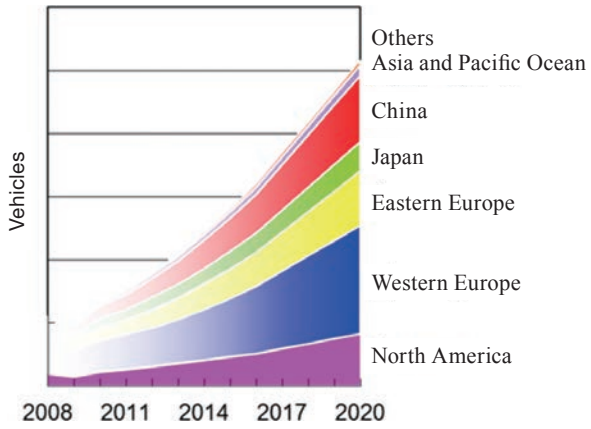


**Fig. 1** Projected number of vehicles equipped with semi-active suspension

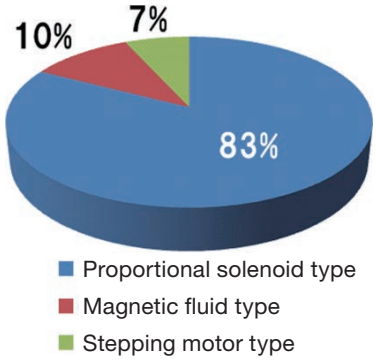


**Fig. 2** Damping force adjusting systems (FY2016)

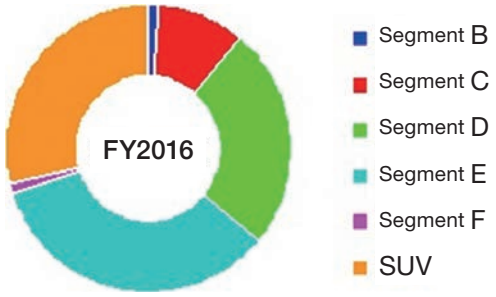


**Fig. 3** Vehicles equipped with damping force adjustable SA by segment

There are two types of solenoid damping force adjustable SA. One is "internal type" with a solenoid valve installed in a shock absorber cylinder, and the other is "external type" with a solenoid valve on shock absorber cylinder. "External type" that has is in the majority of adjustable SA.

KYB has conducted mass production of adjustable SA since late 2016. This report introduces the development of adjustable SA with external solenoid (hereinafter "adjustable SA with external SOL").

## 2 Product Overview

### 2.1 Appearance

Fig. 4 shows the appearance of adjustable SA with external SOL.

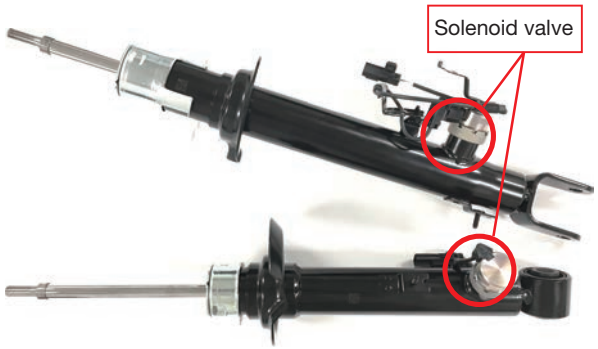


**Fig. 4** Appearance of damping force adjustable SA with external SOL

### 2.2 Specifications

Table 1 shows the specifications of adjustable SA with external SOL.

**Table 1** Specifications of adjustable SA with external SOL

| | |
|---|---|
| Basic structure | Triple tube uniflow |
| Control method | Pressure control |
| Valve size (maximum outer diameter x height) | maximum $\phi$ 39 x 53<br>In the world smallest size for superior-vehicle mountability |
| Electric current | Low current: SOFT<br>High current: HARD |
| Switching response | Faster than KYB's existing product (stepping motor type) by 8 times or more<br>SOFT ⇔ HARD |
| At fail-safe Damping force | Can be set equivalent to HARD damping force |

### 2.3 Target of Damping Force Characteristics

Semi-active suspension can realize both handling stability and ride comfort at a high level by widening variable range of damping force (low for SOFT damping force, high for HARD damping force) and achieving fast switching response. The damping force adjustable SA with external SOL is also designed with the aim of achieving a wide damping force adjustable range and higher switching responsivity while implementing the world's smallest valve body. Fig. 5 illustrates the target damping force characteristics.

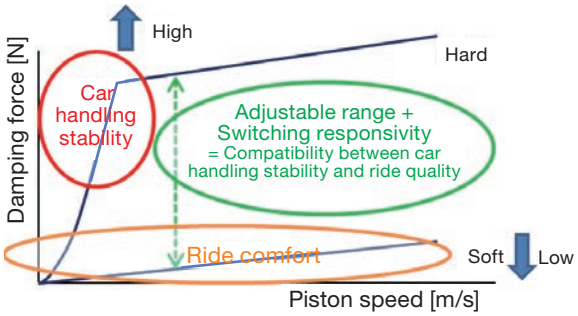


**Fig. 5** Target of damping force characteristics

## 3 Development of Adjustable SA with External SOL

### 3.1 Triple Tube Configuration

To guide hydraulic oil into solenoid control valve (hereinafter "SOL valve") on a shock absorber cylinder, the development team selected a triple tube configuration conposed of a cylinder, middle pipe and outer shell. The oil flows in the shock absorber only in a single direction (uniflow) to allow the single SOL valve to adjust the damping force during both expansion and compression

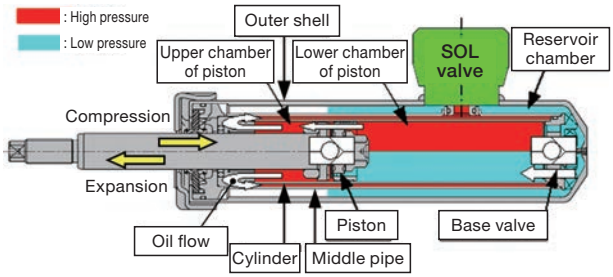


**Fig. 6** Triple tube uniflow configuration

strokes. Fig. 6 shows the triple-tube uniflow configuration and flow of the hydraulic oil.

In this configuration, a piston valve and base valve basically have the sole function of a check valve, and damping force is mainly generated by the SOL valve. During both compression and expansion strokes, the upper chamber of piston is under high pressure while the space between the cylinder and the middle pipe to the SOL valve is under control pressure. The oil is then discharged from the SOL valve to return to the reservoir chamber. During expansion stroke, the amount of oil equivalent to the changed volume of the lower chamber of piston is supplied via the base valve.

### 3.2 Control Methods

The SOL valve uses a pilot type electromagnetic proportional relief valve that can operate the valve body by using difference in pressure between the fluids. The pilot valve can be controlled in two ways: pressure control and valve opening area control. Fig. 7 shows damping force characteristics.

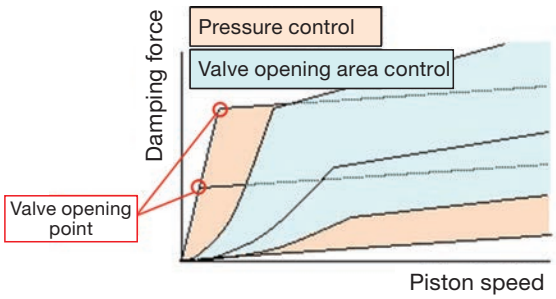


**Fig. 7** Damping force characteristics for pressure control and valve opening area control

In the case of pressure control, the control current is used to control the pressure in the pilot chamber (pilot pressure). The relationship between damping force and piston speed can be represented by a fixed slope over the entire range from SOFT to HARD damping although the valve opening point varies. Therefore, even if damping force is raised in the low-speed region for higher car handling stability, damping force at mid or high-speed region will be curbed without degrading ride comfort.

This feature of a fixed slope is the same as a feature of a damper that integrates a standard passive damper and variable damper that produces a damping force by solely relying on the electric current (Fig. 8).

On the other hand, in the case of valve opening area control, the control current is used to control the opening

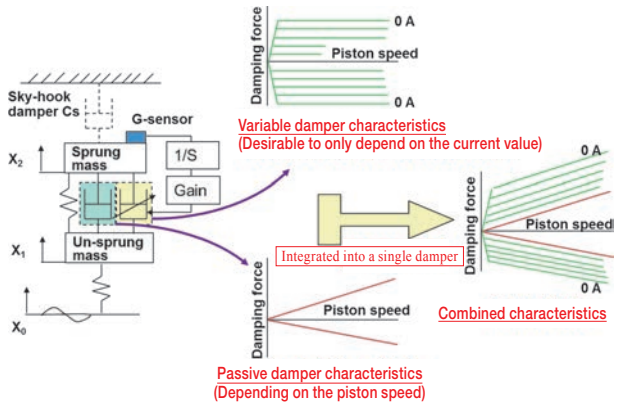


**Fig. 8** Pressure control and its controllability

area of the pilot valve. The slope of the relationship between the damping force and piston speed varies with the control current. The damping force is decided by both the current and piston speed.

In implementing semi-active control as seen in Skyhook dampers using these damping force control methods, if the damping force can be only set by the electric current as seen in pressure control, the detection of the piston speed is no longer necessary. This is an advantage of this method. The valve opening area control requires the related mechanical parts to be made with high precision that results in higher cost.

All these control systems have been applied to commercial products. In this development, the pressure control system has been used from the viewpoints of controllability and mechanical part precision, and relatively easy achievement of compatibility between handling stability and ride comfort.

### 3.3 SOL Valve Configuration

Fig. 9 a simplified model of the SOL valve is shown in shows and Fig. 10 the principle of operation shows.

The flow of hydraulic oil controlled by the SOL valve is explained below.

Pilot flow: Part of the main flow passes through the pilot orifice provided in the plug and flows into the pilot chamber. The oil pressure therein is controlled to a pressure set by the solenoid thrust. When the pilot pressure exceeds the set pressure the poppet valve is pushed up and the oil is discharged from the pilot chamber.

Main flow: For a low flow (medium pressure = main pressure), the main valve is made up of the laminated leaf valve and the spool, and receives the medium pressure on the bottom and the pilot pressure on the top. When the medium pressure reaches the product of the pilot pressure and the preset pressure boost ratio, the leaf valve is pushed up to discharge the oil to the reservoir chamber. When the flow rate increases (medium pressure < main pressure), similar movement takes place above and below the movable disc located in the lower section, which pushes up the movable disc to discharge the oil to the reservoir chamber.

Fig. 11 a typical illustration of damping force characteristics shows.

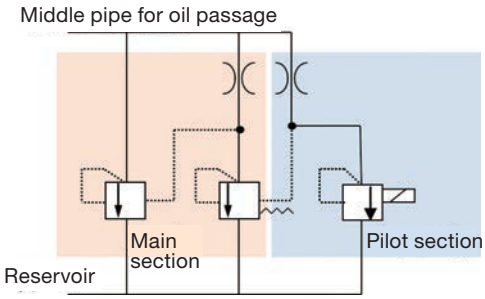


**Fig. 9** Simplified model of SOL valve

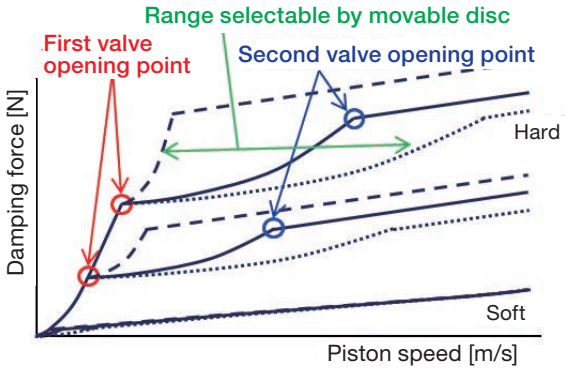


**Fig. 11** Illustration of damping force characteristics

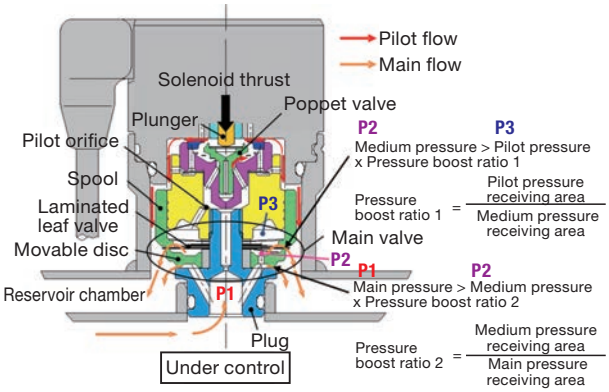


**Fig. 10** Principle of operation

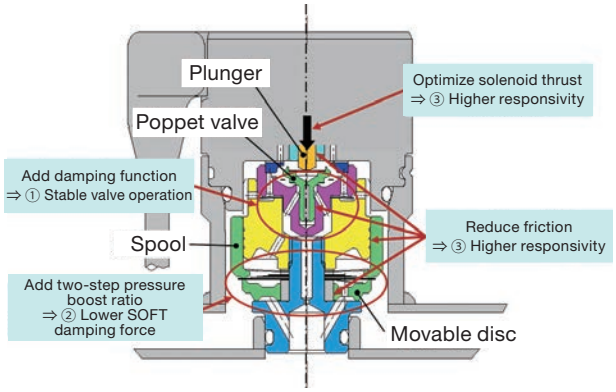


**Fig. 12** Development target parts

### 3.4 Development of SOL Valve

The following challenges extracted in the component development valve are resolved in the SOL valve dev. Fig. 12 the target parts shows.

① Stable operation for valve (improved damping force oscillatory wave form)
② Lower SOFT damping force
③ Higher response

① Stable operation for valve (improvement of damping force oscillation)

In the component development stage, the shock absorber, was found to have a abnormal damping force oscillation in a shaking test. This was caused by self-excited vibration of the poppet valve. A damping function has been added to the poppet valve to suppress the vibration, because it is generally effective to damp the poppet valve. Fig. 13 shows an enlarged view of the poppet valve.

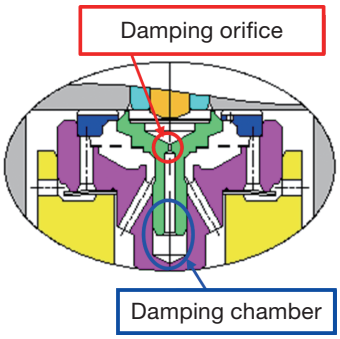


**Fig. 13** Enlarged view of poppet valve

② Lower SOFT damping forces

In the component development stage, the main valve was designed to be opened in a single step, and the opening pressure was set high to ensure a wide adjustable range for HARD damping force. This design inevitably made SOFT damping force higher too. To solve the problem, the valve configuration was modified to allow the valve opening pressure at two different levels. In the low-speed region, the valve opening pressure was kept low to lower the SOFT damping force. In the normal speed region, the second opening pressure can be set to a higher level. In addition, two valve ports were provided to ensure a larger opening area, suppressing the increase in damping force in the mid-speed and high-speed regions.

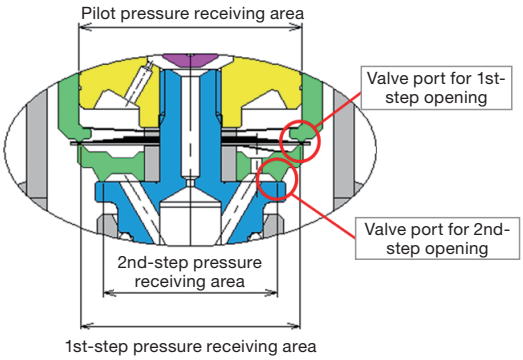


**Fig. 14** Main valve section

These improvemented ride comfort. Fig. 14 the main valve section is illustrated in shows.

③ Higher response

In addressing the higher response challenge, the development team considered it effective to improve the solenoid thrust response and reduce the sliding resistance of the plunger, the poppet valve, the spool and the movable disc during their interaction within the SOL valve.

In terms of the solenoid thrust response, a dynamic behavior analysis was conducted using a quality engineering approach (Figs. 15 and 16). As a result, the analysis revealed a tendency that the magnitude and response of the solenoid thrust are trade off. Then, the solenoid thrust was set to a minimum level to improve response. Geometry and material of the sliding part are optimized to ensure a lower sliding resistance. The design implemented smooth movements of the sliding parts and achieved higher response.

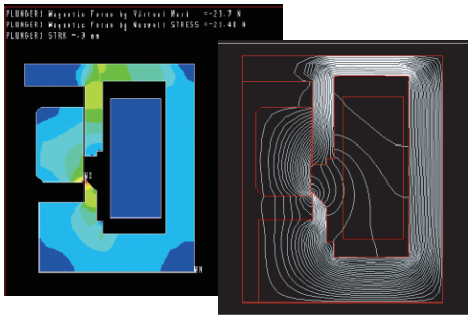

**Fig. 15** Dynamic behavior analysis (example)

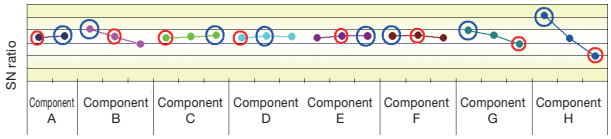


**Fig. 16** Cause and effect diagram based on quality engineering (example)

## 4 Development of Middle Pipe

The middle pipe (Fig. 17) is an indispensable component of adjustable SA with external SOL. A side-hole oil passage protruding from the pipe introduces the hydraulic pressure generated in the SOL valve into the upper

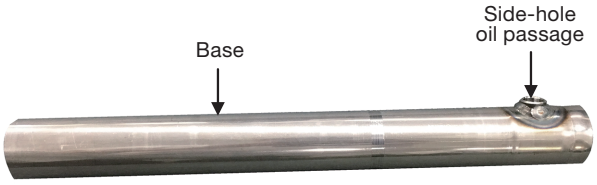


**Fig. 17** Appearance of middle pipe

chamber of the piston.

The middle pipe must have sufficient pressure fatigue strength (Fig. 18). With the wide adjustable range of damping force and uniflow configuration, the middle pipe

is exposed to repetitive pressure fluctuations as a damping force is generated during each expansion/compression stroke. This requires the middle pipe to have not only static strength but also sufficient fatigue strength.

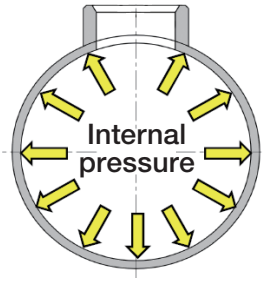


**Fig. 18** Pressure applied to middle pipe

When the middle pipe receives with an internal pressure (repeatedly), a radial tensile force (generally called a "hoop stress") occurs. The repetitive radial force may result in stress concentration particularly around the side-hole oil passage, causing cracks to depressurize the oil, and the function to produce damping forces may be lost (Fig. 19).

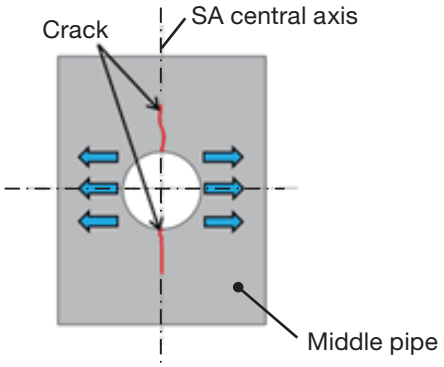


**Fig. 19** Cracked middle pipe

To reduce the stress, it is generally effective to increase the wall thickness of the middle pipe. However, the development team needed to guarantee strength without increasing the wall thickness with concerns about mass increase and constraints on the perimeter space (Fig. 20).

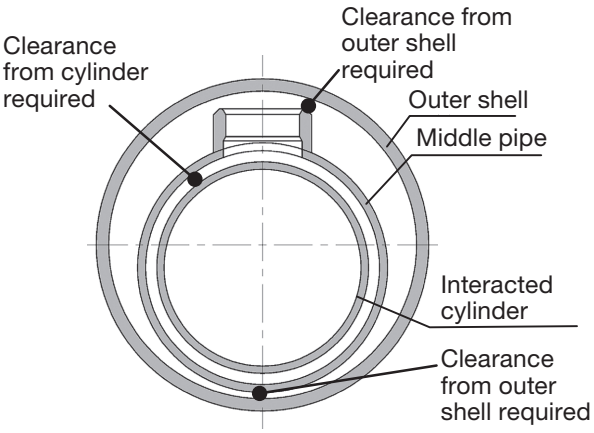


**Fig. 20** External/internal casing space constraints during assembly

As a means to ensure stress relaxation, the finite element method (FEM) stress analysis and verification using actual vehicles were conducted. As a result, the side-hole of the middle pipe was modified from the original round hole to a flat oval hole, successfully reducing the maximum stress in the stress concentrated part by about 40 percent (Fig. 21). By using the flat oval side-hole, the middle pipe eventually ensured the required strength with a thin wall of 1.3 mm regardless of the original requirements for the wall thickness of about 2.2 mm to satisfy the specified pressure resistance (Fig. 22).

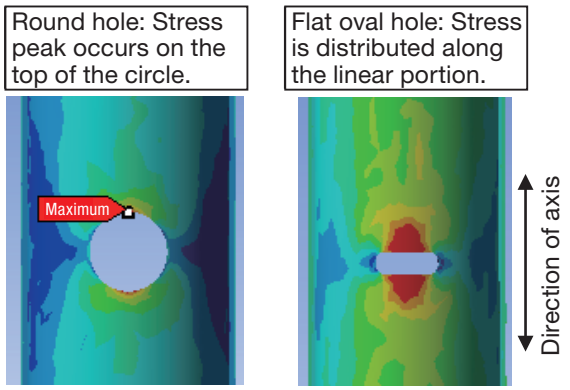


Fig. 21 Flat oval hole stress analysis (example)

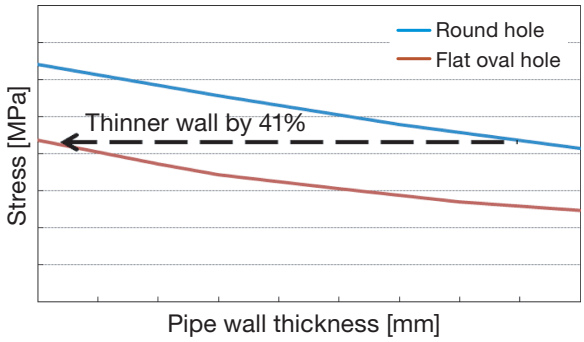


**Fig. 22** Relationship among hole shape, wall thickness and pipe stress

## 5 Current Application

This developed product was put into mass production in November 2016. Currently, adoption of the product for many vehicle models is considered and development for adaptation is on-going. The product is recognized as a high-value added product, separated from the standard shock absorber. KYB plans to roll it out as the company's future key product. Both the number of vehicle models using the product and production are expected to increase (Fig. 23).

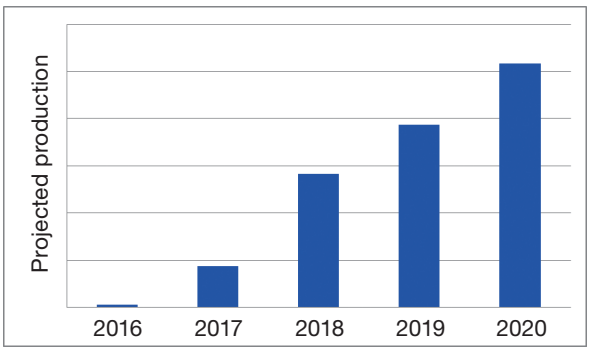


**Fig. 23** Projected production of damping force adjustable SAs with external SOL

## 6 In Closing

KYB has developed adjustable SA with external SOL that can be easily installed to vehicles and makes it possible to ensure both handling stability and greater ride comfort. KYB is also going to promote the development of adjustable SA with internal SOL as another product model to meet additional customer needs.

Finally we would like to cordially thank those who have cooperated with us.

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1) KIMISHIMA: Development of High Damping Force Piston Valve for Extra Low Velocity, KYB Technical Review No.54 (April 2017)

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Glossary

# Semi-active Suspension

Included in "The technical term used in Development of Externally-Mounted Shock Absorber with Adjustable Solenoid Damping Force" P. 25

ITO Naoki
KYB TECHNICAL REVIEW editor

## 1 Semi-active Suspension

Semi-active suspension is a type of automotive suspension systems that controls the damping force of the shock absorber in response to input from the continuously varying road surfaces. It is intended to approximately implement the active suspension (to be described later) with a damping force adjustable shock absorber (hereinafter "SA").

Semi-active suspension may be implemented by several types of control methodologies. A generally known typical technology is Skyhook control.

Fig. 1 shows a Skyhook control model. An imaginary damper (= Skyhook damper) hung from an aerial height with its end fixed there is implemented by generating a force of the sprung (vehicle body) speed multiplied by the damping coefficient $C_s$. A passive (= uncontrolled) damper ($C_p$), which is installed in parallel with the Skyhook damper ($C_s$), provides a force equivalent to the SOFT damping force of the damping force adjustable SA.

When this damper model is given a random input from the road surface, the relationship between the required combined damping forces of the Skyhook and passive dampers, and the relative speed (piston speed) between the sprung and unsprung components (including tires) is shown in Fig. 2 as an example. The required damping forces appear in all of the 1st to 4th quadrants.

The damping force of SA is a resistance force against the contraction. Even the damping force adjustable SA can only deliver damping forces in the 1st and 3rd quadrants. In other words, to achieve the required damping forces in the 2nd and 4th quadrants, negative damping forces must be generated. However, this is totally impossible. Therefore, in the coordinate plane of piston speed and sprung speed shown in Fig. 3, the damping force is controlled to the required level (optimum value) for the 1st and 3rd quadrants and controlled to the minimum level for the 2nd and 4th quadrants.

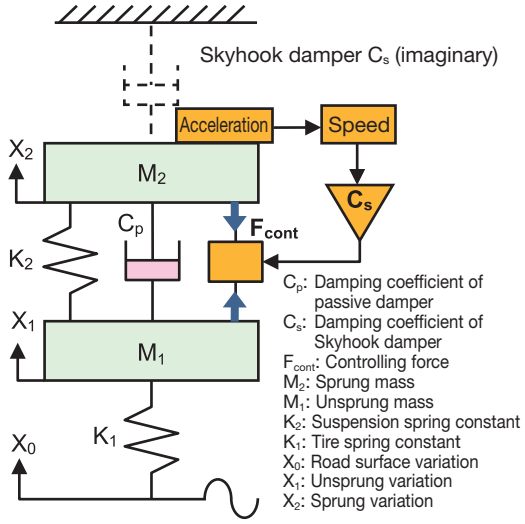


**Fig. 1** Skyhook control model

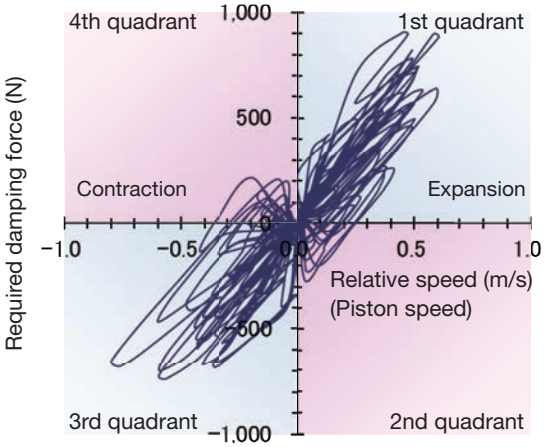


**Fig. 2** Required damping force and relative speed

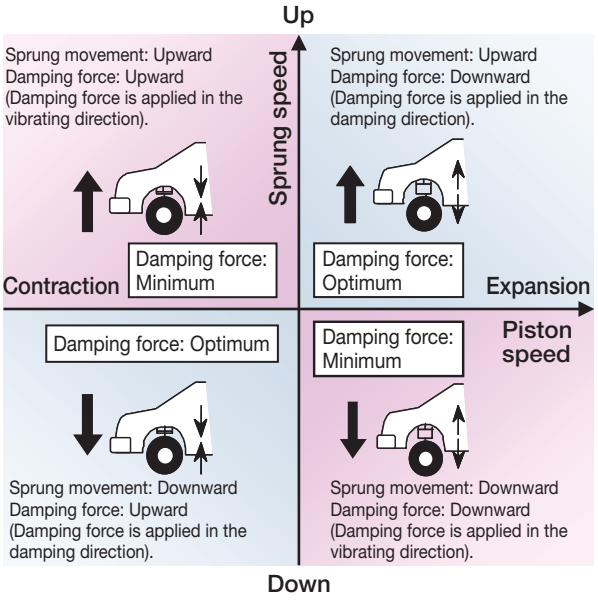


**Fig. 3** Concept of semi-active control

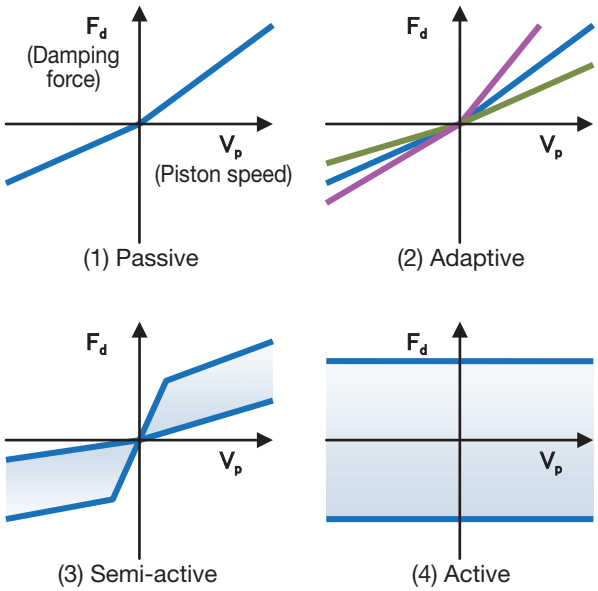


**Fig.4** Potential of various systems

## 2 Active Suspension

Active suspension may be called ultimate suspension and provides many different functions including vibration control (Skyhook control), posture control that reduces body roll, dive and squat, steering characteristics control, and body height control.

For vibration control, active suspension can deliver desired damping forces, even in the 2nd and 4th quadrants in Fig. 2 where semi-active suspensions are unable to generate them. This difference enables active suspension to provide superior sprung damping effects.

## 3 Comparison Among Damping Force Control Systems

The history of damping force control systems has evolved from adaptive (adjustable), active to semi-active. These systems have their own potential, as shown in Fig. 4 when using a coordinate plane of piston speed $V_p$ and damping force $F_d$.

Passive suspension using standard SA can be expressed in a single property as shown in diagram (1).

Adaptive suspension shown in (2) is the result of selection of two or more properties. Semi-active suspension shown in (3) has controllability potential in the 1st and 3rd quadrants, and active suspension in (4) has the same in all quadrants.

Active suspension can substantially reduce vibration compared to semi-active suspension with capability in the 2nd and 4th quadrants. However, this system has many drawbacks including large equipment size. Currently more and more vehicles use semi-active suspension.

### References

(1) MASAMURA: History of Control Suspensions, KYB Technical Review No.47 (October 2013).

Product Introduction

# Hydraulic Pump and Track Motor for Hydrostatic Transmission

INADA Takanori, MIURA Takuya, MATSUZAKA Keita

## 1 Introduction

There is a wide variety of hydraulically driven vehicles including construction equipment and agricultural machinery. These vehicles use hydro static transmissions (hereinafter "HST") as a driving transmission compatible with hydraulic pumps and motors because of their benefits of easy speed control and forward/backward travel without gear shifting. KYB has manufactured such compatible pumps and motors. Transmission systems integrated with pumps and motors in a single housing are called integrated HST. Transmission systems with separate pumps and separate motors connected by hydraulic piping constituting closed circuits are called separate HST. To meet the demand of the separate HST market for carriers (Photo 1), loaders and other base machines movable with crawlers, KYB has developed a hydraulic pump with modified swash plate control and a track motor with higher output and higher speed (compared to the level of the KYB's existing counterpart). This new separate HST has just been added to the KYB product lineup. This report introduces the overview of the development.

**Photo 1** Crawler Carrier C30R-3 (Source: Yanmar Construction Equipment Co., Ltd. Website)

## 2 Hydraulic Pumps

This hydraulic pump is a compact design basically consisting of two swash plate type axial piston pumps assembled together back to back (tandem pump). The KYB conventional counterpart (PSVH2-28 Series) used a pump control system operated by a manual lever for use in mowers or other vehicle applications. However, KYB needed to meet the then-recent market demand for introducing a hydraulic-pilot or electronic control system into the swash plate control for higher usability and easier installation of additional functions. In response to demand, KYB has developed this hydraulic pilot controlled pump based on conventional technology. Table 1 compares the specifications between the conventional product and this new product. Photo 2 shows the appearance of the new product. As shown in Fig. 1, the pump consists of a swash plate piston pump section, swash plate control section, power regulating valve section and gear pump.

**Table 1** Comparison of specifications between conventional and new products

| Model | | Conventional product | New product |
|---|---|---|---|
| | | PSVH2-28CGH | PSVH2-28C-R35-SP |
| Displacement setting [$cm^3$/rev] | | 2×28.1 | 2×22.0 to 28.1 |
| Specified pressure [MPa] | | Maximum effective pressure: 25.0 | Maximum effective pressure: 34.3 |
| | | Maximum discharge pressure: 25.9 | Maximum discharge pressure: 37.3 |
| Rated input speed [rpm] | | 2800 | 3000 |
| Maximum theoretical discharge [L/min] | | 78.7 | 84.3 |
| Auxiliary | Control system | Manual lever | Hydraulic direct |
| | Power regulation | N/A | Speed sensing |
| Product mass [kg] (including gear pump) | | 40.0 | 55.0 |

### 2.1 Mechanical Features

#### 2.1.1 Hydraulic Pilot Control System

While the conventional product uses the swash plate control system with a manual lever, this new product uses a hydraulic direct control system with a pilot pressure. There are two types of hydraulic pilot control systems: swash plate inclination feedback control and hydraulic direct control. In the feedback control, the control

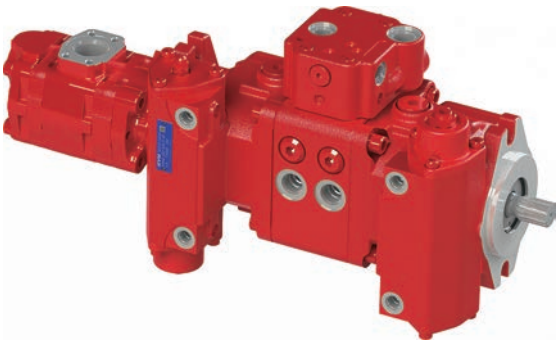

**Photo 2** Appearance of new product (PSVH2-28C-R35-SP)

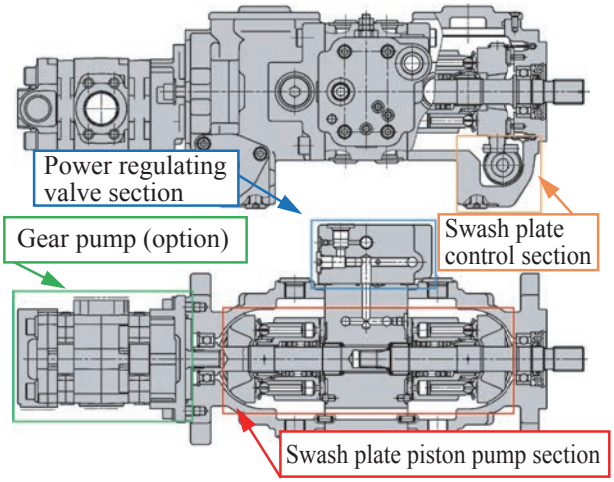


**Fig. 1** Pump internal construction

pressure introduced into the swash plate control pistons is automatically regulated to achieve the target swashplate inclination according to the pilot pressure. In the hydraulic direct control, the pilot pressure is directly used as the control pressure, so the swash plate inclination is decided by the balance between the angular moment of the swash plate and the thrust of the swash plate control pistons.

### 2.1.2 Angular Moment of Swash Plate

The swash plate of a pump receives a hydraulic reaction force from a set of pistons. Each piston is exposed to large pressure variations while it turns one revolution including intake and discharge strokes. The swash plate is applied with moment forces with which the swash plate would be vibrated and/or inclined depending on the number of pistons and the internal pressure variation patterns decided by the valve plate settings.

The direction of inclination or the vibrating force can be tuned by modifying the valve plate settings.

### 2.1.3 Self Power Regulation

This new product is designed to increase the swash plate inclining moment under a higher load. When the motor drive load is high during slope climbing for example, the inclining moment overcomes the thrust of the swash plate control pistons to automatically reduce the inclination of the swash plate. These characteristics are shown in Fig. 2.

The theoretical torque consumption of the hydraulic pump is expressed in Equation (1):

$$T = \frac{V \cdot P}{2\pi} \quad \ldots(1)$$

$T$: Theoretical torque consumption of hydraulic pump, $V$: Displacement volume of hydraulic pump, $P$: Effective discharge pressure of hydraulic pump

According to Equation (1), a higher load will reduce the inclination of the swash plate, resulting in a lower displacement volume. This will automatically reduce the torque consumption of the pump. These characteristics can help suppress engine stalls due to an unexpected increase in load.

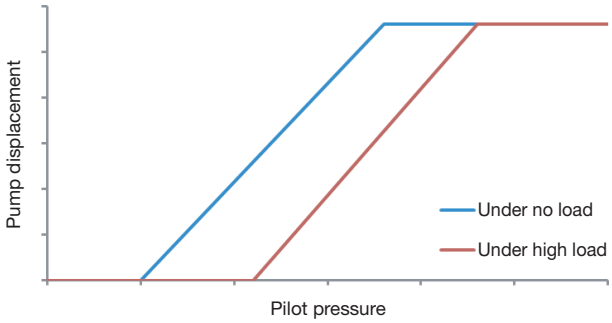


**Fig. 2** Hydraulic pilot control characteristics

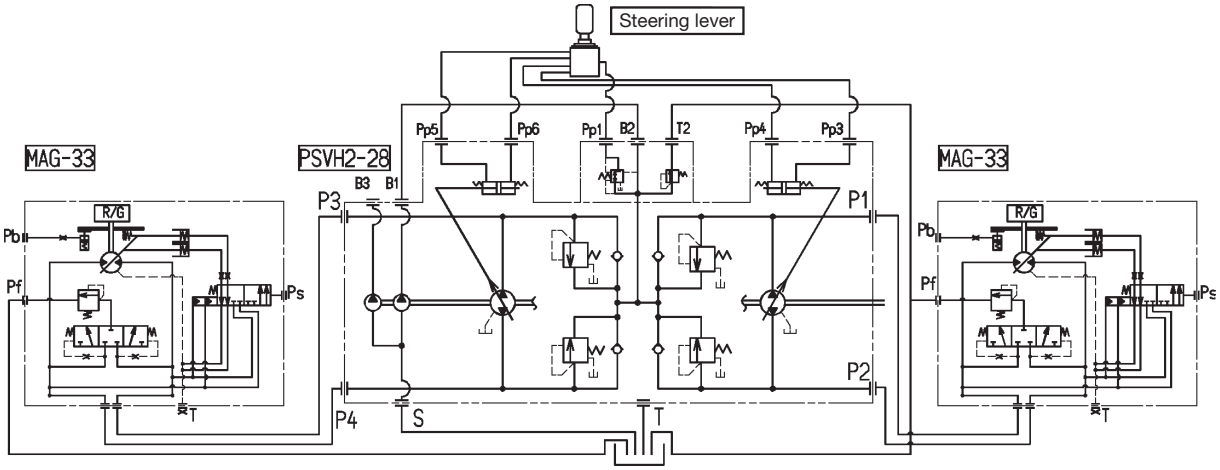


**Fig. 3** HST circuit diagram

### 2.1.4 Non-Straight Travelling Correction

Fig. 3 gives a hydraulic circuit diagram of the new product (HST). This 2-pump, 2-motor crawler travelling system has right and left crawlers, each driven by their own motor. When the vehicle of this system is trying to go straight ahead, the difference in discharge flow rate between both pumps may cause the vehicle to move in non-straight direction. The tandem pumps are usually shipped after their maximum discharge flow rate is adjusted on the assembly line during delivery inspection so that there will be no difference in discharge flow rate between the two pumps. However, the mid-range discharge flow rate will be regulated by the pilot pressure, engine speed and motor load as stated above. This means that it will not be easy for the right and left pumps to have the exact same flow rate. Against the problem, the "setting to decrease the swash plate inclination under a higher load" described in section 2.1.3 will work to correct the non-straight motion, contributing to improved driving straightness of the vehicle.

For example, when a vehicle slightly curves to the left in spite of the driver's straight steering, the left wheels are turning at a lower speed than the right crawler. The motor for these slower crawler has a lower load as the left side of the vehicle is pulled toward the front by the right side of the vehicle that is moving ahead faster with the other motor, which has to bear a higher load. In this case, increasing the discharge of the pump on the side with lower load and decreasing the discharge of the pump on the opposite side will eventually diminish the difference in speed between the left and right motors, contributing to improved straightness of the vehicle.

### 2.2 Power Regulation (Speed Sensing)

As a power regulation option, a speed sensing valve has been added to the new product. This valve controls the pressure supplied to the steering lever manipulated by the operator (Fig. 3, Pp1). The control characteristics are shown in Figs. 4 and 5. The upper limit of control pressure is regulated to the varying engine speed of the base machine. If the allowable engine load is exceeded, the pilot pressure to the pump is automatically reduced according to the engine speed drop, which reduces the swash plate inclination, thereby reducing power consumption. This process can prevent a complete engine stall. The maximum engine stall level is decided by the self-power regulation characteristics stated above, speed sensing characteristics and engine power. Thus the engine speed is no longer dropped to a predetermined level or lower. Operator is now able to operate the vehicle without paying attention to engine power. In this way the speed sensing valve can help reduce the work load of the operator.

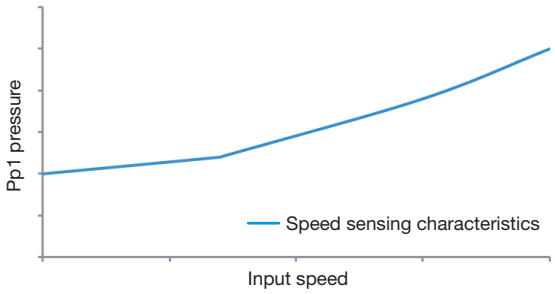


**Fig. 4** Speed sensing valve characteristics

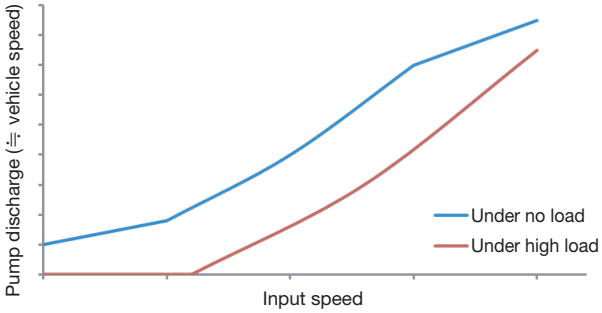


**Fig. 5** Power regulation characteristics

### 2.3 Challenges in achieving compatibility between noise reduction and stopping on slopes

As the pressure requirement becomes higher, the amplitude of the vibration applied to the swash plate increases. Particularly, it had been known for long that the pump issued higher noise when it was applied with a higher load. Noise reduction was one of the challenges to be overcome in developing this product. Various approaches were available to reduce the noise. The development team reviewed the valve plate specifications to optimize the variation patterns of the internal piston pressure.

Another issue to be considered when using HST for vehicle applications is stopping on a slope. Being able to move the vehicle ahead, back, or stop it with a single lever, and to use the hydraulic dynamic brake during stoppage is an advantage of HST. When the vehicle is stopped on slope for instance, the pump is in neutral position and the motor has to bear a continual load. In this condition, the motor would turn as long as the closed circuit leaks internally, which cannot prevent the vehicle from slipping down the slope at a very low speed. The valve plate is one of the components that are most likely to leak internally. The development team needed to optimize the design by taking this issue into account.

Optimization with these points in consideration achieved a valve plate design that satisfied the requirements for noise reduction and stopping on slope, as well as all of the swash plate control characteristics stated in section 2.1.3. The optimized valve plate was also recognized by customers to have been effectively improved through actual machine testing. Table 2 shows the result of optimization:

**Table 2** Valve plate optimization

| | |
|---|---|
| Internal leakage | Lower by 50.7% |
| Swash plate vibrating force | Lower by 11.6% |
| Swash plate inclining moment amplitude | Lower by 15.2% |
| Discharge pressure pulsation amplitude | Lower by 17.6% |
| Noise under high load | Lower by 3.1 dB |

## 3 Track Motors for Closed Circuit

This product is a hydraulic motor with a case-rotating transmission for crawlers. KYB has manufactured the conventional counterpart without changing the original specifications since its release. The track motor for a closed circuit that can be typified by crawler carriers is required to be run more frequently and last longer than the excavator motor. In addition, the market has demands for higher-speed motors with a higher output torque. To meet the demands, KYB has developed this product that can provide a longer life, higher torque and higher speed, based on the conventional counterpart.

**Table 3** Comparison of specifications between conventional product and market demands

| Model | | Conventional product | Market demands |
|---|---|---|---|
| | | MAG-33VP-550 | —— |
| Maximum output torque (N・m) | | 3649 | Not less than 4000 (higher by 10% or more) |
| Maximum output speed (rpm) | | 130 | Not less than 140 (higher by 8% or more) |
| Outer dimensions (height x max outer diameter) | | 313×φ286 | ← |
| Mounting dimensions (vehicle side) | | Fit diameter: φ200, Fastening holes: 10 x M14 x 2.0 | ← |
| Mounting dimensions (output side) | | Fit diameter: φ230, Fastening holes: 9 x M14 x 2.0 | ← |
| Life ratio | | 100% | Not less than 170% (higher by 70% or more) |
| Auxiliary | Transmission | Manual transmission | Manual or automatic transmission |
| | Parking brake | Equipped as standard | Equipped as standard |
| | Flushing valve | Mountable | Equipped |

**Photo 3** Product appearance (MAG-33VP-650)

Photo 3 shows the appearance of the product. The hydraulic track motor consists of a control valve section, swash plate piston motor section and reduction gear section as shown in Fig. 6.

KYB's hydraulic track motor has the following major features:

① Specially-designed case-rotating type motor that is most suitable for driving crawlers and so small that can be accommodated within the crawler width

② High continuous running performance (= high output torque) achieved by use of a case-rotating planetary reduction gear and hydraulic pistons

③ Shifting system supports Run and Traction modes. It is possible to select an automatic shifting system that monitors loads during Run mode and switches into Traction mode upon detection of a high load. The speed ratio between Run and Traction modes is up to two times for the same flow rate.

④ Workability and stopping performance on a slope are generally required depending on the work environment. The product allows the operator to work or stop on a slope with the parking brake function. Equipping of a parking brake function is required by laws in some European regions.

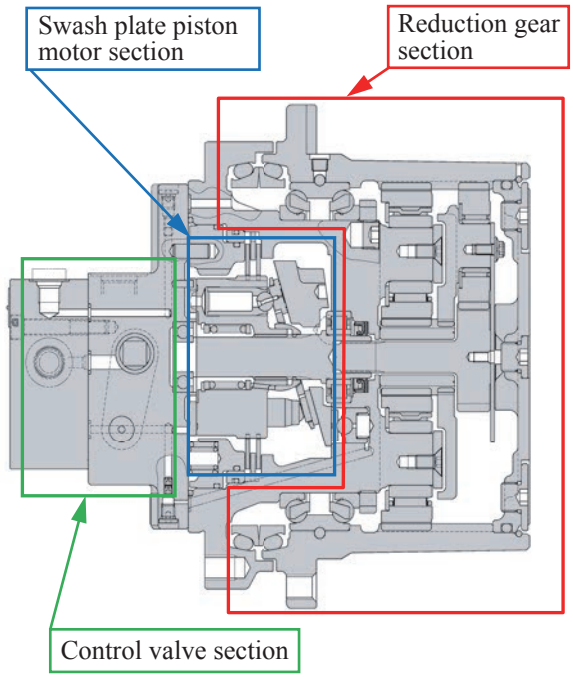


**Fig. 6** Cross section of hydraulic track motor

### 3.1 Challenges to be overcome for longer life and higher output

For higher service life of hydraulic track motors, various approaches are available, including enhancing the strength of the tribological rotary parts to improve durability and increasing the gear module or face width to enhance reduction gear strength and durability. The output torque of the motors could be raised by expanding the motor volume, by elevating the motor pressure or by increasing the speed reduction ratio. These conventional approaches may compensate for the drawbacks of the motors, but will inevitably upsize them.

Construction machinery manufacturers always demand to maintain the compatibility with conventional products

during installation. (Any remodeled motors must be able to be mounted on conventional machinery). Therefore, it is a must to achieve "longer life and higher output" without changing the fit diameters on the vehicle side, as well as on the output side as shown in Fig. 7.

In this product development, a longer-life, higher-output motor with existing outer dimensions that can deliver the existing vehicle speed as construction machinery must be developed. To do so, it is indispensable to increase the rotary parts pressure for higher output, to improve the tribological characteristics for longer life, and to improve gear strength and durability without changing the gear size of the transmission.

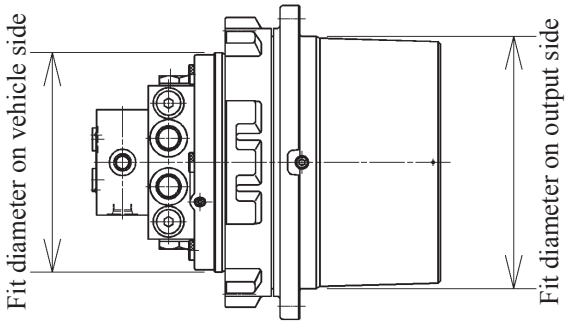


**Fig. 7** Vehicle fitting diameter

## 3.2 Development Technologies for Longer Life, Higher Output and Higher Speed

### 3.2.1 Piston Motor Section

The piston motor outputs the hydraulic energy in the form of rotation or torque as the rotary parts slide with each other.

Fig. 8 shows the rotary parts of the piston motor. The surface treatment of the cylinder block and swash plate has been optimized. The piston shoes have been changed from conventional single pads to multipad to suppress shoe deformation occurring with high pressure and to enhance the tribological characteristics. These improvements have resulted in longer life and higher pressure, thereby enabling the motor to satisfy demands for higher output and higher speed.

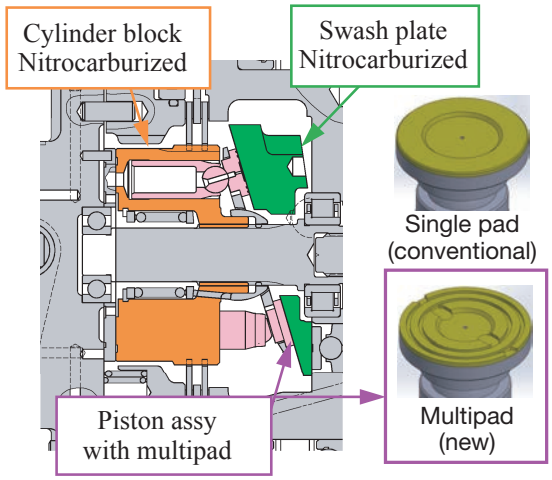


**Fig. 8** Cross section of piston motor

### 3.2.2 Reduction Gear Section

The reduction gear section has been improved to achieve a longer life, higher output and higher speed with the conventional outer dimensions unchanged. Part of the improvement is described below.

#### (1) Gear strength and gear shaft rigidity

Gears with a larger module have higher flexural strength and, those with a larger face width have higher durability because of a lower contact surface pressure. However, changing the module or face width will inevitably upsize the transmission in the radial or axial direction, making it difficult to design a construction with the same fit diameter and same total length as the conventional ones.

It should also be noted that, even if a gear has higher strength itself, the tooth surface may have pitching or other faults unless proper engagement is ensured. In this case durability cannot be enhanced. To ensure proper engagement, shaft rigidity is one of the important factors.

Here, the total rigidity balance of the reduction gear assembly was reviewed to suppress the shaft deflection, ensuring e shaft rigidity. The tooth profile was also reviewed to correct the gear engagement, resulting in a longer life and higher output.

#### (2) Floating seal

It is indispensable for achieving a higher speed to take measures against heat generation in the sliding interfaces of the floating seals. Changing of the floating seal material and ring profile resulted in a lower seal load. The development team eventually developed a seal compatible with high-speed revolution without degrading the resistance to sediment invasion, and introduced the seal into the new product.

## 3.3 Product Features

Table 4 provides the major specifications of the product.

**Table 4** Comparison of specifications between conventional and new products

| Model | | Conventional product | New product |
|---|---|---|---|
| | | MAG-33VP-550 | MAG-33VP-650 |
| Maximum equivalent volume [$cm^3$/rev] | | 863 | ← |
| Maximum pressure (inlet) [MPa] | | 30.9 | 37.3 (20%UP) |
| Charge pressure [MPa] | | 3.0 | ← |
| Maximum motor speed [rpm] | | 3600 | 4000 (11%UP) |
| Reduction rate | | 25.526 | ← |
| Maximum output torque [N・m] | | 3649 | 4050 (11%UP) |
| Maximum output speed [rpm] | | 130 | 150 (15%UP) |
| Life ratio | | 100% | 177% (77%UP) |
| Outer dimensions (height x max outer diameter) | | 313×φ286 | ← |
| Mounting dimensions (vehicle side) | | Fit diameter: φ200, Fastening holes: 10 x M14 x 2.0 | ← |
| Mounting dimensions (output side) | | Fit diameter: φ230, Fastening holes: 9 x M14 x 2.0 | ← Fastening holes: 12 x M14 x 2.0 |
| Auxiliary | Shifting system | Manual shifting | Manual shifting Automatic shifting (option) |
| | Parking brake | Equipped as standard | ← |
| | Flushing valve | Mountable | Equipped |
| Product mass [kg] | | 55.0 | ← |

The new product achieves a longer life by 77%, a higher torque by about 11% than that of the conventional counterpart with the outer dimensions unchanged from the conventional ones, and a faster output speed than that of the conventional one by about 15%.

In addition to the conventional manual shifting, an automatic shifting system has been successfully added to the product lineup.

## 4 In Closing

The development team has achieved the hydraulic pilot control, longer life, higher output and higher output speed that are demanded by the market, and has successfully expanded the separate HST product lineup. The new product introduced in this report has already been ordered for mass production by customers and delivery started in spring 2017.

The development team efficiently promoted the product development by making full use of simulation approaches against various challenges. The demands of the construction equipment and agricultural machinery markets are increasingly becoming even more sophisticated in a wide range of aspects including computerization, efficiency enhancement and cost reduction. The team is committed to continue making efforts to catch up with these demands. Finally, we would like to extend deep gratitude to those concerned who have extended their great support and cooperation to us.

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Product Introduction

# Development of Control Valve for Wood-Splitting Machine

ISHIJI Rei

## 1 Introduction

KYB Engineering & Service Co., Ltd delivers hydraulic equipment products including agricultural machinery and construction equipment to many different customers.

The company was requested by HONDA-WALK CO., LTD., which imports and sells wood-splitting machines, to offer a hydraulic system for a new wood-splitting machine to be developed.

To set up the specifications of the hydraulic system, both companies began joint survey and measurement of the existing wood splitting machines.

Prior to describing the control valve, the following explains wood-splitting machines.

## 2 Wood-Splitting Machines

General wood-splitting machines have a power source to move a splitter blade or log so as to split it into smaller pieces. Wood-splitting machines can be divided into stationary and portable types (Photo 1).

**Photo 1** Example of wood-splitting machine
(Source: HONDA-WALK CO.,LTD. Catalog)

The blade of the wood-splitting machine has a tapered shape and is used to literally split a log rather than cut it. The machine is also called a log splitter machine. People throughout time usually swing an axe down onto a log to split it into pieces. This work requires physical strength and skill, which has driven the mechanization of wood splitting work. Currently many different types of wood-splitting machines utilizing gravity, mechanical, electrical or hydraulic power to split wood are manufactured and sold, instead of using an axe by hand.

The target wood-splitting machine in this development project is supposed to be equipped with a hydraulic system that uses an engine to drive a hydraulic pump, controls the hydraulic oil with a control valve, and pushes a blade through a log with a hydraulic cylinder. The machine also has a crawler or tires to enable movability. This configuration is the most popular and sold most.

## 3 Hydraulic Properties of Wood-Splitting Machines

### 3.1 2-stage Pumps

A series of work to split a log can be roughly divided into two processes.

The first is a process requiring not so much power.

All that is needed in this process is to move the blade. Travel speed, rather than power, is essential. For this process a low-pressure high-capacity pump is needed.

The second process is to split a log.

This process requires hydraulic power rather than speed. Hydraulic power will be the source of splitting logs. For this process a high-pressure low-capacity pump should be used.

Thus the first speed-oriented process, using a low-pressure high-capacity pump, and the second power-oriented process, using a high-pressure low-capacity pump, should be automatically switched over to implement a wood-splitting machine.

Almost every wood-splitting machines use this switching system to allow log splitting, even with a low output engine in a short time cycle.

### 3.2 Control Valve Operation

The control valve has the following three operation modes selected by the lever position (Fig. 1).

① Neutral

The lever remains in neutral position until it is operated. The hydraulic oil flows from the hydraulic pump to a tank. The hydraulic cylinder is stopped.

② Pull (Hydraulic cylinder: Expand)

When the lever is pulled, the hydraulic cylinder expands to start splitting the log. When the lever is released, it returns to neutral position and the cylinder comes to a stop.

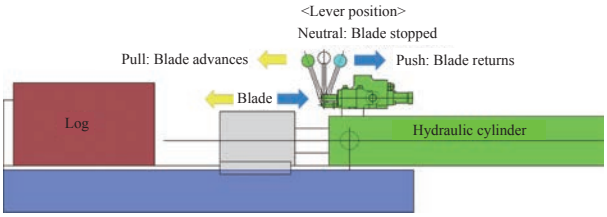


**Fig. 1** Lever position and hydraulic cylinder motion

③ Push (Hydraulic cylinder: Contract)

After the log has been split, pushing the lever will fix the lever in the current position. Even if the lever is released, the hydraulic cylinder continues contracting.

During this time, the operator can set up another log. This function is probably used in almost all wood-splitting machines.

Fig. 2 gives the hydraulic circuit diagram including the series of motion above. Fig.3 shows the motion of wood-splitting machines along with pressure and flow rate measurements.

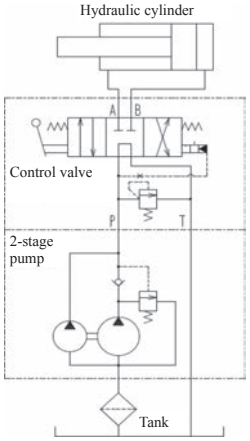


**Fig. 2** Hydraulic circuit diagram of wood-splitting machine

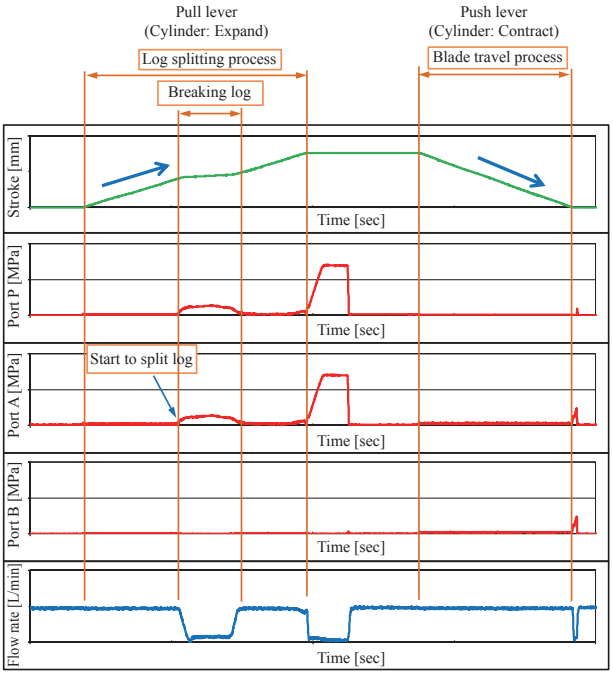


**Fig. 3** Wood-splitting machine motion and pressure measurements

## 4 Development of Control Valve

### 4.1 Specifications

The control valve specifications (Table 1) were determined based on actual measurement of existing machines as well as customer demands.

The control valve of the wood-splitting machine needs to have the following functions:

**Table 1** Control valve specifications

| Item | Specifications |
|---|---|
| Maximum operating pressure | 20.6MPa |
| Service flow rate | 30L/min |
| Allowable back pressure | 1.5MPa |
| Relief valve pressure setting | 20.6MPa at 6.5L/min |
| Hydraulic oil | Oil equivalent to ISO VG32 |
| Oil temperature range | -20°C to 80°C |
| Cylinder port leakage | 6 to 60 $cm^3$/min at 6.9MPa |
| Product mass | 4.5kgf |

① Neutral: P-T open
② Pull: Spring return
③ Push: Holding by detent mechanism
These functions have been already described in section 3.2.
④ Push: Auto return upon full stroke

The auto return function refers to a mechanism that, when the cylinder has gone through a full stroke, automatically returns the lever to neutral position with a higher pump pressure. This mechanism had never been implemented with traditional technology and has been successfully developed by making use of the pressure receiving area of the spool. Note that the lever and relief valve share proven parts to ensure higher reliability and lower cost, reducing the number of new parts to be introduced.

### 4.2 Improvements after Prototype Test

#### (1) Increasing the holding force of the detent mechanism

For the conventional design, the spool was fixed with the detent mechanism to hold the lever position during the contraction stroke of the hydraulic cylinder. However, the spool accidentally returned to neutral position. This problem occurred because the detent mechanism could only provide a weak holding force and was released at a low pressure. To solve the problem, the spool diameter was changed to diminish the difference in area between the sections. The spool length was also changed to be compatible with standard parts and seals. In addition, the groove angle and spring force were increased to raise the holding force, eventually satisfying the target (Fig. 4).

#### (2) Reducing the lever operating force

Operator was likely to be tired from continual lever manipulation with the existing machine. Then the development team tried to reduce the lever operating force from the existing level. To prevent return failures, the return spring load has been reduced as far as possible

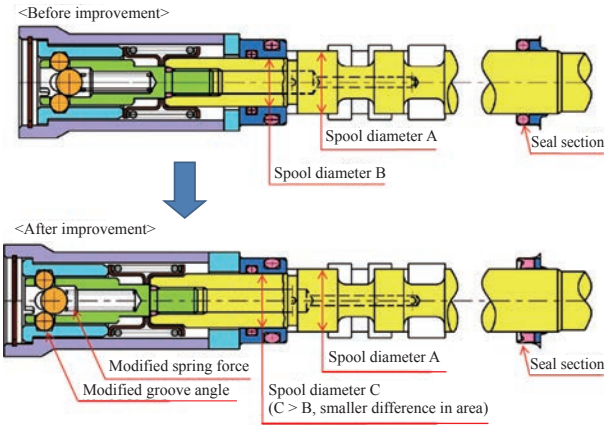


**Fig. 4** Higher holding force of detent mechanism

within the range of the operating conditions.

### (3) Durability of the seal section

The seal section externally leaked during the operation durability test. It was revealed that the detent mechanism returned from the holding state to neutral too quickly due to poor seal performance. Therefore the seal has been replaced with one with good following performance, satisfying the durability target (Fig. 5).

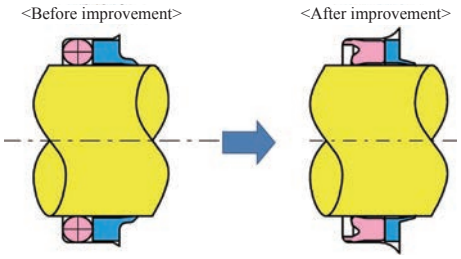


**Fig. 5** Seal improvement

## 4.3 Using a Cast Body

The control valve body was conventionally fabricated by shaving. In the prototyping of the new control valve, the manufacturing method was changed from shaving to casting. The method of mounting the valve body onto the hydraulic cylinder was also changed from conventional screwing to fastening with bolts.

This change reduced the piping part cost and installation fee, and also eliminated oil leakage due to loose screwed-in piping (Fig. 6).

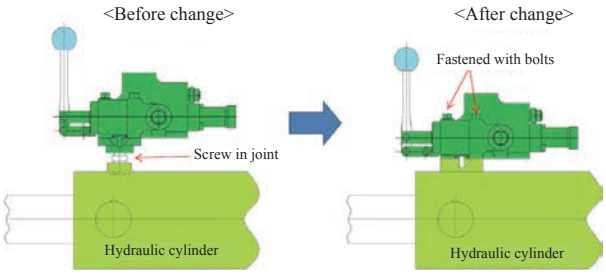


**Fig. 6** Valve installation

These improvements have been successfully introduced before the launch of mass production. Photo 2 shows the appearance of the control valve, and Fig. 7 gives the outline drawing.

**Photo 2** Appearance of control valve

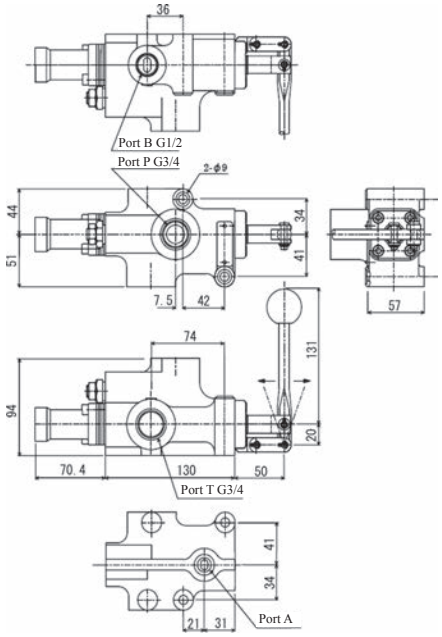


**Fig. 7** Outline drawing of control valve

## 5 Future Development

This section introduces the wood-splitting machine MS4000J jointly developed by HONDA-WALK CO., LTD. and KYB (Table 2, Photo 3).

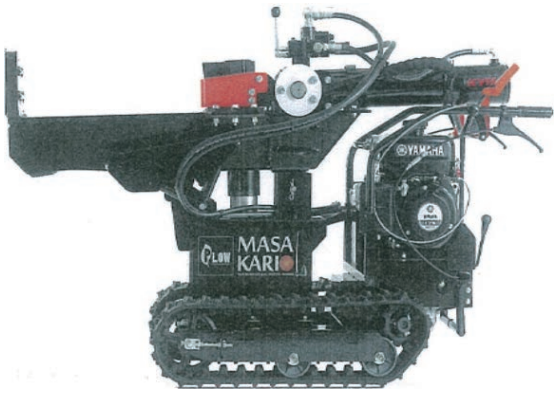


**Photo 3** Appearance of wood-splitting machine MS4000J (Source: HONDA-WALK CO.,LTD. Catalog)

**Table 2** Major specifications of wood-splitting machine MS4000J (Source: Hondawalk Inc. Catalog)

| Major specifications | | |
|---|---|---|
| Model | | MS4000J |
| Engine | Manufacturer | Yamaha |
| | Type | Air-cooled four-cycle inclined type OHV gasoline engine |
| | Engine model | MZ175 |
| | Displacement | 171cc |
| | Fuel tank capacity | 4.5 l |
| | Engine oil capacity | 0.6 l |
| | Plug | NGK BPR4ES |
| Cylinder thrust | | 20 ton |
| Breakdown force | | 40 ton |
| Dimensions | Length (horizontal version) | 1,850 mm |
| | Height (horizontal version) | 1,150 mm |
| | Width | 690 mm |
| | Length (vertical version) | 1,800 mm |
| | Height (vertical version) | 1,730 mm |
| Dry mass | | 310kgf |
| Hydraulic oil tank capacity | | 16 l (hydraulic oil #32) |
| Maximum splittable size | | 630 mm |
| Drive | | Two forward gears, one backward gear |
| Cycle time | | 21 sec (12-sec advance, 9-sec retract) |

Following the domestication of imported models, the companies will continue to develop cost-oriented models and those with a modified hydraulic system. Hondawalk plans to use KYB's control valve as a common part of these models.

## 6 In Closing

Wood-splitting machines equipped with the developed product have just begun to be manufactured and sold.

Experienced wood splitters and purchasers seemed to have various opinions and demands for improving the conventional machine.

I believe Hondawalks would enjoy the benefits from the machine equipped with the developed product in satisfying those demands.

Recently the value of wood as woody biomass has been reconsidered in power generation applications since chips or pellets of woody biomass are more readily burned than firewood. This application definitely requires mass production of chips or pellets. Briquettes produced by solidifying sawdust (artificial firewood) and other woody biomass products have also become available, but seem to be inferior to firewood in cost.

Thus, the demand for wood-splitting machines will probably still continue.

KYB would like to continue developing products satisfying customer demands.

Finally, I would like to take this opportunity to thank those concerned inside and outside KYB who have supported the development of the control valve for wood-splitting machines.

## Author

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Product Introduction

# Variable Damping Type Oil Damper

SAKAKIBARA Kento

## 1 Introduction

Many buildings are made earthquake-proof with various seismic measures to protect lives and property. One of them is a "seismic isolation structure" that uses oil dampers. KYB Technical Review No.52 introduced the Seismic Isolation Damper for Narrow Land in City (with External Damping Force Switching Mechanism) and KYB Technical Review No.54 described the Oil Damper System for Seismically Isolated Structures with Lock Mechanism (Wind Sway Reduction System Using Electric Control). This report introduces an oil damper with a built-in damping force adjusting mechanism.

## 2 Challenges Left Against Big Earthquakes Including Long-Period Ground Motions

It is feared that a big earthquake would occur in the Nankai or Sagami Trough in the near future. If this is the case, a long-period ground motion that slowly sways the ground repeatedly for a long time is highly likely to occur. Seismic buildings are designed to slowly sway in the event of a long-period ground motion, but may sway much more heavily than the design seismic level. For example, seismic buildings designed in the early stage were constructed without taking into account the possibility of long-period ground motions. The seismic isolation layer in such buildings (a layer between the ground and the building into which a base isolator is inserted) only has a low allowable deformation range. It is pointed out that the building may collide against the retaining wall (the wall of the seismic isolation layer). In addition, even a newly constructed seismic isolation building is assumed to have big tremors that would exceed the deformation limit of isolators (such as laminated rubber or slide bearings).

With the background, attempts are being made to reduce the deformation of the seismic isolation layer. To suppress the deformation, it is effective to increase the damping force of the damper installed along with the isolator. However, if the damping force of the damper is determined from the postulated maximum quake, the whole seismic isolation layer would be too hard. Such a hard seismic isolation layer would suppress the deformation too much in the event of a small or mid-scale earthquake, which is relatively more likely to occur and would cause the layer only to slightly deform in the first place. The inherent performance of the layer that will not transfer the shake of a quake to the building (acceleration reduction effect) may be lost (Fig. 1).

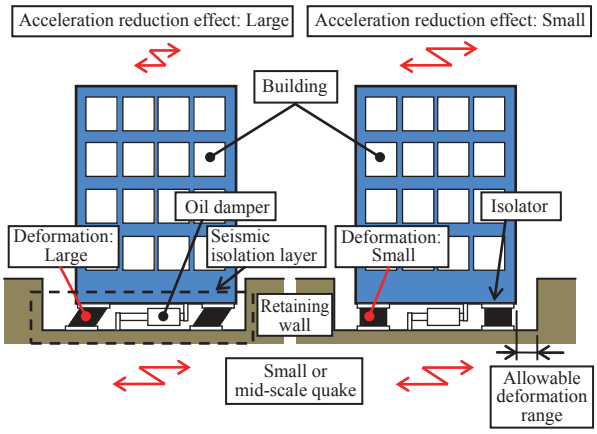


**Fig. 1** Effect of damper's damping force on seismic buildings

## 3 Background of Development

The variable damping type oil damper introduced in this report has been jointly developed by Shimizu Corporation and KYB. As stated above, if the damping force of the damper is set for big earthquakes, the acceleration reduction effect of the isolator would be degraded.

This seemingly contradictory problem can be solved by enabling switching of the damping performance between for large quakes and for small/medium strength quakes to achieve both improved habitability and prevention of excessive deformation during a big quake. To achieve this, it is necessary to detect the magnitude of earthquakes. However, an electrically controlled switching system using sensors and solenoid valves may fail to work in the case of power failure.

Here, another system has been developed in which the seismic isolation layer detects the magnitude of an earthquake through its own deformation (i.e., the deformation quantity of its oil damper) and mechanically selects a damping function suitable for the magnitude of the quake without using electricity. This is called a "displacement-dependent damping performance switchable base isolator". Many of these types of products are designed to select a function for large quakes when a predetermined displacement is exceeded and retain the high damping force once the function is switched over. This design will greatly deliver the deformation suppression effect of the seismic isolation layer. However, because of this feature, the system needs to be manually returned to the function for small/medium strength quakes after shaking has subsided.

On the other hand, the variable damping type oil damper described in this report is constructed so that the damping performance can be mechanically switched over according to the damper deformation. The system automatically selects a low damping force for small/medium strength quakes at around the center where only small damper deformation occurs, while it selects a high damping force for large quakes when a predetermined displacement is exceeded. The relationship between the damping force and displacement of a standard oil damper can be plotted as an elliptical shape as shown in Fig. 2,

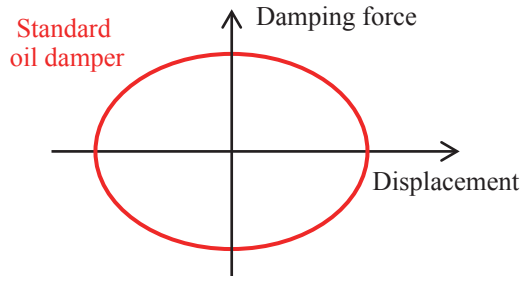


**Fig. 2** Hysteresis loop of standard oil damper

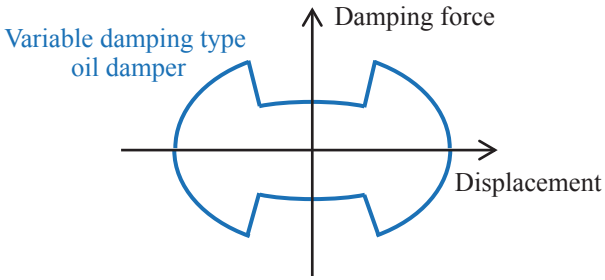


**Fig. 3** Hysteresis loop of variable damping type oil damper

and that for the variable damping type oil damper can be plotted as an H-shaped profile with its top and bottom centers concaved as shown in Fig 3. This implies that the deformation suppression effect during a big quake will slightly decrease. Still the system does not require manual operation after each quake since it switches the function over whenever necessary.

## 4 Configuration and Principle of Operation of Developed Dampers

Fig. 4 shows the configuration of the variable damping type oil damper. The damper mainly consists of a cylinder tube, inner tube, piston rod, piston and hydraulic fluid. In the cylinder tube there are pressure regulating valves that provide a damping force according to the speed, relief valves and check valves. This configuration is based on the standard Building Damper hi-Speed type (BDS) base-isolation oil damper for Kayaba's system machinery. For more information about the BDS oil damper, see KYB Technical Review No.26.

The variable damping type oil damper is added with a switching rod as a mechanism to adjust the damping force according to the deformation. The switching rod has a longitudinal groove along its center line over a certain length. The switching rod is installed so as to penetrate through the piston. The groove of the switching rod and piston constitutes a passage for the hydraulic oil, which is opened or closed by the relative movement of these two components. The damping performance can be switched over by the relative position of the switching rod. This relative travel of the switching rod is called switching displacement.

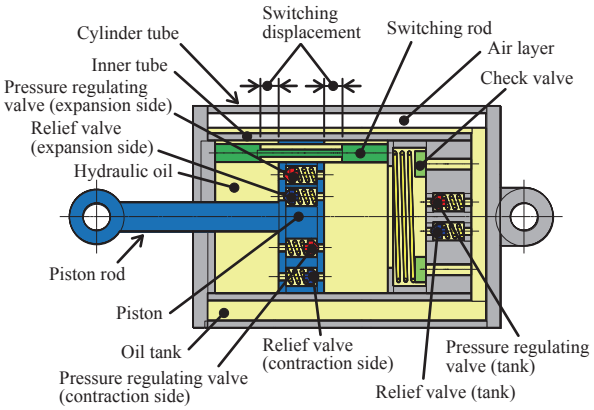


**Fig. 4** Configuration of variable damping type oil damper

Since the mechanism to implement the variable damping performance (switching rod) is completely included in the oil damper, the shape and dimensions are the same as those of the standard (BDS) oil damper (Photo 1).

Fig. 5 shows the design damping characteristics of the variable damping type oil damper. Low damping performance with small damping deformation is called low damping and high damping performance with large damping deformation is called high damping. In the primary damping region for low damping, the damping performance of the expansion side differs from that of


**Photo 1** Appearance of test specimen

the contraction side. This is because the piston rod of the variable damping type oil damper only extends to one side and the contraction and expansion sides have different pressure receiving areas, but the groove area of the switching rod is evenly distributed between the contraction and expansion sides.

The damping performance is designed to be represented by a bilinear diagram in which the damping force is switched over at a certain speed for either the high or low damping. The damper can deliver high damping forces at low speeds up to a certain speed level (primary damping region). Once the speed level is exceeded, it maintains the damping force at almost the same level without a spike up to the maximum speed (secondary damping region). This switching feature is also used in the standard (BDS) oil damper.

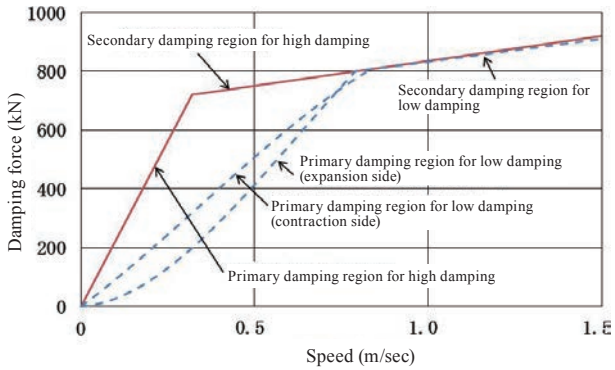


**Fig. 5** Design damping characteristics

The following explains the principle of operation of the variable damping type oil damper.

(1) Principle of operation (expansion, low damping)

Fig. 6 shows the principle of operation during the expansion stroke for low damping. The variable damping type oil damper expands or contracts in response to vibration of the objects installed on the both sides of the damper. When the piston rod expands, the connected piston moves to raise the pressure in chamber A. The hydraulic oil passes through the pressure regulating valve (expansion side), relief valve (expansion side) and groove of the switching rod, and then flows into chamber B. The hydraulic resistance then acts as a damping force according to the piston speed. During this stroke the hydraulic oil mainly flows through the groove of the switching rod, rather than through the pressure regulating valve (expansion side) and relief valve (expansion side), resulting in a lower flow in the latter two valves. Compared to the case in which the oil only passes through the pressure regulating valve (expansion side) and relief valve (expansion side), the damping force is lower for the same speed (i.e., low damping). The damping force is controlled by the pressure regulating valves for the primary damping region and is controlled by the relief valves for the secondary damping region. Note that the amount of hydraulic oil in chamber A is lower than that in chamber B by the volume of the piston rod. To compensate for the difference, the hydraulic oil is supplied from the oil tank to chamber B via the check valve, making the piston ready for next contraction process.

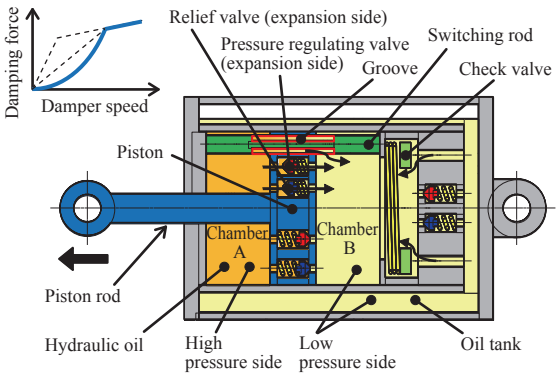


**Fig. 6** Principle of operation (expansion, low damping)

(2) Principle of operation (expansion, high damping)

Fig. 7 shows the principle of operation during the expansion stroke for high damping. The piston rod further expands. When the damper deformation exceeds the relevant switching displacement, the piston goes beyond the groove provided on the switching rod. The hydraulic oil no longer flows in the switching rod section and only flows in the pressure regulating valve (expansion side) and relief valve (expansion side). Now the oil flows into chamber B via the pressure regulating valve (expansion side) and relief valve (expansion side), and the hydraulic resistance based on these two valves acts as a damping force according to the piston speed (high damping).

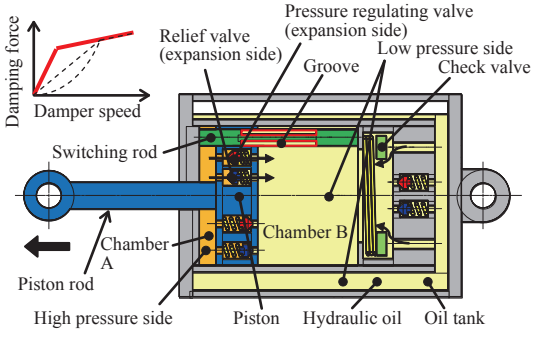


**Fig. 7** Principle of operation (expansion, high damping)

(3) Principle of operation (contraction, low damping)

Fig. 8 shows the principle of operation during the contraction stroke for low damping. As the piston rod contracts, the check valve is closed and the pressure in chamber B increases. The hydraulic oil passes through the pressure regulating valve (contraction side), relief valve (contraction side) and groove of the switching rod, and

then flows into chamber A. Like the expansion stroke, this contraction stroke also controls the damping force with the pressure regulating valves for the primary damping region and controls the force with the relief valves for the secondary damping region. The hydraulic resistance then acts as a damping force according to the piston speed. During this stroke the hydraulic oil mainly flows through the groove of the switching rod rather than through the pressure regulating valve (contraction side) and relief valve (contraction side), resulting in a lower flow in the latter two valves. Compared to the case in which the oil only passes through the pressure regulating valve (contraction side) and relief valve (contraction side), the damping force is lower for the same speed (i.e., low damping). The amount of hydraulic oil equivalent to the volume of the piston rod flows into the oil tank via the pressure regulating valve (tank) and relief valve (tank). The oil flows through the groove of the switching rod on a priority basis again, resulting in a lower damping force for the same speed.

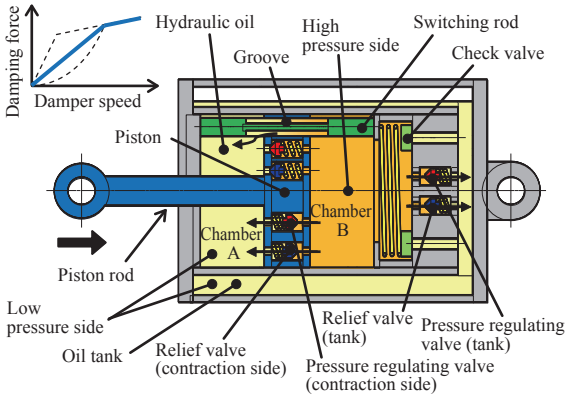


**Fig. 8** Principle of operation (contraction, low damping)

(4) Principle of operation (contraction, high damping)

Fig. 9 shows the principle of operation during the contraction stroke for high damping. The piston rod further contracts. When the damper deformation exceeds the relevant switching displacement, the piston goes beyond the groove provided on the switching rod. The hydraulic oil no longer flows in the switching rod section and only flows in the pressure regulating valve (contraction side) and relief valve (contraction side). Now the oil flows into chamber A via the pressure regulating valve (contraction side) and relief valve (contraction side), and the hydraulic resistance based on these two valves acts as a damping force according to the piston speed (high damping). In addition, the amount of hydraulic oil equivalent to the volume of the piston rod flows into the oil tank via the pressure regulating valve (tank) and relief valve (tank). The hydraulic resistance then acts as a damping force according to the piston speed.

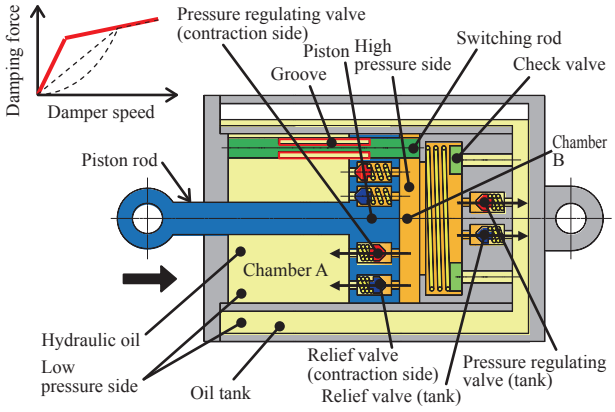


**Fig. 9** Principle of operation (contraction, high damping)

## 5 Verifying the Variable Damping Performance

In relation to the performance of the variable damping type oil damper, the repeatability of the design damping characteristics was examined. To verify the performance for both low and high damping forces, sine wave vibration experiments were conducted with the vibration starting point shifted. The vibration center was established at the point when the piston was contracted until it went beyond the installed length for low damping measurement, or until it went beyond the switching displacement for high damping measurement.

Fig. 10 shows the result for low damping and Fig. 11 for high damping. In both figures, the experiment results at five different vibration speeds overlapped. The piston speed is higher at a larger displacement, thereby raising the damping force. The two most external curves in the low damping diagram and all five curves in the high damping diagram show the experiment results for the secondary

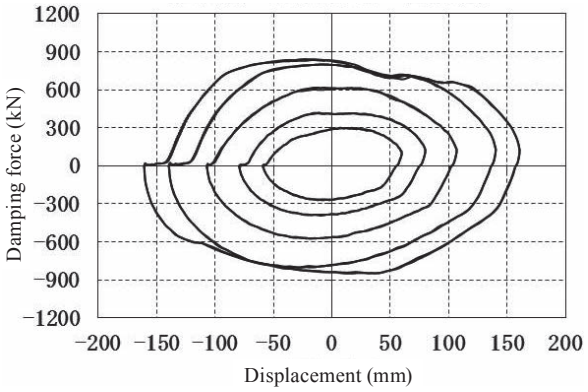


**Fig. 10** Damping force - Displacement hysteresis curves (low damping)

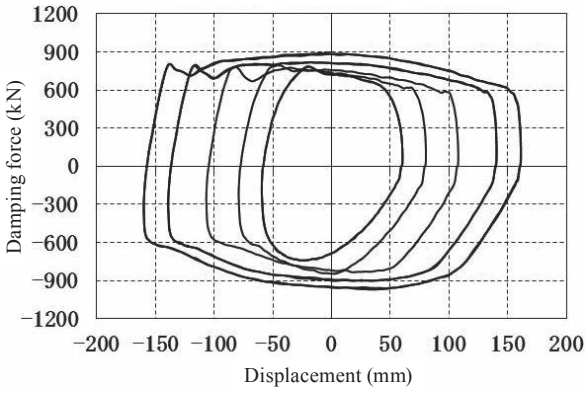


**Fig. 11** Damping force - Displacement hysteresis curves (high damping)

damping region. They indicate that the damping force becomes unlikely to rise from a certain value due to the effect of the relief valve, making the profile of the curves almost rectangle.

Fig. 12 plots the maximum damping forces at various speeds for the high and low damping forces. For comparison purposes, the design damping characteristics in Fig. 5 are also indicated by solid and broken lines. It can be verified from the figure that the experiment results are in accordance with the design damping characteristics for both high and low damping forces.

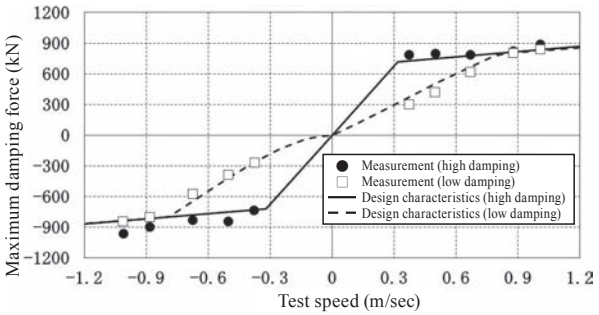


**Fig. 12** Maximum damping force - speed characteristics

To verify the switching performance, an experiment using sine and random waves with a vibration amplitude exceeding the switching displacement was conducted. Fig. 13 plots the experimental result of vibration with a large amplitude. The variable damping type oil damper used in the experiment has a switching displacement of +/-200 mm. According to the diagram, the damping force is switched over at a displacement of 200mm at any of the speed conditions.

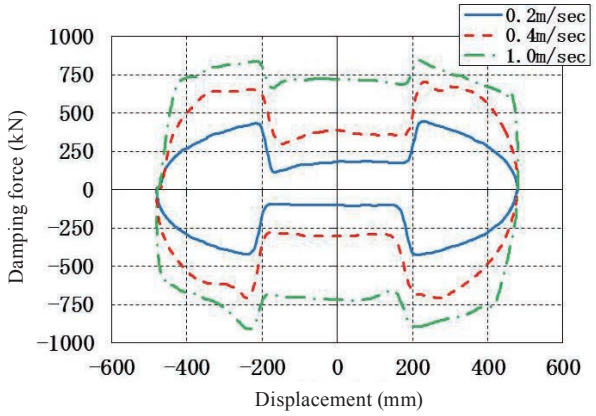


**Fig. 13** Damping force - displacement hysteresis loop (vibration with a large amplitude)

After the vibration experiment with a random wave input, the measurements were compared to the analysis result. Fig. 14 shows a hysteresis loop of the overlapped measurement and analysis results. The comparison of the hysteresis loop between measurement and analysis has revealed that the damping performance is switched over repeatedly at the switching displacement of +/-200 mm for both measurement and analysis. In addition, the switch-over of damping performance measurements occurs with almost no delay from the analysis result. Therefore, it is unnecessary to take into account the time needed for switching-over when carrying out an earthquake response analysis to verify the seismic performance of base isolation buildings as well.

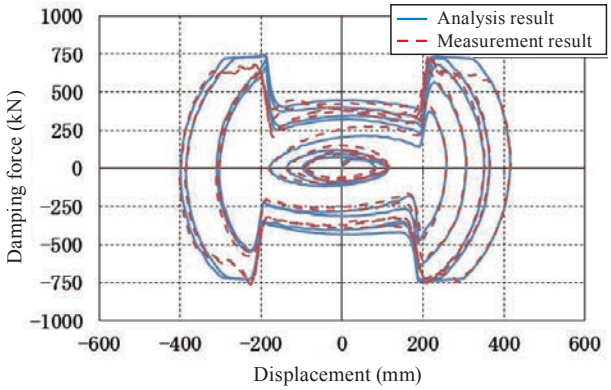


**Fig. 14** Damping force - displacement hysteresis loop (vibration with a random wave)

## 6 In Closing

The variable damping type oil damper was certified by the Minister as a seismic isolation component (certificate No. MVBR-0576) in April 2017. The damper is expected to help improve the habitability of base isolation buildings in the event of a small or medium strength quake, or prevent base isolation buildings from colliding with the retaining wall in the event of a large quake.

Finally, I would like to extend deep gratitude to those who are in charge of the development and personnel in the related functions of Shimizu Corporation, various internal divisions, as well as those from related partner companies for their cooperation in product development.

## Author

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Technology Introduction

# Development of Equipment for Evaluating Automotive Vane Pumps

TSURI Takuya, FUJII Toshihiko, KODERA Yasuhiro

## 1 Introduction

As automotive manufacturers have been addressing production of environmentally friendly cars, components manufacturers are also required to improve the performance of automotive components for lower environmental load.

Under the daily efforts to improve the performance of KYB products, the Experiment Dept., which is responsible for evaluating product validity, has addressed many different challenges, including development of necessary technologies for product evaluation (testing machines), improvement of test accuracy and enhancement of test efficiency.

## 2 Product Introduction

The world's first vane pump for CVT [Note 1)], which was put into mass production in 2004, has successfully increased in production and is now one of KYB's key products.

KYB has developed many different models of vane pumps, including the world's first CVT vane pump (6K), the vane pump with aluminium die-cast cover for small and medium size cars (7K), its advanced model with even higher performance (6K2) and the lower torque model with the flow control valve eliminated (7K3, see Photo 1).

The company has a lot of overseas production sites, with recent additions in China, Thailand and Mexico, to produce several hundred thousand vehicles per month. They are highly rated by customers for their performance and quality.

Note 1) Stands for Continuously Variable Transmission.

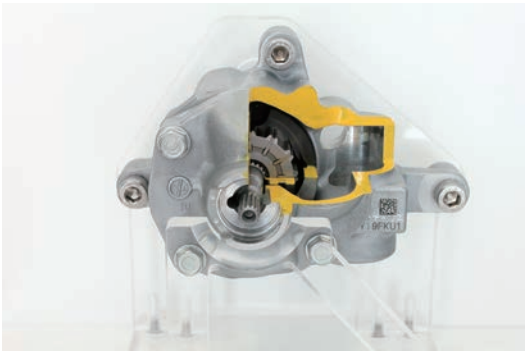

**Photo 1** CVT vane pump (7K3)

## 3 Efforts by Experiment Dept.

The vane pump is used as a hydraulic power source of CVT and greatly contributes to the transmission performance. For this reason, customers stringently require manufacturers to improve the performance. Engineers often argue the specification values for flow rate or driving torque at an accuracy as small as the 1/100 level, which is very minute compared to the case of multi-purpose pumps.

Product evaluation cannot be done accurately if the testing machine or measuring instrument used shows greater variations than those permitted by the product specifications. It is an important role of the Experiment Dept. to improve the measurement accuracy by eliminating various disturbances affecting the measurements and by sophisticating the data processing method, as well as to develop testing machines. This report introduces part of the efforts.

## 4 Development of performance testing machines

There are two major basic characteristics of pumps: P-Q characteristics and driving torque characteristics. The P-Q characteristics of a pump can be determined through a test to measure the flow rate (Q) of the pump applied with pressure (P). The driving torque characteristics can be determined through a test to measure the friction of the pump running.

Before the development of the new testing machine, all processes, including set-up and measurement, were manually carried out by humans. However, involvement by humans inevitably caused minute differences in operating procedures (adjustment of temperature, pressure and pump speed), which was one of the causes of the variations. To ensure accurate evaluation of product characteristics, it was necessary to eliminate any variations attributable to differences in operating procedures of the testing machine by humans (effects of individual humans).

To address the challenge, KYB has developed another performance testing machine with the following features:

(1) Automated pressure adjustment

(2) Modified torque measurement system

(3) Standardized measuring jigs

The following sections explain each of these features in detail.

### 4.1 Automated Pressure Adjustment

The most important role of the pump as a hydraulic power source is to discharge oil. Since the discharge flow rate varies by pressure, pressure adjustment is one of the critical control items in testing. Great pressure fluctuations may not only cause an unstable flow but also greatly affect the torque variations. To further stabilize the pressure, a balance piston type relief valve has been introduced for pressure adjustment.

In the conventional testing machine, flow rate variations occurred because the pressure adjusting valve was operated by humans at different speeds. When trying to identify a minute error, one could not determine whether the error was attributable to the specimen itself or to the variation in the measurements. Then we addressed an effort to automate the pressure adjustment.

First of all, we discussed the use of a commercially available proportional solenoid valve. For the proportional solenoid valve with an internal spool, however, we feared that the spool might oscillate when the oil was aerated or the characteristic frequency of the piping coincided with the resonance frequency of the spool. We then decided to continue using the existing relief valve, and invented an automatic valve for adjusting the relief valve opening pressure with a servo motor. Furthermore, the servo motor was designed to control its speed in response to the pressure feedback. Consequently, this automatic valve helped achieve pressure elevation at a fixed rate, eliminating the existing dispute over the pressure adjustment speed.

However, another problem arose a couple of months after the introduction of the automatic valve. That was wear of the pressure adjusting screw. The relief valve used was designed to work as a safety valve and was not supposed to be frequently opened or closed for pressure adjustment. The automation of pressure adjustment resulted in a change in feed rate and a longer feed travel to return to the origin, which probably caused the wear in the threaded portion of the pressure adjusting screw. To solve the problem, a grease nipple was provided to facilitate the lubrication (Phot 2).

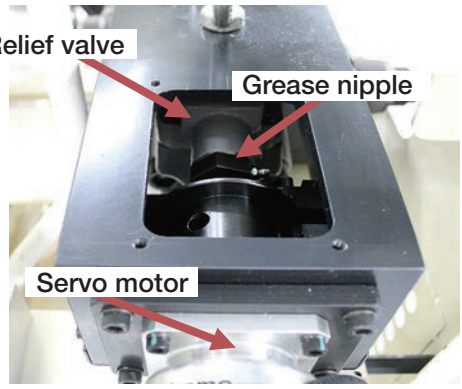


**Photo 2** Developed automatic valve

### 4.2 Modified Torque Measurement System

Along with the introduction of automated pressure adjustment, the torque measurement system was also reviewed. Conventionally, the pump torque measurement was made with the pump speed and pressure set to a specified value and the average of the measurements was calculated. For this system, however, it was unavoidable for different operators to set the pressure to an exactly same value, resulting in minute differences in the test results.

Thus, averaging method has been changed to another torque measurement system in which the pressure is gradually increased across a specified value, and torque values corresponding to different pressure levels are given by a linear interpolation. Finally the specified pressure value can be assigned to the formula to obtain the torque value.

The new system also includes a process to warm up the pump for a certain period of time to stabilize the local temperature of the jigs, measuring instruments, pump bearings and internal parts.

Fig. 1 gives a graph of the measurements. This modification resulted in a smaller variation.

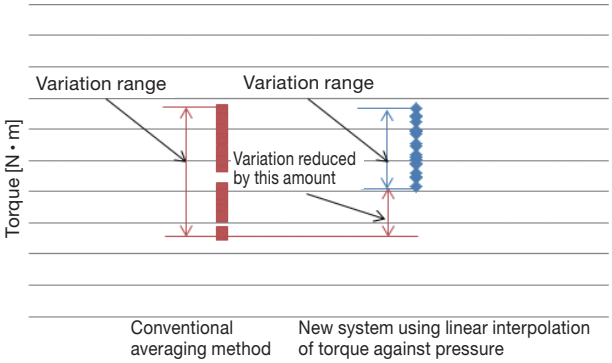


**Fig. 1** Variation reduction by modified torque measurement system

### 4.3 Standardized Measuring Jigs

The existing two jigs have been standardized.

The conventional testing machine (before development) was equipped with two jigs: a P-Q measuring jig and driving torque measuring jig. The belt over the pulleys on the input shaft had to be replaced before another type of measurement (Photo 3). The main reason for the replacement was to prevent an expensive torque meter, if kept installed, from getting broken in the event of an excessive torque.

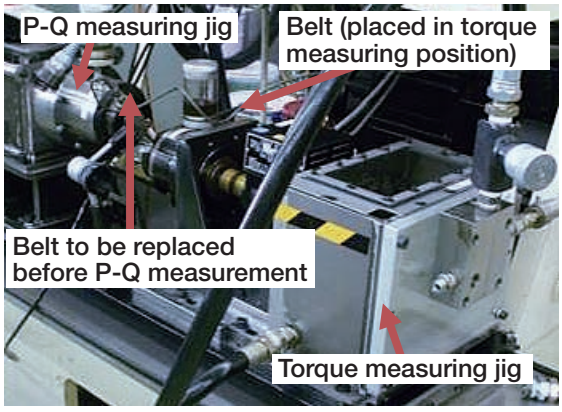


**Photo 3** Conventional performance testing machine

To standardize the jigs, an intermediate shaft was added to the machine with reference to the jig used to measure the P-Q characteristics. The machine has been redesigned so that the

torque meter and the intermediate shaft can be replaced along a linear guide. Through the improvement, the set-up change man-hours have been substantially reduced (Photo 4).

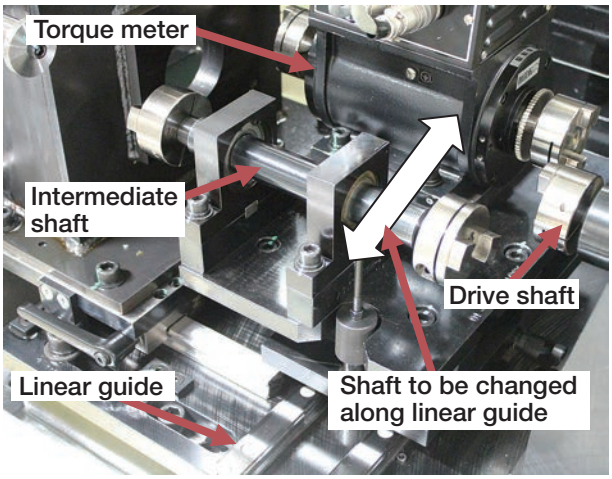


**Photo 4** Developed jig

### 4.4 Effects of Full Automation

With the newly developed performance testing machine, the operator only has to press the Start Evaluation button after a set-up change. The machine then automatically carries out all the processes, including raising the oil temperature, zero adjustment of the measuring instruments and evaluation. The full automation contributes to not only higher measurement accuracy but also higher evaluation efficiency.

The developed performance testing machine is laterally spread to overseas production sites in response to strong requests. Copies of the Japanese testing machine have been introduced to KST (Thai Plant), KMEX (Mexico Plant) and KIMZ (China Plant).

Japanese staff have travelled to the sites to support installation of the testing machines. The staff have also widely provided training and education on how to determine the correlation of measurement data and how to utilize the results, routine and periodical maintenance, and even staff education. Now the overseas sites are able to evaluate the equipment to the same quality as of that in Japan.

The performance testing machines are generally used today for routine evaluation in all the sites of KYB Group (Photo 5).

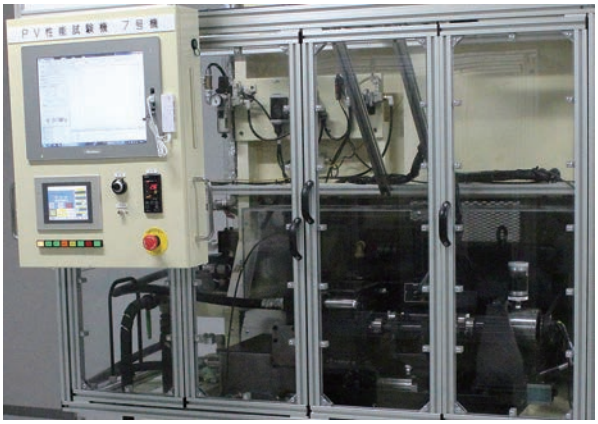

**Photo 5** Fully automated performance testing machine

## 5 Development of Micro Torque Testing Machine

This section introduces a micro torque testing machine that enables the measurement of 1/100 order torque mentioned above (Photo 6).

The specification item critical to fuel efficiency is the torque value at a low speed over a low pressure range, which is a very small value. Its actual measurements are close to the theoretical value with an efficiency of 100%.

The conventional testing machine caused large variations in measurements and required the operator to carry out tests over and over again in order to identify any differences caused by a change in the pump specifications. We then addressed the development of a testing machine for micro torque measurement at a high accuracy.

To develop a new testing machine, we first tried to identify possible factors affecting torque. Finally we decided to review the following items:

(1) Accuracy of measuring instruments (torque meter, pressure gauge)
(2) Drive system
(3) Shaft run-out
(4) Oil temperature control

### 5.1 Accuracy of measuring instruments (torque meter, pressure gauge)

The conventional torque testing machine stated above was fabricated for the purpose of achieving measurement across the total operation range. The machine used a torque meter of a capacity corresponding to the maximum value stipulated in the pump specifications.

First of all, we discussed torque meters so as to improve the measurement accuracy and eventually selected an optimal torque meter by taking into account accuracy, delivery date and cost. Similarly, we discussed pressure gauges and selected one that was most suitable for the measurement conditions.

### 5.2 Drive system

The conventional testing machine transmitted the motor torque output to the pump via the belt. In fact the belt often slipped and caused rotational fluctuations, which adversely affected the torque fluctuations.

To prevent rotational fluctuations, the new machine uses a directly coupled pump drive. It also uses a servo motor to achieve a speed change rate of 0.01% or lower.

### 5.3 Shaft Run-out

When the jig and the pump are misaligned with each other, shaft run-out occurs to cause torque fluctuations, which may result in variations in the measurements. That's why the jig accuracy has been stringently designed. To minimize the shaft run-out, a total manufacturing system from jig machining to assembly has been introduced. A 3-dimentional measuring instrument has been used to control the height dimensions of the shaft.

### 5.4 Oil Temperature Control

The viscosity of hydraulic oil affects the sliding wear of the pump, thereby changing the torque value. Thus, the oil temperature (viscosity) was stringently controlled.

The measurement results are shown in Fig. 2. The variation

in the torque measurements was calculated with a standard deviation of 3$\sigma$. The result did not reach the target value. Another trial to improve the processing method was made.

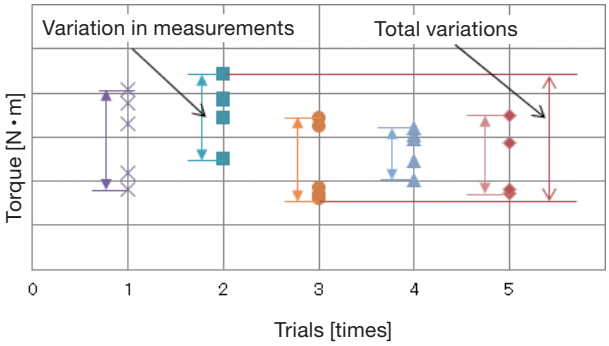


**Fig. 2** Variations in measurements

To further diminish the variation in measurements, we decided to carry out measurement five times and then recorded the average, instead of the conventional single measurement. As a result, accuracy was improved by one digit order with 3$\sigma$.

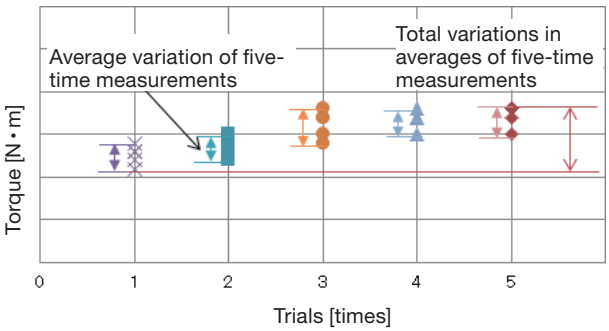


**Fig. 3** Variations in measurements by averaging

With the increasingly rising demand for lower fuel costs, it will be even more difficult to determine whether a micro value is attributable to the pump characteristics or to variations of the testing machine. We are committed to aggressively address achieving even more accuracy-focused measurement so as to evaluate micro values.

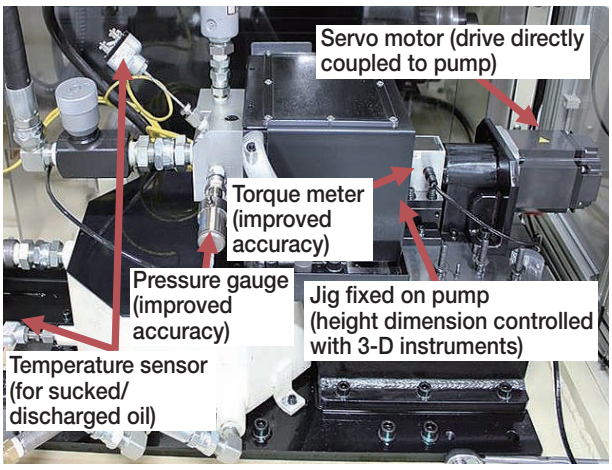


**Photo 6** Developed micro torque testing machine

## 6 Development of Environmental Performance Testing Machine

A vane pump has vanes accommodated in the slits of a rotor. The vanes are tensioned to maintain contact with the bore of a cam ring. The volume of the room formed by the rotor, the vanes and the cam ring is increased or decreased as the pump rotates, thereby sucking or discharging oil. To keep the vanes in contact with the bore, it is necessary to establish a back pressure of the vanes in addition to the use of the centrifugal force. The pump remains unable to discharge oil for the time being until the vanes are brought into contact with the bore.

The time is the longest in cold climate areas. The vanes have a higher sliding resistance for oil with a higher viscosity. The pump needs a longer time until it is ready for discharging oil.

In addition, the pump has more pressure loss in the intake piping at a lower temperature, thereby reducing the discharge flow. In this case the required flow to the CVT may not be ensured. Therefore, reliable evaluation at low temperatures is essential to the development because of the vane pump's construction, as seen in the high utilization of low-temperature evaluation testing machines.

Next is an environmental performance testing machine for which the low-temperature evaluation man-hours have been reduced. The conventional low-temperature evaluation testing machine had a jig installed in its thermostatic chamber. The oil temperature was controlled using the room temperature in the chamber, requiring a very long time to cool the oil. Once the pump was started, the oil temperature increased as the pump generated heat. This limited the number of times of measurements per day.

Then we developed a new testing machine with the aim of reducing the oil cooling time and achieving continuous operation at low temperatures.

### 6.1 Oil Cooling in a Shorter Time

To improve the hydraulic oil cooling efficiency, the first thing to do was to change the cooling system from ambient temperature cooling to heat exchanger cooling. Aside from the main hydraulic circuit, a sub hydraulic circuit was provided to be cooled first. The cooled sub circuit was used for heat exchanging to reduce the temperature of the main hydraulic circuit. This system allows direct cooling of hydraulic oil, substantially reducing the cooling time.

As a cooling medium, we decided to use oil with a low freezing point to ensure liquidity, even at -40°C.

### 6.2 Design of Optimal Testing Machine

The cooling capacity is substantially affected by radiation cooling and frost forming. We then decided to install the jigs and piping inside the thermostatic chamber. With the effect of radiation cooling suppressed and an optimal heat exchanger selected, the testing machine has come to be able to deliver maximum cooling capacity. This resulted in higher cooling efficiency, obtaining a cooling capacity equivalent to the calculated value. The completed testing machine is shown in Fig. 7.

With the testing machine introduced, the time conventionally required to cool the oil was substantially

reduced as shown in Fig. 4, leading to higher test efficiency. The direct cooling of hydraulic oil enabled continuous operation at low temperatures.

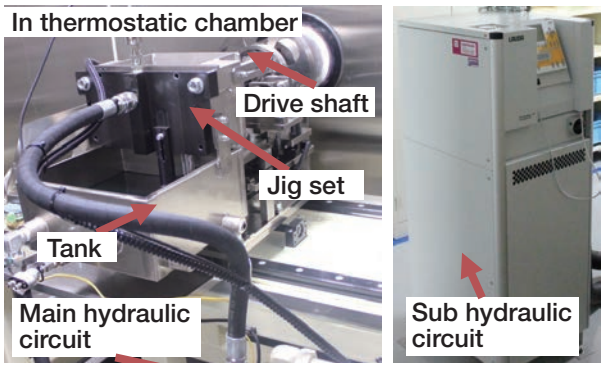


**Photo 7** Completed environmental performance testing machine

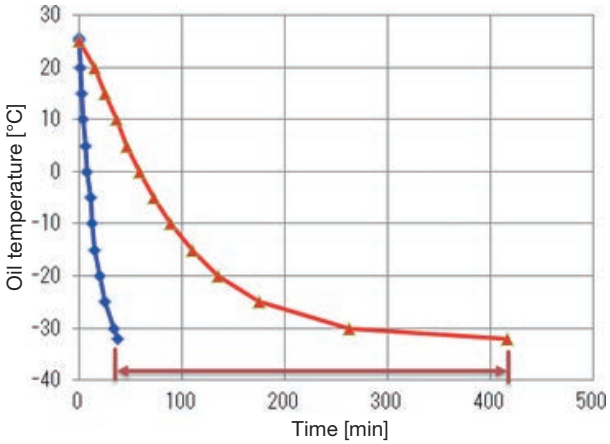


**Fig. 4** Time reduction by the testing machine introduced

The new equipment fabricated in this project raised evaluation efficiency, greatly contributing to faster improvement of the low-temperature characteristics of vane pumps.

## 7 Future Challenges

A dozen or so years have passed since the launch of the evaluation of CVT vane pumps. Our experiments are entering a new phase.

We have evaluated the pump independently from the equipment. In fact the evaluation jigs and conditions for the separate unit testing machine are different from the actual operating environment of the transmission. We believe that we should develop products based on our understanding of our customers' product configuration and service environment. This will lead to the creation of products wanted by customers and customer satisfaction. Now we have to be sure to proceed in that direction.

Actually we should look at customer products directly with our eyes and touch them directly with our hands, and develop a service environment for such products. By focusing on the whole unit, not just looking at the pump alone, we hope to hit upon new ideas or inspiration we have never come up with before.

## 8 In Closing

This report has introduced the efforts of the Experiment Dept. with a focus placed on the development of evaluation equipment. We have encountered more and more opportunities to be required to develop an evaluation method and improve accuracy at the same time as developing a product. Under these conditions, we are committed to reliably play the role of the Experiment Dept. by making use of our expertise and knowledge.

Finally, we would like to take this opportunity to cordially thank the related companies and those concerned in the development of the testing machine, as well as those who have extended their guidance and support to us.

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Technology Introduction

# Standardization of Windows PC System for Inspection

OGISO Shigetoshi

## 1 Introduction

KYB internally fabricates its inspection devices to be used for internal production inspections because the critical inspections during production processes are packed with the company's abundant knowhow. Among them are a shock absorber (hereinafter "SA") performance inspection system and SA appearance inspection system using image processing. With a necessity of high-speed processing of mass data, these inspections use personal computer (PC) systems. However, inexpensive PCs for office automation (OA) applications are remodeled at an interval as short as six months to two years. This has troubled the company since the same model of PC as the previous one was not available to be used for addition or replacement in the case of a failure.

With this background, KYB developed inspection systems running on an operating system (OS) for embedded systems Note 1) for use in industrial PCs that were available over the long term. The developed systems had been used since the internal fabrication in 2007. However, the software vendor's support service for Windows® Note 2) XP Embedded (XPE), which was the OS for embedded system Windows® XP on which the developed systems ran, was terminated in 2014.

These inspection systems were connected to a communication network to enable production data collection and central control, as well as remote maintenance services. Once the software support service was terminated, however, the vendor was supposed to no longer release new security patches or other measures to fix any serious security holes in the OS. The inspection systems might even be unable to be online depending on the type of the security holes detected. In this case somebody would have to struggle to directly collect data from all the PCs online. In addition, the systems could not provide remote maintenance services any more, resulting in delayed responses to any failures. Thus there arose the urgent need to reestablish an inspection system running on another OS.

Moreover, the production of PC parts was terminated as well. There also arose a need to update the hardware to a new configuration.

Besides the systems described above, some other inspection systems compatible with earlier PC versions were being operated. These systems also needed to be updated in the near future.

The situation made KYB develop a standardized Windows® PC based inspection system.

Note 1) Operating system (OS) for measuring equipment, automatic teller machines (ATMs) or vending machines, not for office equipment or computer servers.

Note 2) Windows is a registered trademark or trademark of Microsoft Corporation in the United States and other countries.

## 2 Specifications

The basic specifications are shown in Table 1.

Year by year, the image processing technology required for appearance inspection, in general, has increased in degree of difficulty, and the related processing operations have become more and more complicated. To catch up with the changes, the basic specifications of PCs have been enhanced with higher CPU processing speed and higher main memory capacity.

**Table 1** Basic specifications

| | Conventional PC system | New PC system | |
|---|---|---|---|
| | For SA performance inspection and image processing | For SA performance inspection | For image processing |
| OS | Windows® XP Embedded (32bit) | Windows® Embedded Standard7 (64bit) | |
| CPU | Intel® PentiumM Intel® Core2Duo | Intel® Corei7 (3th) 1.7GHz Note 3) | |
| Main memory | 512MB | 2GB | 4GB |
| Bus standard | CompactPCI | PCI | PCI Express PCI |
| C Drive capacity | 1GB | 8GB | 16GB |
| Security software | N/A | Whitelist | |

Note 3) PentiumM, Core2Duo and Core i7 are registered trademarks or trademarks of Intel Corporation in the United States and other countries.

The conventional bus used CompactPCI compatible with Peripheral Component Interconnect (PCI). The CompactPCI standard features high resistance to vibration and contact failures. This standard was originally introduced because the PC systems of two earlier generations had had frequent faults due to poor contacts in the board. However, the market share of the CompactPCI standard was likely to drop, posing uncertainty about future parts supply. KYB then decided to introduce the PCI bus, which is still the mainstream, because of the substantially improved quality of recent boards. Most other similar in-house systems also used the PCI bus, proving no compatibility problems. The introduction of the PCI bus brought another benefit where the system update can be shared with similar in-house systems. A faster PCI standard called PCI Express was needed to achieve higher-speed transfer of image data from cameras.

## 3 Features of the System

This chapter describes four features of the renewed system.

### 3.1 Compatibility

An important point of the development was to maintain compatibility with conventional systems.

SA performance inspection system has long been introduced in large numbers both outside and inside Japan. On the contrary to the long life of expensive mechanical inspection equipment, the electronics-based PC system has a shorter life and has to be updated periodically. Thus, maintaining compatibility with the conventional systems of about 20 years ago remains a challenge, and achieving efficient part replacement remains an important issue. In the image processor, compatibility between the internally developed inspection software and cameras actually used is a key issue.

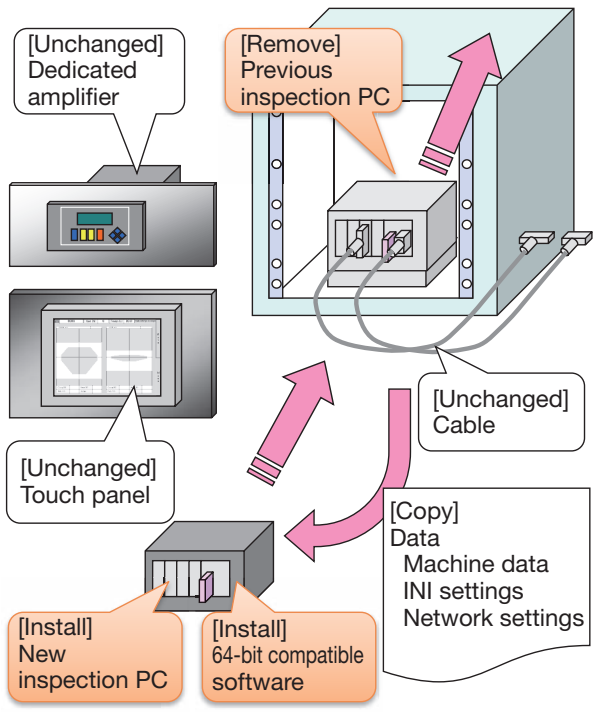


**Fig.1** Compatibility for system update

The following gives a concrete example of SA inspection system compatibility. Fig. 1 shows a case in which an inspection PC of the previous generation is replaced with a new PC.

The PC is connected with the following three major devices:

① Dedicated amplifier
② Touch panel
③ Sequencer (Only the cable is shown in Fig. 1).

For replacement, the previous inspection PC is removed and replaced with a new inspection PC that has been already set up. The new PC is connected online with the peripheral equipment unchanged. The conventional 32-bit type inspection software is updated to a 64-bit compatible version. The machine data used for setting the inspection standard and setting files are just copied to the new system as they can be shared between the two systems.

These setup tasks as well as operation verification have already been actually conducted on line, confirming proper operation.

For the systems from two generations back that use a monitor-integrated PC, a touch panel needs to be added. Converter cables are available to support any peripheral equipment with different types of connectors. In this way the system can be updated at a low additional cost.

### 3.2 Robustness

To maintain software/hardware compatibility, it is a precondition to use Windows® OS. Furthermore, to implement a robust OS for embedded systems, KYB selected Windows® Embedded Standard7 (WES7) designed for Windows® 7 that had been proven in the company at the time of development in 2014. The image processor was changed from the conventional 32-bit type to a 64-bit compatible unit in order to support input of high-volume image data.

WES7 features the recovery of the previous state in a power cycle after a setting change. In other words, the storage area of the system, including the OS is write-protected. If you change the settings normally, new settings will be written in a virtual drive, which will be erased when the power is turned off. The system will be next started up from the original drive. To write a new setting, you must use a special command after inputting the new settings. This design allows the system to be restored in a power cycle, even if the data is lost in the case of power failure or infected with malware Note 4).

Robustness has been checked with several systems already running, verifying that no problem has occurred since the introduction.

Note 4) Generic name for a variety of forms of malicious software programs including computer viruses, worms and Trojan horses.

### 3.3 Security Measures

Even OSs for embedded systems need security software because they may be infected with malware during operation. In general, security software needs to

periodically update its virus definition files. However, it is impossible for the systems used in some of KYB's overseas sites not connected to the network to automatically update the definition files. The systems, even if connected to the network, may have OS failure during update of the definition files in the case of power failure or inadvertent shutdown due to an operating error, which may directly lead to a halt in the production line. Therefore, KYB uses security software that does not require updates for use in OSs for embedded systems.

Security software can roughly be divided into two types: blacklisting and whitelisting. This system uses whitelist security software.

Both types have a list of files in advance and check each application software program against the list before start-up to determine whether to permit or reject the start-up of the program. These security software programs behave differently as they operate in accordance to their permit system:

(1) Blacklisting

Based on the list of malicious programs, start-up of any applicable programs is prohibited.

(2) Whitelisting

Based on the list of safe programs (those existing in the PC), only start-up of whitelisted programs is permitted.

Specifically, the two types of security software behave as indicated in Table 2. The blacklist type permits the OS to fully work and application programs to be updated while the whitelist type prohibits all updates. For malware control, the blacklist type may fail to reject unknown malware while the whitelist type is able to prohibit the start-up of all programs including malware.

Therefore, it is generally said that the whitelist security software is better for industrial applications.

In fact, KYB checked with the security software vendor through an infection risk survey that the whitelist security software was effective in protecting systems from even the notorious ransomware [Note 5)] Wanna Cryptor, which caused a large-scale worldwide infection in May 2017.

Other technologies including Firewall and User Account Control (UAC) are also combined with the security software to protect the system.

Note 5) Type of malware that encrypts data in the victim's PC and requires the victim to pay ransom in exchange for a password.

**Table 2** Blacklist and whitelist security programs

| | | Blacklist | Whitelist |
|---|---|---|---|
| OS | Start-up | ○ | ○ |
| | Update | ○ | × |
| Application | Start-up | ○ | ○ |
| | Update | ○ | × |
| Known malware | Activate | × | × |
| Unknown malware | Activate | △ | × |

○: Yes ×: No △: Unclear

### 3.4 Automated Set-Up

The developed system has been installed into several PCs by several departments every year. The installation procedure normally includes setting of numerous parameters for networking, and security and installation of driver software programs for peripheral equipment along with customization. These tasks are likely to be done erroneously if carried out by humans. The whole procedure needs man-hours of around half a day to a whole day for full manual work.

KYB then constructed an automatic installer to allow anybody to establish a PC system with the same quality level in a short time.

The following describes how the installer has been constructed to automate the set-up.

First, the standard WES7 development kit was used to build an installation function for key components of the OS, including disk configuration and user accounts. Next, an installer for the drivers provided by the vendors who released the peripherals was prepared. The installation was automated by combining the installer with a software program with which you can program keyboard typing and mouse operation according to instructions shown on the screen during installation. Finally, a batch file [Note 6)] was created to automate the sequential installation and setting of Windows® parameters.

In practice, Windows® XP and later OSs have stricter security. Specifically they are designed to require human approval in order to allow software installation or function change, which makes automation difficult. That is why the set-up sequence was decided by finding favorable timing for setting up with no need for approval, which eventually consumed of a lot of man-hours. This issue should be taken into consideration in future development.

The developed automatic installer was then used to carry out set-up, verifying that the installation procedure, except preparation, was completed quickly in a time as short as about 30 minutes.

Note 6) File containing OS operating commands in the order of execution. The batch file can also be executed itself.

## 4 System Maintenance

Thanks to simplified PC system installation, several departments now have more and more employees capable of setting up the system. Therefore the necessity of establishing a scheme of sharing the latest versions of installer, instruction manual and fault information has arisen. Instead of the conventional in-house network that enables distribution of the latest versions by file sharing, the web system has been introduced to facilitate the security enhancement.

Using the existing in-house web server, the web site shown in Fig. 2 has been developed to establish an information sharing system. The right of access to the web site is only provided to the departments concerned.

## 5 In Closing

PC-based production facilities are not so common and their percentage is very low. Around 15 years ago, system management from development to maintenance was sometimes covered by only two employees, which was very hard work. In spite of difficulties with system management, PC-based production facilities are indispensable to product quality. Since the departments involved in plant operation came to understand this issue, the facilities have been introduced and put into service in many production sites, both home and abroad, under the initiative of the departments concerned. I would like to take this opportunity to extend my gratitude to those involved in the introduction and operations.

I am committed to continue making efforts to bring the system even nearer to perfection in order to meet the needs of the sites.

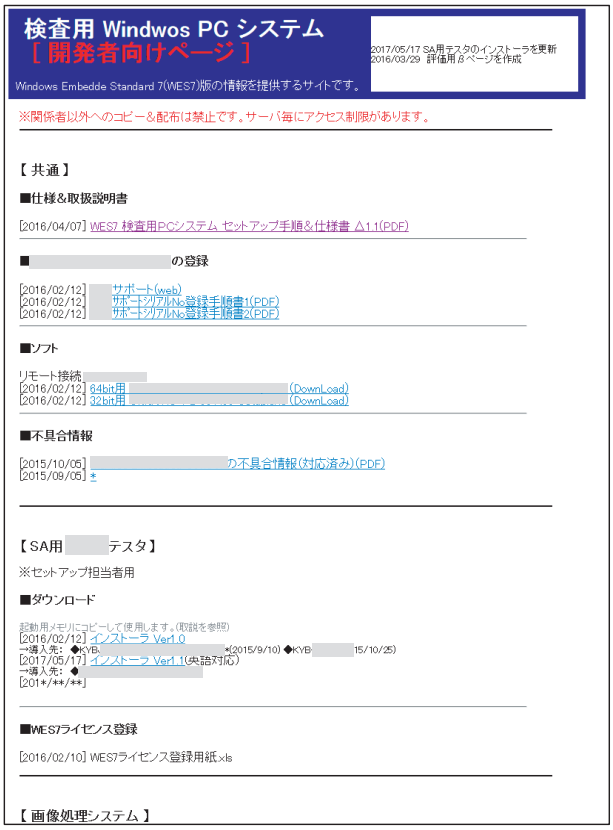


**Fig. 2** In-house web site

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Introduction

# Company-Wide Standardization Activities Regarding ISO 26262 at KYB

KOZUMA Fumihide

## 1 Introduction

An international standard on functional safety of electrical and/or electronic (E/E) systems for road vehicles was published as ISO 26262 in November 2011. KYB first applied the standard to automotive electronic power steering [1] and currently promotes the application to other automotive components.

In 2013, a new organizational function was established in Engineering Planning Dept., Engineering Div. for the purpose of promoting activities related to functional safety across the departments involved in functional safety.

This report introduces ISO 26262 and KYB's company-wide standardization activities for related development.

## 2 Overview of ISO 26262 and Related Standards

Before describing the main topic, this chapter will introduce ISO 26262 and related standards.

### 2.1 Overview of ISO 26262

This standard aims to address functional safety. The term "functional safety" is defined as "absence of unreasonable risk due to hazards Note 2) caused by malfunctioning behavior of E/E systems Note 1)". In other words, this standard requires a reduction in the risk caused by malfunction in E/E systems to a permissible level. It also requires an evaluation of the safety of the systems through confirmation measure, including functional safety assessment.

ISO 26262 defines the matters required to achieve the requirements above and the number of work products as large as 100. The standard consists of the 10 parts as listed in Table 1. Parts 3 to 6 contain development processes for safety design based on ASIL Note 3), as well as for ensuring traceability from requirement analysis, design to testing. Part 2 provides a scheme and management methods to maintain a safe culture. Part 8 indicates various measures to support development.

Note 1) Electrical and/or Electronic systems. An E/E system consists of electronic control units (ECUs), input devices such as sensors, and output devices such as actuators (Fig. 1).

Note 2) Potential source of harm caused by malfunctioning behaviour of the item.

Note 3) Automotive Safety Integrity Level. There are four ASILs from ASIL A to ASIL D, with ASIL D representing the highest level. ASIL level decides what should action should be taken.

**Table 1** Structure of ISO 26262

| | |
|---|---|
| Part1 | Vocabulary |
| Part2 | Management of functional safety |
| Part3 | Concept phase |
| Part4 | Product development at the sysytem level |
| Part5 | Product development at the hardware level |
| Part6 | Product development at the software level |
| Part7 | Production and operation |
| Part8 | Supporting processes |
| Part9 | Automotive Safety Integrity Level (ASIL)-oriented and safety-oriented analyses |
| Part10 | Guideline on ISO 26262 |

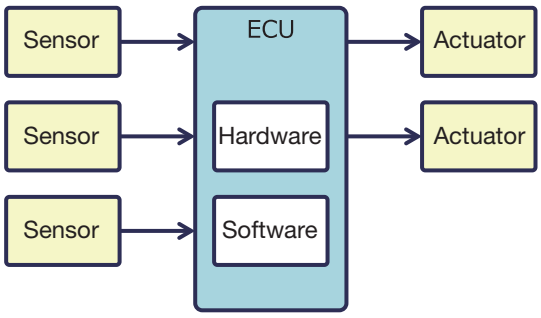


**Fig. 1** Example of E/E system configuration

### 2.2 Overview of Automotive SPICE Note 4)

Automotive SPICE (Software Process Improvement and Capability dEtermination) is the industry standard process model of on-vehicle software established by European automotive manufacturers. The first edition was published in 2005. The standard aims to improve the software processes and consists of the three process

categories and eight process groups shown in Table 2. Under each process group, carrying out an assessment using detailed process models will allow determination of the organization's capability.

The aforementioned ISO 26262 standard requires the establishment of a process infrastructure. As the best practice of the establishment, Automotive SPICE has been introduced by a number of companies.

On the contrary to the scope of ISO 26262, Automotive SPICE includes no description about hardware development, but places an importance on software development as well as development of ECU systems that are the source of the software development. However, Automotive SPICE describes the process consisting of ECU system development and software development being aware of the "V model" Note 5), which is shared by ISO 26262.

Note 4) Automotive SPICE is a registered trademark of the German Association of the Automotive Industry (VDA).

Note 5) A kind of development process model. The left part of the letter "V" represents requirement analysis and design processes while the right part a testing process. If the requirement analysis/design process is located at a height in the letter "V" that is the same as that of the testing process, this means that these two processes share the same level.

**Table 2** Structure of Automotive SPICE

| |
|---|
| [Primary Life Cycle Process Category] |
| Acquisition Process Group (ACQ) |
| Supply Process Group (SPL) |
| System Engineering Process Group (SYS) |
| Software Engineering Process Group (SWE) |
| [Supporting Life Cycle Process Category] |
| Supporting Process Group (SUP) |
| [Organizational Life Cycle Process Category] |
| Management Process Group (MAN) |
| Process Improvement Process Group (PIM) |
| Reuse Process Group (REU) |

## 3 Industrial Trend Related to KYB's Products

As mentioned above, the automotive functional safety standard ISO 26262 was published in 2011. As of 2017, it is said that domestic and foreign automotive manufacturers and major suppliers have completed conformance to the standard. To win contracts for on-vehicle E/E products, it is a must to have development activities conforming to the standard. ISO 26262 is scheduled to be revised as a second edition in 2018, in which the scope is expected to cover motorcycles and large vehicles as well.

KYB manufactures many different products for a wide variety of applications, including not only automotive and motorcycles, but also railway, aircraft, construction equipment, industrial machinery, agricultural machinery and special purpose vehicles. These individual products are increasingly electronified. [2)]

With the trends in the automotive industry including the compliance to ISO 26262, other industries are also raising their awareness of functional safety. Base machine manufacturers will probably accelerate their demands for functional safety to their suppliers, such as KYB.

For your reference, the hierarchy of international safety standards is shown in Fig. 2. ISO 26262 falls under Type C standards that specify detailed safety requirements for particular machines. This layer of the standard hierarchy includes the standards on railways or construction machinery that many KYB products are subject to. Note that the aircraft industry has another scheme of international safety standards that is different from the one shown in Fig. 2.

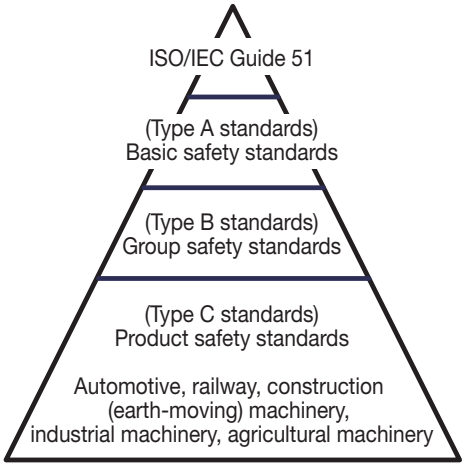


**Fig. 2** Hierarchy of international safety standards

## 4 Aim of Company-Wide ISO 26262 Standardization Activities

The company-wide standardization activities on ISO 26262 and its related development aim to:

① Define not only functional safety, but also a standard development process that will be the base to realize functional safety for development of E/E products;

② Define "common words" and "a common way of doing" which work at an international level in the form of a company-wide manual, not leaving it up to individual developer competence, and;

③ Use the manual to achieve the quality of E/E products to meet the customer and market demands.

These standardization activities are expected to bring the following effects:

① "Product quality assurance" by reducing omissions in the development process

② "Better mutual understanding and higher company confidence" by strengthening the liaison between personnel, departments and companies

③ "Improved development expertise" by sharing and

accumulating knowhow and design/evaluation techniques

④ "Improved development process and higher improvement efficiency" by creating opportunities in improving the development process.

## 5 Overview of Standardization Activities

Under the slogan "Support activities to develop E/E products which meet customer/market demands", the Engineering Planning Dept. has promoted company-wide standardization activities with the following three pillars:

① To establish, disseminate and improve company-wide standard processes

② To create and apply the development environment

③ To support actual projects of related departments

Fig. 3 gives a conceptual image of activities. In phase 1 to kick off activities, Engineering Planning discussed the standardization of development processes with Engineering that had already addressed ISO 26262 compliance, established "E/E company-wide standards" defining company-wide processes and created a KYB base of E/E product development. The Phase 1 also included establishment of rules to access development activities, development of human resources for assessment, and selection and introduction of software to support the development activities.

Engineering Planning is currently in Phase 2, where company-wide standard processes are being also applied to E/E products for applications other than automotive, leading to more departments involved. Phase 3 aims to strengthen the application of company-wide standard processes to individual departments and finally achieve constant use of the processes throughout the company.

The following sections describe details of the activities.

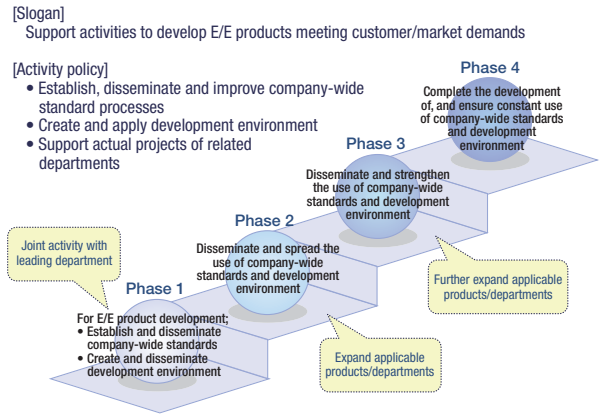


**Fig. 3** Conceptual Image of Company-Wide Standardization Activities

### 5.1 Establish, Disseminate and Improve Company-Wide Standard Processes

#### 5.1.1 Establishing Company-Wide Standard Processes

KYB uses a quality management system (QMS) conforming to ISO 9001 or ISO/TS 16949 at its production sites. Since the majority of KYB products are mechanical products, QMS used at production sites is not sufficient from the viewpoint of the electric/electronic industry.

With the aim of establishing a company-wide standard development process for E/E products, Engineering Planning has established company-wide E/E standards: "Electronics Development Manual" based on Automotive SPICE with an additional scope of ECU hardware, and "Functional Safety Manual" that defines what should be conductor to ensure compliance to the automotive functional safety required by ISO 26262. These manuals were prepared with due care to avoid any discrepancy between the manuals and the processes defined in the existing QMS (development events and gates).

Based on these manuals, Engineering Planning has established, as part of the E/E company-wide standards, a "Guideline for establishing department standards on electronics development" and a "Guideline for establishing department standards on functional safety," both of which allow individual development departments to draw up their own standards. Both guidelines include a collection of templates to which relevant development departments can actually refer in creating their department standards. The collection has several templates for corresponding typical development processes (for example, software development and change control processes) so that development personnel can select a template suitable for the development range or features of the development department.

Fig. 4 shows the relationship between company-wide E/E standards and department standards at production sites. The figure only covers the standards of products for automotive. It is under discussion to promote compliance to the standards on products for other industrial fields. Engineering Planning continues its routine survey activity to keep track of any amendments to related national/international standards.

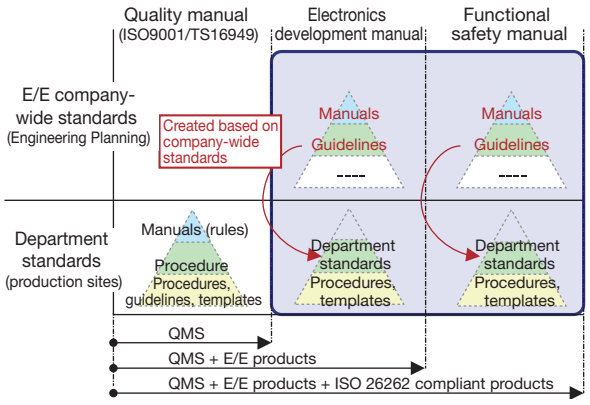


**Fig. 4** Relationship between E/E company-wide standards and department standards

#### 5.1.2 Disseminating Company-Wide Standard Processes

The company-wide E/E standards indicated above are stored in the KYB general database so that Development can access them whenever necessary. In the

standardization activities, however, not only defining rules but also disseminating them and encouraging the related departments to actually put them into use are important. To this end, an education and training course on the Electronics Development and Functional Safety Manuals has been developed and is used as part of dissemination activities.

As well as this, some other education and training courses are available, which will be described in section 5.2.3.

### 5.1.3 Improving Company-Wide Standard Processes

Engineering Planning Dept. continues to review the improvement of the existing E/E company-wide standards that are still being disseminated. Specifically, department checks whether the standards are easily readable and usable, and written with an appropriate degree of detail. In addition to this text expression aspect, it also reviews from the aspect of documentation structure, namely, whether there is no overlap or discrepancy between the company-wide standards and the department standards, or how the company-wide standards should be if the number of applicable products or standards increases.

Another improvement activity is to create standard templates for work products. A number of work products to be created through development activities are defined in ISO 26262 and Automotive SPICE. Then, a set of templates for these work products was prepared to build an environment in which employees can share the templates within the company. Many of the templates were supplied by different departments actually involved in development, although some were original templates from Engineering Planning. Each template consists of a template body, a fill-in guide and fill-in samples, and is arranged to help the actual user easily fill in the form. The templates are planned to have more and more fill-in samples so as to be used for various development activities in the future.

## 5.2 Create and Apply Development Environment

To ensure that departments involved in functional safety properly carry out development activities, not only to establish rules but also to create an associated environment, are important. This section describes the following three items:

① Assessment
② Development support tool
③ Education and training

### 5.2.1 Assessment

As mentioned above, ISO 26262 requires safety evaluation through functional safety assessments for each product to be developed. The process assessment according to Automotive SPICE extracts development activity challenges, which can result in improvement. Those who carry out these assessments are accessors.

KYB has promoted development of human resources for internal accessors. For this purpose, the company defined the role and required capability of assessors, and has promoted obtainment of the official qualification by applicable certifying bodies. The number of qualified assessors is increasing not only in Engineering Planning, but also in Development.

An assessment implementation manual was prepared for standardized operation and is shared by assessors. Furthermore, activities by accessors themselves to establish an evaluation policy is being continued to suppress variations in evaluation results and improve quality. These activities are helpful for deeper understanding of the standards and improving assessor skills.

In actual assessment, an internal assessment is conducted two or more times depending on the progress of the product development project. The result is input to the relevant development department as feedback. KYB can support assessment of KYB by its customers or assessment of its partner company.

### 5.2.2 Development Support Tool

Development of E/E products deals with an enormous volume of data. Manual efforts to ensure traceability of the information is limited. ISO 26262 and Automotive SPICE require configuration management, change management and problem resolution management of work products. For efficient management, several dedicated software products called development support tools are commercially available and introduced by KYB too.

Engineering Planning has prepared an operating procedure for the development support tool to be used by Development and provides education and training on the introduction. Engineering Planning also responds to regular inquiries from users, and periodically updates information obtained through such inquiries to be available in the form of FAQs [Note 6)] as feedback to users.

In addition, Engineering Planning established a dedicated server for the development support tool, and also provides daily maintenance service on the server to ensure reliable use of the infrastructure.

Note 6) Frequently Asked Questions.

### 5.2.3 Education and Training

To facilitate the dissemination of the company-wide standard processes (section 5.1.2), the development of human resources for assessors (section 5.2.1) and the introduction of the development support tool (section 5.2.2) for E/E product development, KYB held the education and training courses listed in Table 3. All the courses are provided by instructors from Engineering Planning and irregularly held upon request by Development. The results of taking these courses are maintained as evidence of employee competence.

**Table 3** Education/training courses on E/E development

| |
|---|
| Electronics development |
| General functional safety |
| Specific functional safety |
| Assessor training |
| Development support tool training |

### 5.3 Support Actual Projects of Related Departments

Besides the activities related to the company-wide processes and development environment as described above, support to actual product development projects is also one of the priority activities. This activity mainly implements the assessment stated above and supports the development support tool users. In addition, Engineering Planning sets up regular opportunities to meet together to provide advice on the introduction or implementation of the standard processes.

Engineering Planning also holds regular meetings of two or more departments involved in functional safety so that they can share information about the trend and details of related domestic/international standards, and the progress and challenges of various projects.

## 6 In Closing

It's been a long time since people started to say that the wave of applying electronic control to many different general products and technology was accelerated. The same trend has been seen with the KYB's products. Probably the opportunities and necessity of conforming to the specified processes and standards related to functional safety are increasingly rising.

I can easily imagine that Development requires more and more man-hours every time another rule is established. Although it may be somewhat contradictory, I could say I want Development personnel to smartly use the standard processes and various domestic/international standards as a tool to provide "evidence of proper design".

### References

1) ISHIZUE: Toward Adopting ISO 26262 in EPS development, KYB Technical Review No.50 (April 2015).
2) MATSUDA: Electronic Device Product Development and Future Outlook in a KYB group, KYB Technical Review No.50 (April 2015).

Author

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Engaged in promotion of engineering standardization.

Introduction

# Reduction of Industrial Waste with Chemical Reactions - Waste from Paint Could be Reduced -

HAYAKAWA Yoshitaka

## 1 Introduction

Human kinds cannot live without generating waste.

Most companies, particularly manufacturers like KYB, are bound to generate both useful products and industrial waste, namely a negative legacy, at the same time. These two are like be light and shade.

How much energy could we put into coping with the light as well as the shade? We are entering an age where the capability of companies to do so is tested.

KYB Gifu East Plant, which is in a residential area (Photo 1), has taken different environmental measures since its foundation with a goal of building a plant friendly to the local environment.

**Photo 1** Gifu East Plant surrounded by a residential area (center)
(Photo created from an official map issued by Geographical Survey Institute)

The use of water-based paint on painted line was one of the measures, and successfully eliminated the odor of organic solvent (so-called thinner) from the plant exhaust and improved the work environment. We thought we could make a good start at that time.

## 2 Problems of the "Environmentally Friendly" Plant

The painting process generates three types of industrial waste:

① Contaminated paint equipment
Cloth, plastic and paper, such as rags, gloves and masking tape (Photo 2)

② Paint chips
Collected paint deposited on objects other than the product and solidified (Photo 3)

③ Liquid paint waste
Remaining mixed paint after changing color and water used to clean contaminated pipes and nozzles (Photo 4)

Among these, ③ "Liquid paint waste" had not been recognized as industrial waste until the introduction of water-based paint.

Most of the no longer necessary liquid originated in the conventional organic solvent-based paint was purchased and taken out by contractors for solvent recycling or evaporated in the atmosphere. Almost none of the liquid

**Photo 2** ① Contaminated painting equipment (actual waste)

**Photo 3** ② Paint chips (actual waste)

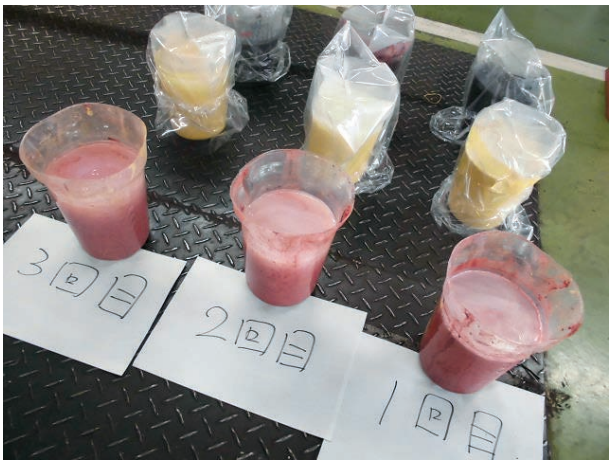


**Photo 4** ③ Liquid paint waste (experiment samples)

was disposed of as industrial waste.

However, after introducing the environmentally friendly water-based paint, the plant was caught in a vicious circle:

1) Liquid waste was not purchased by any contractor.

2) Liquid waste was unlikely to evaporate.

3) Extra wash water was needed for cleaning cleaning due to lower cleaning properties.

As a result, a high volume of liquid paint waste was left. In other words, the plant was contradicting itself in that, "the environmental burden was increased by using environmentally friendly paint."

Without having recognized the presence of liquid paint waste, the plant had not given any consideration as to how to treat or dispose of it. The manufacturing team managed to handle the liquid waste by intentionally soaking it in rags out of desperation and disposing of it as contaminated paint equipment, or by mixing it up in paint chips that were originally dry and had almost no moisture.

This way of disposal resulted in drum cans filled with waste that were heavier than usual, leading to higher disposal costs. The extremely wet waste troubled the industrial waste contractors and damping sites.

Gifu East Plant generates a lower volume of industrial waste from the painting process than that from Gifu South Plant, which manufactures similar types of hydraulic machinery products, but the unit weight of industrial waste from Gifu East Plant is obviously higher. This fact was proven by the statistical data (Fig. 1) before I became aware of the issue. This is what I regretted most.

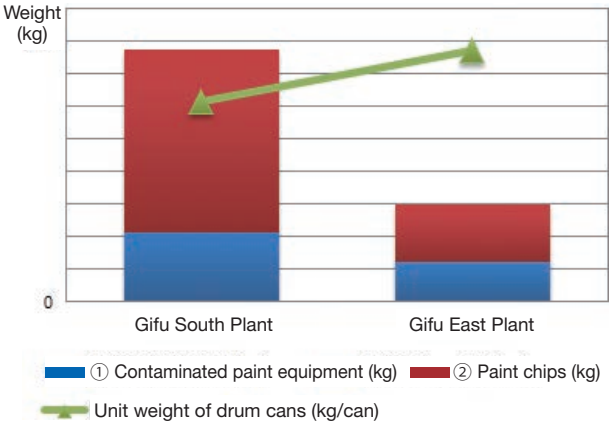



**Fig. 1** Waste from paint and unit weights at the two plants (Source: FY2013 data before measures taken)

To begin with, Gifu East Plant conveyed to the employees the procedure of thoroughly separating liquid paint waste (③) without mixing with any other waste on the source manufacturing floor, and then collecting it in a separate "liquid waste" container.

## 3 Another Problem Triggered by the Measures

Actually I thought "liquid waste", once just separated, could be treated in the sewage treatment facility within the plant site. I did not take things seriously enough. In fact, however, "liquid waste" was not just sewage that could be easily treated.

Numerous troubles happened frequently, for example, liquid spills, container overflow, unremovable paint stains, too slow transfer, and delayed empty containers...

The most troublesome problem was that the pump or hose used to intake liquid waste for treatment was clogged.

I knew that paint was liquid that will solidify sooner or later.

But I never thought paint would solidify anywhere else but in the pump or hose. This was unexpected. Or rather, I was too optimistic.

Of course, paint naturally solidifies when brought into contact with a metallic or resin part of the hose, namely a foreign element. What should we do to prevent paint from solidifying in our favor? Many reasons existed as to why paint could not easily be treated.

What we should treat was not only pure paint, but also liquid waste of different qualities discharged from the painting process that might have been diluted with wash water or mixed with some other contaminants. This liquid waste would solidify at different times or under different conditions (Photo 5).

However, if we wash and rinse paint equipment, including containers, with water, or dilute the liquid every treatment session, it would take a long time to complete

treatment, resulting in inefficient operations and higher costs.

**Photo 5** Liquid paint waste whose timing to solidify could not be known

Most of the pump or hose clogging cases were in a muddy semi-solid state. To remove the dirt, acid cleaning with dilute sulfuric acid in addition to water washing was effective. Most of the paint products used were alkaline liquid and the paint itself (except some resin products) never affected the metallic part of the machine.

However, it was unavoidable for the paint to attach to any sliding or rotary parts of the machine because of its own stickiness. Therefore, these movable parts had to be cleaned with acid, which was unfavorable to the metal parts, to restore movement and then have lubricant reapplied. These complicated time-consuming steps were needed every time the machine was clogged.

## 4 A Sense of Fun Inspires You

One day I came up with an idea that "I'd rather thin the waste with acid than wash with acid every time the machine is clogged" just as a joke!

When I poured dilute sulfuric acid in the liquid paint waste in a bucket, a minor foaming-like change occurred around the liquid surface where the acid was poured. As soon as I stirred the liquid, paint particles in the liquid quickly stuck together to each other. The liquid was split into two layers: mud and liquid. I noticed the liquid had precipitated.

Obviously something changed in the liquid waste with a chemical reaction.

The reaction time of the solid-liquid separation was as short as several minutes. In addition to this reaction time, more time for precipitation was taken. The liquid waste was finally separated into semi-transparent supernatant liquid and precipitate as shown in Photo 6.

This phenomenon is called polymerization [Note 2)], in which a bond called condensation [Note 1)] continuously takes place. This is one of the macromolecular chemical bonding reactions.

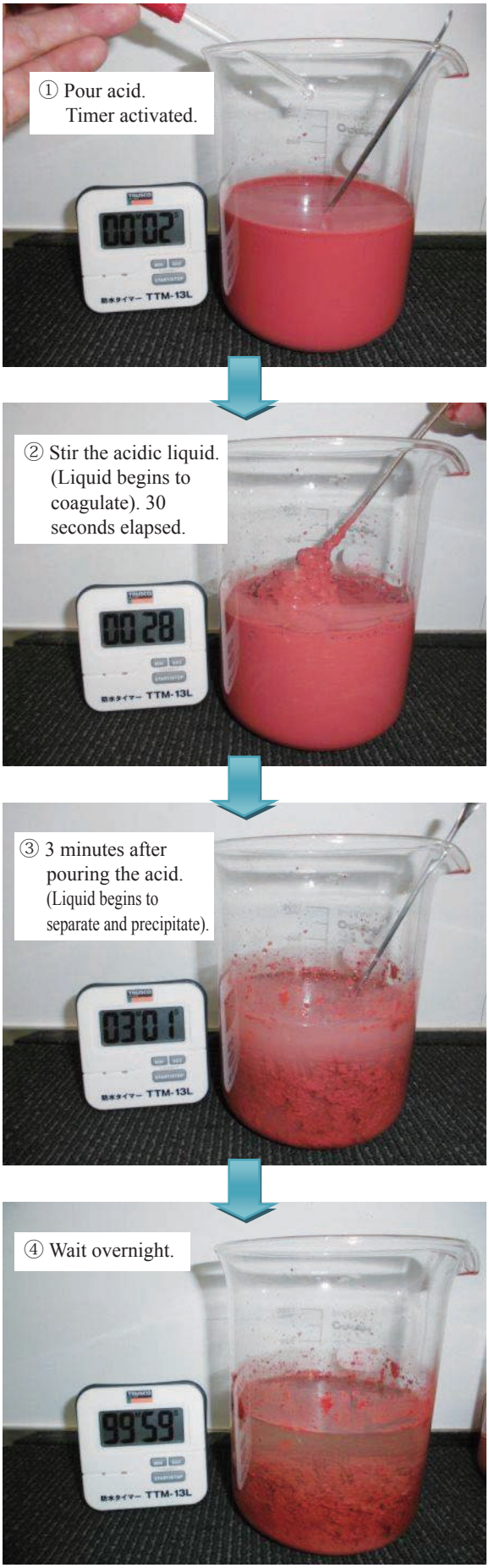



**Photo 6** How liquid coagulates with acid

Note 1) A process in which two organic compounds mutually synthesize simple molecules, such as $H_2O$, from part of their molecules and expel the synthesized molecules so that the two compounds can link with each other (Fig. 2).

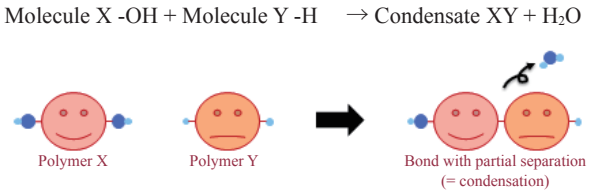
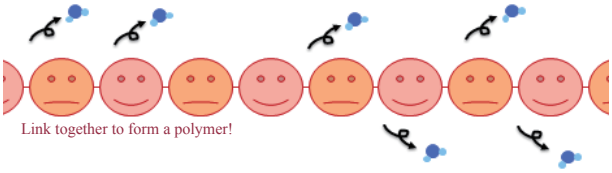



**Fig. 2** Sketch of condensation

Note 2) The condensation process is continuously taking place (polymerization) (Fig. 3) to form a chain polymer molecule.




Example) Esterification takes place in a chain reaction to form a polymer called polyester.

**Fig. 3** Sketch of polymerization

For oxidation polymerization in drying paint, some molecules are oxidized when exposed to oxygen in the air during the vaporization process of the solvent (actually water in this case) into the atmosphere, causing polymerization. Thus the molecules become dry while chemically bonding together.

The paint's inherent property that is likely to solidify is triggered by forceful oxidation with the addition of dilute sulfuric acid. As a result, the paint is increasingly coagulating itself, even in the water. I discovered this phenomenon by chance.

This finding is not a big discovery or a centurial breakthrough worthy of applying for a patent or being awarded a Nobel Prize. It is just a regular chemical reaction that has been well-known to paint manufacturers for a long time.

Still, the phenomenon of solid-liquid separation I noticed was very effective as an industrial waste countermeasure, which was the original purpose.

Through repeated experiments using a beaker, I finally determined the treatment concept for the liquid paint waste generated from the painted lines at the plant.

1) Liquid paint waste normally generated from the plant including that mixed with washwater, can be treated through solid-liquid separation with almost no problem, although too thick liquid with a high paint concentration solidifies too much and is difficult to treat.
2) The acid used may be dilute sulfuric acid, dilute hydrochloric acid or another acid that can change the pH of the liquid paint waste from neutral to slightly acidic. Although even strongly acidic liquid could be treated, addition of acid should be limited to the extent that it neutralizes the liquid to slightly acidic, to avoid excessive use of chemicals and prevent damage of the equipment.
3) Supernatant liquid can be smoothly treated in the same manner as for other liquid waste without causing clogging in the pump or hose.
4) Liquid paint waste can be reduced to one twentieth in volume or one fiftieth in weight under the best conditions, after being squeezed and sun-cured.
5) Squeezed solid residue can be disposed of as paint waste (industrial waste) (Photo 7).

If this disposal method can be commercialized in the size of buckets or drum cans, the waste volume is expected to be largely reduced, leading to a substantial reduction of the industrial waste from painting operations.

**Photo 7** Rag filtering test

## 5 Waste Disposal Using Waste

Dilute sulfuric acid is always available in the plant where waste water is treated on a regular basis. However, we do not use new chemicals for oxidation of the liquid paint waste. Anyway, the plant is a place in which different kinds of liquid or solid waste are collected. Utilizing such waste would produce much simpler benefits than the discovery of a new chemical reaction.

Waste hydrochloric acid that has expired on the manufacturing floor is regularly collected. If this is reused as the treatment chemical, material cost reduction, or even zero running costs, could be achieved.

In terms of treatment facilities, used baskets and rags are also collected (at no cost or even lower), which are just right to filter the muddy precipitate and squeeze it in order to remove the water content. These waste goods were reused to successfully commercialize the finding at almost no initial cost (Photo 8).

**Photo 8** Filtering device I made from waste

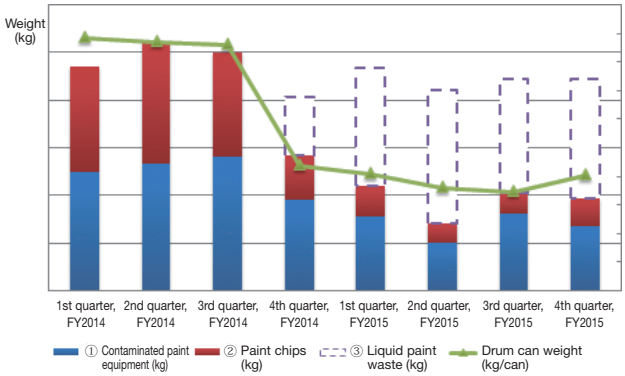



**Fig. 4** Output and unit weight of waste from painting operations
(The bar graph enclosed by a dotted line indicates actual reduction and the line graph the unit weight).

This activity achieves all of the 3Rs representing Reduce, Reuse and Recycle, which is one of the environmental consideration keywords. This is a case in which waste reduces waste.

Finally, the following routine disposal procedure has been established on the manufacturing floor partly with the cooperation of the personnel there:

Separation→Fill-up→Container change
↑ ↓

In addition, the internal disposal site established another routine disposal procedure:

Acceptance→Oxidization→Empty containers
↑ ↓

A continual activity cycle has been successfully established through collaboration.

As a result, the initial goal of reducing the unit weight of drum cans containing liquid paint waste by one-half has been achieved, leading to about a 20 ton reduction per year. The new disposal system has taken root (Fig. 4).

Note that the reduction is equivalent to about 15% reduction of the annual output of industrial waste at Gifu East Plant.

## 6 In Closing

As mentioned in the beginning of this report, products and industrial waste are something like light and shade for the manufacturing industry.

I'm proud of myself that, using cost-conscious ideas and devices, I carried out this activity to reduce the "shade" without reducing the "light", although the core part of the activity began with a chance discovery.

I have to say that the industrial waste contractors we are trading with suffer less business. However, this activity did reduce fuel consumption related to transfer and disposal. I hope we have returned a favor, even slightly, to the global environment.

Finally, I would like to take this opportunity to extend my gratitude to those involved in painting from Manufacturing Sect. who responded to my unreasonable request based on a snap decision with no prospect for outcome, as well as my colleagues who materialized my reckless idea.

## Author

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Joined the company in 2011.
Environment & Anti-disaster Control Sect., Production Engineering Dept., Hydraulic Components Operations.
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Introduction

# Participating in an IIP Intellectual Property School

INOUE Teruhiko

## 1 Introduction

I participated in a round of IIP Intellectual Property School held by the Institute of Intellectual Property (IIP) for one year from June 2016.

The purpose of the School is to develop human resources capable of making suggestions on how intellectual property systems should be in the big picture. Aside from their daily work, students are encouraged to debate intellectual property systems from a broad point of view.

The participants from a wide variety of industrial fields and positions associated with intellectual property conducted high level discussions throughout the year.

The outcome of the discussions over the year was communicated to experts including government officials and university professors in the form of a written report and a debriefing meeting.

In this article of KYB Technical Review, I will briefly introduce the activities of IIP Intellectual Property School and the research theme I worked on.

## 2 What is IIP Intellectual Property School Like?

IIP Intellectual Property School was founded by the General Incorporated Foundation Institute of Intellectual Property (IIP) in 2005, with the aim of developing human resources capable of perceiving things in the big picture from a wide variety of viewpoints, including society, state and international relations, based on the Institute's practical experience in intellectual property work and taking into account what is happening at the front of intellectual property systems. The 2016 School was the 10th round.

The participants included practicing judges as observers and university professors as instructors. Students are screened with a thesis writing enrollment test from among lawyers, patent attorneys, intellectual property businessmen working for private companies, and officials and examiners from the Japan Patent Office, all of whom play an active role in the front line of the intellectual property field (Fig. 1).

In the School, students investigate, review and discuss intellectual property systems in terms of possible contributions to future Japanese society with the big picture in mind (related to society, state or international relations,) regardless of background or social standing.

Speaking of the track record of the School, activity reports by the students were cited by the Government in its policy making process. The School has also produced a number of people playing active roles in many fields. For example, former students have been selected as members of the Government policy-deliberation committee.

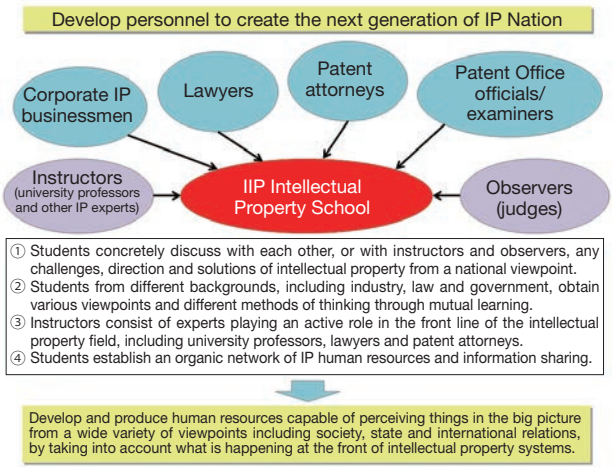


**Fig. 1** Purpose and configuration of IIP Intellectual Property School [1)]

## 3 Reasons Why I Participated in IIP Intellectual Property School

I decided to attend the IIP Intellectual Property School for three reasons:

① Darwin's theory of evolution, which is often referred to by people involved in business management, can also be applied to the intellectual property field. The field has to continuously evolve in order to adapt to the changing social environment.

To continue evolution, it is not enough to solve any problem arising from daily work. We are going to have to resolve the fundamental problems of intellectual property systems.

Under this situation, there is no other place than IIP Intellectual Property School where we can drastically discuss intellectual property systems.

② The School allowed me to obtain the latest information from other students from various backgrounds playing an active roles at the front of the intellectual property field, and to build a human network from there.
③ I could learn possible solutions from various viewpoints including business, law, corporate management and government administration through discussion with lawyers, patent attorneys, corporate intellectual property businessmen, Patent Office officials and examiners, and judges with their own practical experience.

**Photo 1** Students in a seminar

## 4 Activities

The following briefly describes the activities of IIP Intellectual Property School over the year.

### 4.1 Suggesting Research Themes

Individual students give presentations to suggest their desired research theme for the one-year activity period.

Then, students fill in a questionnaire on the presentations to evaluate each other. The secretariat selects highly evaluated themes and divides the students into groups for the selected themes.

From experts playing an active role in the front line of the intellectual property field, including university professors and businessmen, appropriate instructors are assigned to each of these groups.

The research theme I suggested was "Intellectual property management to enable a global tax strategy". The theme was intended to actively discuss new judicial and tax measures to prevent future leakage overseas of intellectual property produced by research and development (R&D) sites in Japan, and to attract overseas high-value added R&D sites to Japan.

The theme was not selected by the secretariat, with its opinion being that the theme required advanced expertise on the taxation system and a survey on the judicial system related to intellectual property in many countries, and one year would not be enough to reach a conclusion.

### 4.2 Selecting Themes

From the themes suggested by students, the following four themes were selected:

① Application of the examination system to claims for patent infringement
② Relaxation of the requirements for supporting pioneer-like inventions
③ Suggesting a system toward a data utilization society
④ Developing an environment to facilitate joint research and development

### 4.3 Seminars

A seminar is a place for a group in charge to present the then-current result of discussions on the research theme and its future direction before a general discussion with other groups.

Toward the presentation in the seminar, the group identifies the current situation, locates the exact challenges and seeks solutions after much discussion under the guidance and advice of the instructors (Photo 1).

### 4.4 Seminar Camp

An overnight seminar camp was held in a suburb of Tokyo.

The debate themes of this year's camp were:

- "What is needed for Japanese intellectual property policy today?"
- "How should patents on medical inventions be protected?"

Students must submit a thesis on the above themes before participating in the camp.

The camp includes lectures by experts, after which students have discussions based on the submitted theses together with the experts.

### 4.5 Lectures by Experts

Several lectures by experts are held in the seminars and during the camp. Corporate intellectual property managers, executive officers of the Japan Patent Office and judges are asked to talk in lectures that students can rarely hear in their regular lives, such as intellectual property strategies of companies, or the current situation of legal reform.

### 4.6 Result Report and Debriefing Meeting

The outcome of the research through the group discussions and seminars over the year is summarized into a written report and also made public at a debriefing meeting.

Details of the debriefing meeting are described later in this report.

## 5 10th Round Members

Participants of the 10th round school consisted of 22 members:

- [Observers]

Three judges from the Intellectual Property High Court or Tokyo District Court

- [Students]

Four examiners from the Japan Patent Office
Five lawyers
Six patent attorneys
Four managers from corporate Intellectual Property

## 6 Details of Activities under the Theme

The group I belonged to had five members consisting of a Patent Office examiner, lawyer, patent attorney and two managers of a company's Intellectual Property. The research theme was ④ "Developing an environment to facilitate joint research and development" as mentioned above. The theme was suggested by the Patent Office examiner of the group. With respect to the theme, the group analyzed the current situation, identified the challenges of private businesses, and suggested solutions to the challenges. The following describes in detail these discussions.

### 6.1 Current Situation Analysis

With the recent active international joint research & development and collaboration beyond the existing national or industrial framework (particularly in Western countries and China), the number of joint applications for patents is on an upward trend (Fig. 2).

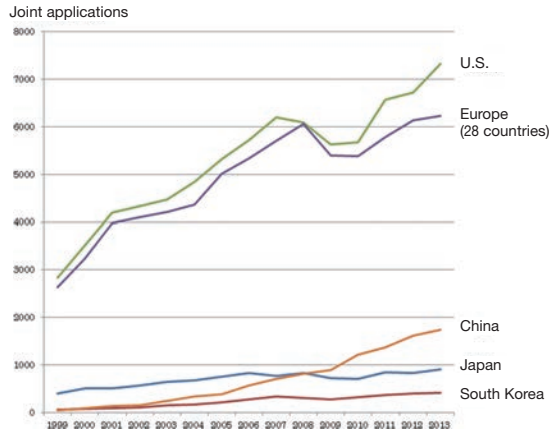


**Fig. 2** Comparison of international joint R&D among nations [2)]

With focus placed on the current situation of joint R&D in Japan, the number of joint R&D projects tends to increase for both national and international projects. This trend is expected to still continue (Fig. 3).

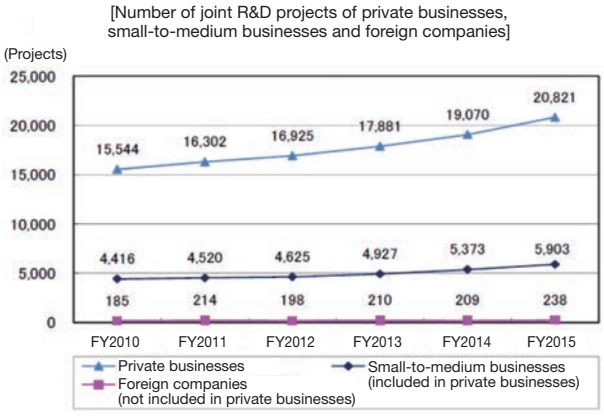


**Fig. 3** Number of Japan's domestic joint R&D projects [3)]

### 6.2 Challenges of Private Businesses

The group identified two challenges:

#### Challenge ①: The length of the examination period from application to patent approval

The patent examination period by the Japan Patent Office is relatively shorter than that of other countries. Still, it is not short enough to catch up with the increasingly shorter lifecycle of products (Table 1).

Product lifecycle refers to "a period of time from market launch to withdrawal of a product". A short lifecycle of a product means a short development period of new models of the product.

**Table 1** Primary examination period of the Patent Office in different countries [4)]

| | Period to primary examination notification | Period to final decision |
|---|---|---|
| JPO (Japan Patent Office) | 9.3 months | 15.2 months |
| USPTO (United States Patent and Trademark Office) | 18.1 months | 27.0 months |
| EPO (European Patent Office) | 9.1 months | 22.8 months |
| SIPO (State Intellectual Property Office of the P.R.C) | 12.5 months | 21.8 months |
| KIPO (Korean Intellectual Property Office) | 11.0 months | 16.7 months |

#### Challenge ②: Finding joint R&D partners

It is desirable for a joint R&D project to make use of resources of other businesses or partners for efficient innovations. Finding appropriate partners with necessary expertise and ideas is the key to the success of the project. However, it is difficult for many businesses and universities to find such appropriate partners without consuming considerable man-hours or cost.

### 6.3 Suggestions of Solutions to Challenges of Businesses

My group thought that the group should solve these challenges to enhance the convenience of joint R&D, further promoting the use of joint R&D and activating innovation.

To promote joint R&D, which was projected to further increase, the group made three suggestions:

#### Suggestion ①: Expand the super accelerated patent examination system

The only solution to the existing, too long examination period of the Patent Office described in Challenge ① is to approve patent rights quickly.

The current Japanese patent examination system can provide accelerated examination. In addition, an even quicker option called super accelerated examination is also available.

However, the super accelerated examination can only be applied to patent applications for inventions already completed, or those due to be implemented soon. In fact,

many joint R&D projects, particularly between private businesses and universities or public research institutes are not necessarily predicated on the "implementation" of the project.

Then, the group suggested to expand the scope of the super accelerated patent examination to include the work products of joint R&D between private businesses, and even between private businesses and universities or public research institutes, in order to further disseminate and accelerate joint R&D in Japan (Fig. 4).


**Fig. 4** Overview of expanded super accelerated examination system

If the super accelerated examination is applied, the examination period will be one month at the earliest to allow even faster approval (or three months for the accelerated examination).

### Suggestion ②: Establishaninternationalaccelerated preliminary examination system

As the product lifecycle has generally become shorter, the profitable period is also likely to be shorter not only in the domestic market but also in the international one.

Nevertheless, the patent offices of major foreign countries have an average period to the final decision much longer than that of the Japan Patent Office as shown in Table 1. These countries fail to make full use of the exclusive effect of patent rights.

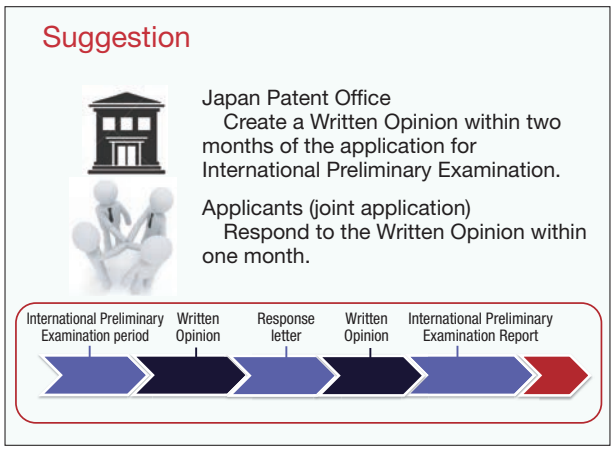


**Fig. 5** Overview of new international accelerated preliminary examination system

The current International Preliminary Examination system is not necessarily designed to ensure adequate responses.

Then, for the purpose of ensuring earlier approval by foreign patent offices on the patent rights of joint R&D work products, the group suggested to establish an international accelerated preliminary examination system that required the Japan Patent Office to create a Written Opinion within two months of the application for International Preliminary Examination, and the applicants to respond to the Written Opinion within one month (Fig. 5).

### Suggestion ③: New matching

Against the challenge ② that private businesses cannot easily find appropriate partners with necessary expertise and ideas, the group suggested establishing a partner matching system in which businesses highly aware of actively finding partners can appeal to each other by disclosing their own patented technology that they want their partners to use for joint R&D, and by communicating their own demands for partner technology they want to use for joint R&D even more actively (Fig. 6).

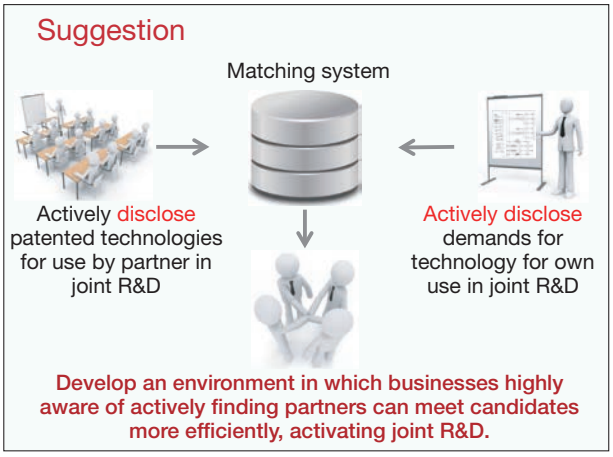


**Fig. 6** Overview of new partner matching system

In the beginning of the discussion about this topic, the group only shared a somewhat vague awareness of the issues that, "just increasing international joint inventions will provide more opportunities of utilizing foreign technology, leading to the promotion of innovation in Japan, where the current percentage of international joint inventions is lower than in other major countries". The group did not know any existing research and surveys including current situation analysis based on data, identification of challenges of private businesses, and suggestion of solutions to the challenges.

The group then spent much time on discussing the questions: "Are you sure you can eventually facilitate innovation by promoting joint R&D?," and "What prevents Japanese businesses from having more international joint R&D?" within the group and with others in the seminars over and over again. Thanks to the advice from the instructors and the pep talks given by the judges and other students, the group finally complied the activities into a report.

**Photo 2** Presentation in debriefing meeting

**Photo 3** Certificate being handed over

## 7 Activity Debriefing Meeting

A meeting to report the outcome of the one-year activities was held at Zenkoku Chosonkaikan on April 7, 2017.

The meeting was very festive, with the total number of participants being over one hundred. The majority was mostly experts playing an active role in the front line of the intellectual property field, including government officials and university professors.

During the year, I had a group discussion after work once or twice a week, and sometimes even had overnight discussions before giving a presentation in a seminar, or writing a thesis.

Moreover, the group often held weekend activities. It was a very tough year for me both physically and mentally.

In fact I felt quite nervous with the marvelous lineup of experts before giving my presentation. Still, with my determination to give the presentation with no regrets, by sharing the final joint work with the members I had spent hard times with together, I stood on the stage with a feeling of enjoying myself.

Thanks to that, I successfully made clear the outcome of the research without feeling nervous on the stage.

In the question and answer session after the presentation, I received many questions from attendees one after another. I could feel how much they were interested in our research theme.

After the debriefing meeting, a closing ceremony was held where we were successfully given the certificate.

## 8 In Closing

In recent years the technology development and commercialization of services using big data, IoT or artificial intelligence (AI) has accelerated dramatically. With the rapid progress of technical innovation, the intellectual property field is also addressing structural reform, particularly changing how intellectual property should be conducted in government and private businesses.

In this situation, I am committed to trying to resolve the various complicated challenges we face in future, by using the challenge, solutions, and human network obtained at the IIP Intellectual Property School, contributing to the future growth and soundness of KYB.

Finally, I would like to express my deep appreciation to those who extended their support and advice from the viewpoint of administration.

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## Author

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Joined the company in 2012.
Intellectual Property Sect. No. 1,
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Engaged in intellectual property negotiations, global intellectual property system design and trademark & brand protection.

## Editors Script

Ten years have already passed since Takako Industries, INC. joined KYB Group. Meanwhile the company has written three articles for KYB Technical Review as a member of the Group. I think that the appearance in the articles, although relatively small in number, has probably made customers from every field recognize Takako's original products.

With Takako's motto of "creating a company to achieve what no other company in the world has achieved by using techniques you can't find anywhere else", I'm committed to continue devoting myself to the development of technology, including manufacturing techniques, and introducing that technology to the world via KYB Technical Review.

(KAWANO Yoshihiko)

I had the opportunity to carefully read non-electronic technical literature since I joined the KYB TECHNICAL REVIEW Editorial Board. Reports on hydraulic or mechanical engineering were exciting for me, but they were often so technical that I could not understand them easily. I often had trouble with reading through the text in Editorial Board meetings, taking much longer than the other editors. For example, when I read a report illustrating the movement of a hydraulic system, I imagined in my own way the dynamic movement in my mind. If I could not figure it out, I tried to understand what it exactly was by referring to the related literature. I would like to continue working hard to learn technology that is new to me, including hydraulics, through the Editorial Board. (KANAI Akifumi)

I believe I'm involved in work with an eye toward the future, trying to determine, plan, act on and achieve a priority. But in reality I feel I am occupied with routine business to solve the problems facing me. In the Editorial Board, I sometimes happen to find new technology leading us to the future, or encounter a stimulating article on an achievement of what I could never achieve myself. Moreover, when I find a name with whom I have been involved with, I'm happy to see proof of his/her growth. Once a latest issue has been released, it is time to start on another issue, and I have to find a new theme for writing again. With our mission of creating another Technical Review repeatedly, I would like to continue working hard. (NOGUCHI Kouichi)




**KYB TECHNICAL REVIEW No. 55**



Published on October 1, 2017
Editor and publisher: KYB Technical Review Editorial Board
Publishing office: KYB Corporation
(From October 1, 2015, Kayaba Industry Co., Ltd. changed its trade name to KYB Corporation.)
World Trade Center Building,
4-1 Hamamatsu-cho 2-chome, Minato-ku, Tokyo 105-6111
TEL: 03-3435-6451
FAX: 03-3436-6759
Published by Shobi Printing Co., Ltd. (Hakusan, Tokyo)


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