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KYB Corporation

KYB

# KYB Corporation

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Foreword

# From Professor's Daily Affairs

FUKADA Shigeo*

The society has been thrown into confusion. Since last year, various situations at home and abroad are shaking what we have thought understandable. The daily life of us members of a faculty is not an exception. Today, the number of 18-year-old population in high schools is rapidly decreasing. Each department and faculty of a university has an enrollment limit that has been recognized by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). It has become a real possibility that the limit may no longer be reached. Reaching an enrollment limit is more critical than the employment rate of graduates. If the competitive rate of applicants become lower and departments can't fill the capacity, they will immediately become a target of elimination and consolidation. Therefore, all universities are making efforts on PR activities for high school students, creating a remarkable PR booklet, participating in various university orientation meetings and holding an open campus day repeatedly. I am engaged in a role related to these activities. Last year, I had a chance to hear recent situations of high school students from career guidance counselors in a prefecture in the Chukyo region. There was a story that left me an impression.

Today's high school students have been told to "have a dream" since they were young, under the education policy that focuses on individuality. As a result, they consider their future occupation more than students in the past. On the contrary, an increasing number of students can't make a decision on their career when they think of failing to realize their dream and they feel cornered, as they have been told that the failure is as a result of their self-responsibility. Having seen these situations of high school students, PR staff of universities become more vigorous for their PR activities to attract students. In the case of an engineering department, they become too quick to jump to conclusions of highlighting the "pleasure of manufacturing." In my university, the number of opportunities in which professors are sent to high schools to hold classes or introduce research activities is increasing. Normally, we take on a subject that attract students' interest such as robot. The problem is that if students take our interesting subjects on faith and enroll in an technical department, many of them would be disillusioned with the actual lectures they take after enrollment. In actual classes, we hear many complaints such as "I would like to experience actual manufacturing more," "mathematics and technical classroom lectures are not interesting," and "I would like to operate an robot."

§

How about theory of mechanism and "machine element design" that I teach? Although both courses, are typical special technical subjects, are they interesting to learn? The goals of lectures in machine element design are to understand the JIS standards regarding basic machine elements including screws, gears and bearing, and to learn how to decide satisfying materials and shapes based on the load conditions given using the knowledge of strength of materials. However, are these contents of any interest that high school students imagine?

For example, students learn about the idea and standards of "fit" in the first stage of machine element design learning. I myself remember finding it innocuous and uninteresting when I first learned about it as a student. However, as I become familiar with when and how the specific values of the eye-hurting fine figures in the tables of fit limits or tolerances were decided, and as I become older, I found out the importance of "fit" and felt it in my body. Needless to say, screws, gears and rolling bearing were all invented by humans from nothing and they don't exist in nature as they are. This is nothing but the enticement of machine elements. These man-made things are standardized throughout the world. When you understand that an M10-screw bolt that is purchased in a tool shop in Germany unconditionally "fits" a nut that is purchased in a home center in Japan is a truly miracle happening, you might find machine element interesting. However, I know that high school students can't imagine such a story.

§

Screws, gears and rolling bearing are invented in Europe. Originally, the idea of engineering came from Europe. I travel to Europe every year to participate in international conferences related to precision engineering. I visited various countries and cities that host each conference. After many visits, I found that "Europe" is a very diverse place and people using different languages and customs are coming and going all the time. For example, there are French-speaking area and Dutch-

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speaking area in Belgium. To me, it is very confusing to see the destination of train on display as different spellings are used for geographical names in each language. Swiss people can speak three languages without hesitation. People from various countries gather in Europe and they share the tradition of Christianity from the Middle Ages and the values in modern Europe. When I chat with the local fellows in an international conference, I feel the foundation supported by their solid tradition in the engineering they are implementing. I can also see the historical inevitability in automobiles and trains that run through the towns in each country of Europe.

Modern science and engineering and industry based on modern science emerged and developed only in Europe. This is because there was little centralized and monopolistic wealth in Europe as no dictatorial centralized government like successive dynasties in China existed, and the fact that all people had a chance to make money equally had a deep influence.[1)] There, engineers and traders (and academics?) were both able to make a profit by cooperating each other to create and upgrade machinery. As a result, the country became wealthy. It is said that, as the École polytechnique in France and TH [Note 1)] in German-speaking areas were established by the government as systematic education and research facilities for such useful and positive knowledge[2)], the idea of "engineering" gradually became deposited and crystallized.[3)] Since European people stepped out of the grace and spell of God that have continued from the Middle Ages and decided to seek for wealth through industrialization - live by their own ideas and actions, the big waves of modernization have emerged and developed the present world. In this modern world, we are running about in confusion around the clock.

Note 1) Technische Hochschule. It started as a technical collage and later became a university of technology.

§

How about engineering in Japan? Japan opened its door to foreign countries with the arrival of the black ships of Commodore Perry after 300 years of the peaceful isolation. The country was suddenly exposed to the Western civilization of science and technology, which led to forced innovative changes. Japan struggled to absorb engineering. Engineering in Japan is so to speak "ersatz engineering" that was forced by Western countries, and it didn't arise as a sequence of Japanese own culture. Japanese people were, however, most excellent in mastering engineering outside Western countries. Today, Japan sees a demand of incorporating roles of university into industrial and economic systems in a more practical way and teaching and studying subjects that can actually be used in the society. However, this might be seen as a matter of course in the engineering field. Since engineering originally had a strong connection with economy (traders). There is one barrier to developing a system that generates economic benefits through practical cooperation between universities and companies. Those, like myself, who are engaged in university and haven't entered the workforce are not able to understand the philosophy of "making a profit." If the real purpose of engineering is to make a profit through the sharing of positive values and cooperation between engineers and traders, academics who have no pleasure in making a profit would be useless.

Nevertheless, we faculty members are expected to tell young people (who are forced to have a dream) the reason why we chose our academic field based on our dream. In fact, the reason that faculty members became involved in their present academic field rather comes from personal situation. In my case, although I was in a robot engineering laboratory as a student, I was assigned to a screw laboratory in the graduate school for certain reasons. All I can say is that I was fated to the field. Then, I became hooked on screw. In any academic field, our tasks that we actually work on every day in laboratory are not interesting, but rather an accumulation of small and boring things. However, I find a pleasure there. Therefore, we continue to be fascinated with the study. This pleasure cannot be learned from others but you have to find on your own in your study and research. The pleasure can't be found if you seek for your dream only. Confucius says, "if you think of something alone without learning from others, you fall into self-righteous" and Max Weber told off, "return to your own business!" [4)] If we can rather deposit the "spirit of Japanese engineering" from our daily work such as above, engineering in Japan will become more valuable. My small dream is to see it actually happens.

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Editorial

# Promotion of Disaster Prevention and Reduction to Overcome Earthquake Disaster and Co-create Future

FUKUWA Nobuo*

## 1. Introduction

Nankai Trough Earthquake is said to occur with a probability of around 70% over the next 30 years. In the worst-case scenario, the Central Disaster Management Council predicts a death toll of 320,000, near three million of completely destroyed houses, and economic damage worth 220 trillion yen which represents 40% of our GDP. The reasons for such tremendous damage are described as follows.

(1) A large-scale earthquake of which epicenter area extends into land could result in about 60 million of disaster victims,
(2) Cities and towns are expanding over coastal lowlands, and
(3) Many buildings with low earthquake resistance remain without exposure to strong shaking as long as 70 years,

and others.

Inspecting the past earthquakes occurred in the areas along Nankai Trough, we can see that every earthquake occurred at a turning point in the history of Japan. If the above-mentioned worst-case scenario happens, it is likely to disrupt the society and lead to a national-level crisis. Since the Nankai Trough Earthquake is an earthquake that will certainly occur, we must make every effort to prevent damage from it.

I, the author of this paper, was born in Nagoya and has been engaged in education and research in the fields of earthquake-resistant engineering and earthquake engineering at the Nagoya University. As one of researchers who live in possible quake-hit areas, I would like to work hard as much as I can to reduce earthquake damage.

Earthquake engineering researchers are basically striving to minimize earthquake damage and maintain social calm through their research into natural disasters including earthquakes and tsunamis. The following four action items are required to reduce earthquake damage.

(1) Avoiding disaster risks: Create an urban structure less vulnerable to disaster in areas with low disaster risk.
(2) Increasing resistance: Enhance structural strength of buildings in urban areas as well as improving infrastructure that can help prevent disasters from occurring.
(3) Enhancing disaster response capabilities: Prevent damage from spreading by accurately understanding damage information and making effective use of resources in the case of disaster.
(4) Becoming resilient: Foster "ability to survive" of community and individuals to recover and reconstruct the community quickly after a disaster.

Promotion of the first two actions can reduce structural damage and the number of casualties, and the remaining two are effective to minimize chances of expanding damage. To move forward with these action items, we need to conduct researches into hazard prediction, urban planning, earthquake-resistant engineering, disaster information, disaster prevention education, and so on.

However, those researches alone are not sufficient to reduce disasters. Various kinds of capabilities should be combined to put this disaster mitigation approach into practice. With this hope in my mind, I have been involved in establishment of the Disaster Mitigation Research Center (DMRC), Nagoya University and the construction of the Disaster Mitigation Research Building (Gensai-kan). This paper introduces a part of the project.

## 2. Vulnerabilities to earthquake disasters of urban areas in Japan

During the years of high economic growth since World War II, Japan has promoted the development of national land focusing on convenience and efficiency while concentrating population into urban areas. This made Japan one of the world's top economic powers, realizing an affluent and mature society. However, concentration of population into urban areas resulted in the expansion of cities and towns into dangerous areas and the density of houses. Additionally, excessive pursuit of efficiency and high functionality made the society less redundant and vulnerable to disaster. On the other hand, population shrinking and aging in rural areas weakened the society.

Table 1 shows changes in Japanese society over the past two decades. All items for comparison between 1993

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and 2013 are derived from the 20th anniversary special website of NHK Close Up Gendai (http://www.nhk.or.jp/gendai/20th/). From this table, we can see how Japanese society has been weakened. Amid the sluggish economic growth, the national debt tripled, the number of young people decreased by 20%, and the number of full-time housewives who defended their communities and homes during the daytime became fewer. Rapid proliferation of convenience stores and family restaurants has led to decrease in amount of food stockpiled in communities and individual households. Furthermore, our society became dependent on logistics services such as home-delivery service. There is an abundance of electrical appliances in every house, and dependence on cell phone or Internet has been increasing. While our life is becoming more and more convenient, traffic disruption or blackout is having an increasing influence on society.

As shown in the example on Fig. 1, large cities in Japan expanded their areas into alluvial lowlands as a result of population concentration. Thermal power plants and refineries are located on landfills in bay areas where the earthquake hazard is high. On the other hand, on soft ground in lowlands protected by dikes, houses are densely packed and high-rise buildings stand side by side. Therefore, there are concerns about damage to electric power equipment or refineries caused by strong shaking, liquefaction-related disruptions of gas supply or water supply and sewerage systems, long-term flood due to collapsed dikes, earthquake fires caused by the density of houses or insufficient fire-fighting resources, strong shaking of high-rise buildings produced by long-period ground motion for long duration of time, and so on.

Japan is about to enter the active period of earthquakes while having a problem of shrinking labor force because of the falling birth rate and the aging population. Now is the time to address the urgent issue of building a resilient society. To create a disaster-resistant, autonomous, decentralized, and cooperative society, the importance of robustness improvement of society and regional revitalization has been stressed in recent years.

**Table 1** Changes in Japanese society over past 20 years

| | 1993 | 2013 |
|---|---|---|
| Population aged less than 15 years [million persons] | 20.84 | 16.59 |
| National and local government debt [trillion yen] | 333 | 977 |
| Gross Domestic Product (GDP) [trillion yen] | 467 | 520 |
| Convenience store [stores] | 23,000 | 47,000 |
| Restaurant [stores] | 3,876 | 12,429 |
| Household with full-time housewife [families] | 9,150,000 | 7,730,000 |
| Cell-phone penetration [%] | 1.70 | 106.80 |
| Internet penetration [%] | - | 79.10 |
| Home-delivered parcel [billion pieces] | 1.19 | 3.40 |

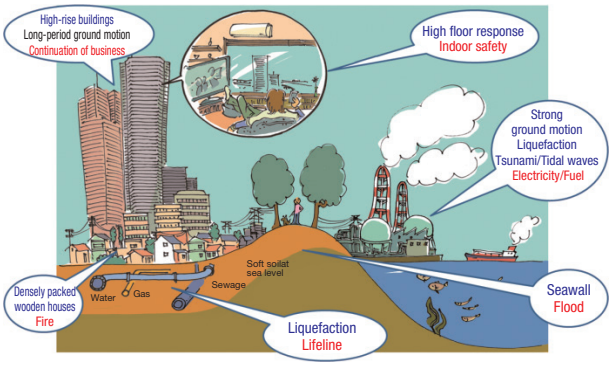


**Fig. 1** Vulnerability of urban area to earthquake disaster

## 3. Mobilization of all social capabilities

In preparation for the Nankai Trough Earthquake that will definitely occur and turn into a catastrophe, we need to make maximum efforts to reduce disaster damage. Since resources available after the occurrence of an earthquake are limited, advance efforts to reduce damage is required.

Earthquake disaster related researches include the following three fields.

(1) Physical research addressing the natural phenomenon of an earthquake occurrence (e.g. seismology).
(2) Engineering research aiming to build earthquake-safe structures (e.g. civil engineering/architecture).
(3) Social scientific research exploring society or individuals that can respond to earthquakes appropriately.

Collaboration between these research fields is necessary to increase the effect of damage reduction.

The following researches are also required to reduce earthquake damage.

(1) Research to predict seismogenic behavior or damage by observing various phenomena triggered by an earthquake and converting them into physical models.
(2) Research to prevent damage from anticipated events by taking necessary measures such as infrastructure development or construction of earthquake-resistant structures.
(3) Research to restore the community by taking recovery and reconstruction measures quickly as well as respond to disaster appropriately by grasping the disaster situation early and utilizing available resources effectively.

Additionally, the results of these researches should be used to help with disaster mitigation; we need to generalize the results, make standards or laws, and then formulate measures to be taken. Specifically, it is necessary to encourage people to take actions actively in industry or families. In other words, collaboration between academia, government, industry, and citizens is essential to promote researches, measures, and implementation of the measures.

As I have discussed, all social capabilities need to be mobilized to accomplish disaster mitigation; collaboration between different research fields (physical/engineering/social scientific), comprehensive approach to prediction,

prevention, and response, and industry-academia-government-citizens collaboration (See Fig. 2).

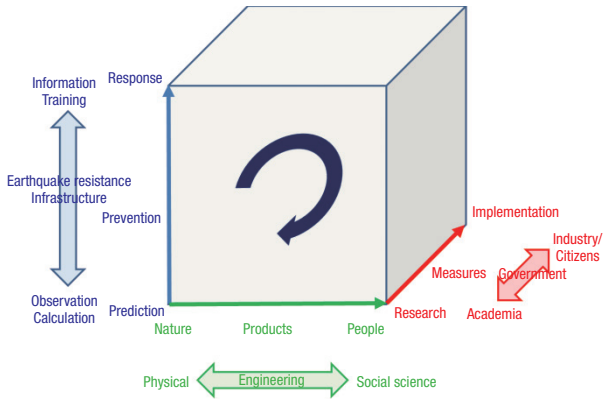


**Fig. 2** Mobilization of all capabilities

A viewpoint of "Think Globally, Act Locally," which means "looking at an issue from a higher perspective and implement a solution in your local community," is important in resolving a comprehensive issue such as earthquake disaster mitigation. A way in which various issues are resolved individually and put together in each of segmentalized fields or organizations is barely effective enough for partial optimization, but not effective for total optimization. In the event of a large-scale disaster, the scale of damage will be too large for available resources. Therefore, we need prioritize action items to be implemented from a higher perspective. We also need to accept social diversity, add bottom-up approach to top-down approach, combine capabilities of national and local governments, and mobilize capabilities of public and private sectors. In short, all types of capabilities, self-help, mutual-help, and public-help, are necessary. On the premise that communities and organizations have been autonomous and decentralized, we must create a mutual-help system in which unaffected regions or organizations provide support for affected regions or organizations. Autonomous, decentralized, and cooperative mutual-help society is the basis of resilient society.

## 4. Disaster Mitigation Research Center and Building

### 4.1 Disaster Mitigation Research Center (DMRC)

In December 2010, the Disaster Mitigation Research Center (DMRC), Nagoya University, was founded under the slogan of "disaster mitigation" and "collaboration," aiming at being a regional think-tank to formulate strategies for disaster damage mitigation. Thanks to donations from companies and external funds for research, the center employed professors who had lots of hands-on experience in disaster prevention and accepted many contracted researchers from local governments and private companies (Fig. 3). Many of the researchers have been involved in Earthquake Resistant Building Engineering in design offices, general contractors, home builders, etc.

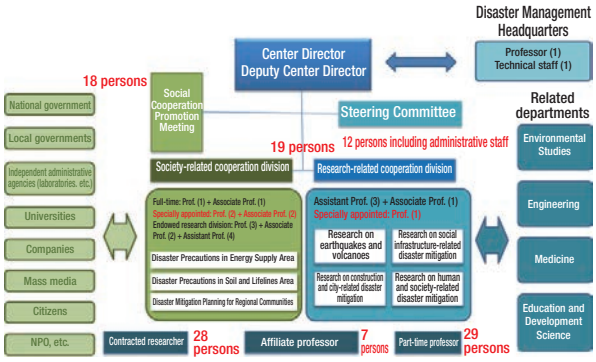


**Fig. 3** Disaster Mitigation Research Center (DMRC), Nagoya University

We have enhanced collaborations between different research fields, between academia, government, industry, and citizens, and with research institutions inside and outside the region for five years after the launch of the center. A system to address disaster damage reduction in collaboration with all capabilities is being established. As well as promoting research programs to reduce disaster damage, development of human resources for disaster prevention, awareness raising among citizens, cooperation towards realization of a cooperative society for disaster prevention, the center is carrying out practical activities related to disaster response and disaster risk prevention.

### 4.2 Disaster Mitigation Research Building (Gensai-kan)

The Disaster Mitigation Research Building called "Gensai-kan was completed in March 2014. This building serves as a hub for disaster prevention and mitigation research, for disaster response, and for education and awareness raising during ordinary times.

It is a base-isolated reinforced concrete building of five stories above the ground and one underground story, amounting to 2,898m$^2$ in total floor space, shaped like a triangle shortcake. An elastic base isolation system has been installed in the basement, which is comprised of a laminated rubber bearing, a direct-operated rolling bearing, and oil dampers. The system is designed so that the natural period is 5.2 seconds to avoid coinciding with the predominant period of the ground motion of about 2.6 seconds. There is 90cm clearance to ensure sufficient design margin. In addition to the underground base isolation system, the rooftop laboratory for disaster mitigation and experimentation on the 5th floor also has a base isolation structure with a natural period of 5.2 seconds – the Gensai-kan is a dual base-isolated building. The underground gallery is designed for visitors to learn the technological history of earthquake resistance/isolation and vibration suppression of structures while observing the base isolation device from outside of the gallery. There are "Gensai Gallery" for oscillation experience and "Gensai Hall" for holding seminars on the 1st floor, "Gensai Library" where visitors can browse relevant information and the Disaster Management Headquarters on the 2nd floor, and space for research projects on the 3rd to 4th floors.

### 4.2.1 Hub for research into disaster mitigation

The Gensai-kan building itself is a subject of research on earthquake resistance as well as a field of experiment. The rooftop laboratory weighing 410 tons has a base isolation structure with 5.2 seconds of natural period and can shake with a half amplitude of about 70cm by applying sympathetic vibration with an actuator. Since there is a virtual reality system comprising a stereoscopic image display and audio equipment in the laboratory to simulate an earthquake situation while shaking the room, visitors can test their states of mind during earthquake or experience disaster response drills. The use of the laboratory's shaking as vibratory force generates an inertia force of about 40 tons, enabling a whole building weighing 5600 tons to shake with an amplitude of about 5cm.

With the newly developed pulling jack installed on the underground base isolation layer, free vibration experiment can be conducted by causing forced displacement of about 10cm. Assuming that the rooftop laboratory is a building standing on the ground (= the entire building of the Gensai-kan), since the natural periods of the entire building and the rooftop laboratory are both 5.2 seconds, it is possible to reproduce resonant response of a multi-story building. This can be used for research and development of vibration suppression techniques of construction to avoid resonance.

The oil dampers installed at the underground base isolated layer and the actuator on the rooftop laboratory are manufactured by KYB Corporation. The actuator also includes a feedback control function. We plan to install on-off switching type oil dampers on the rooftop by the end of this fiscal year to begin considering the protection effect of TMD (tuned mass damper) with additional dampers during strong wind or the feasibility of AMD (active mass damper) for absolute vibration control.

A lot of seismometers, earth pressure meters, and displacement meters installed in the building are useful to clarify vibration behavior of building, aging of building or base isolation system, earth pressure distribution properties during earthquake, and other issues. Aiming at developing inexpensive vibration monitoring methodologies, we have installed lots of simplified seismometers in the building and be currently studying the effectiveness. I would like to develop a new vibration monitoring technology based on these methodologies in the future.

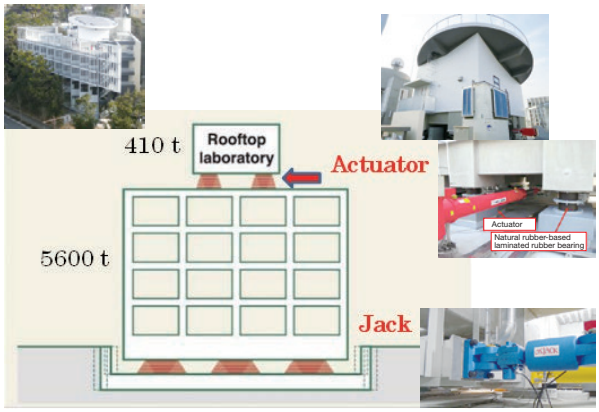


**Fig. 4** Shakable building, Gensai-kan

### 4.2.2 Hub for disaster response

The Disaster Mitigation Research Building (Gensai-kan) has functions as a disaster response hub in local community and the Nagoya University. The Disaster Management Headquarters of the university on the 2nd floor has a mission to protect the lives of 24,000 people (faculty and students). The 1st floor will be open to municipalities, key companies, and mass media, and the 3rd and 4th floors to domestic and international disaster investigation teams in the event of an earthquake.

The Gensai-kan is equipped with various types of disaster response equipment and stockpiles of necessary

**Fig. 5** Base isolated floor of Gensai-kan (Left lower),1st-floor gallery (Middle lower/Left upper/Middle upper), 2nd-floor library (Right lower/Right upper)

supplies. As well as introducing a high-performance base isolation structure, it has a diesel generator capable of one-week continuous operation, a solar power generation device, 3m$^3$ drinking water tank and 17m$^3$ miscellaneous-use water tank for 100 persons × 10 days, a dish antenna for satellite communications with municipalities, a long-distance wireless LAN connected with the national disaster management organizations, etc. on its rooftop. There is lots of other equipment installed in this building; on-campus broadcasting system, drainage tank, city-propane switching type gas-powered air conditioning equipment, power panel capable of connecting to a power supply vehicle, earth tube that utilizes temperature environment in the ground for heat exchange, etc. With the use of all equipment within the building, we intend to keep this building functioning as a disaster response hub even when a large-scale disaster occurs. It also doubles as a model exhibition of disaster response hub.

#### 4.2.3 Hub for preparedness

The Gensai-kan is used as a place of learning or collaboration in ordinary times. The 1st and 2nd floors are open to public on afternoon of Tuesday through Saturday.

In the “Gensai Gallery” and “Gensai Hall” on the 1st floor, visitors can learn about disaster prevention and mitigation through various exhibitions showing fundamental to cutting-edge research information. In addition, diverse seminars are frequently held here.

The 2nd floor has “Gensai Library" where visitors can view or read various disaster-related materials; newspaper, magazines, videos, books, historical materials or hazard maps of municipalities, ground-related data, old maps, etc.

The Gensai-kan is a place of “learning” and “awareness raising” that offers visitors an opportunity to understand natural disasters by contact with various exhibitions or materials firsthand and to think about disaster prevention and mitigation locally. At the same time, it also is a place for cooperation and collaboration where diverse groups of people involved in disaster prevention and mitigation activities, such as researchers, governments, companies, and citizens, join hands with each other.

## 5. In Closing

The Disaster Mitigation Research Center (DMRC), Nagoya University is playing a role as a region-based disaster mitigation think tank with the support of many people in the local community. By positioning the Gensai-kan as “Gensai Agora” (agora means a square in Greek) to mobilize all capabilities from the community, I hope we can create a society where everyone understands that disasters can happen to them, too, saves their own lives, and cooperates with family and community members. What we should do to achieve this goal is as follows; to learn the region’s history, to grasp the actual state of the region, to analyze charms and challenges of the region, to paint a vision of the future, and to promote and implement regional activities. We would like to learn about the region, help the Gensai-kan grow into a local museum that contributes to the creation of local community in cooperation with the society, and capitalize on earthquake engineering research to reduce earthquake disasters in the region. We call this activity in which we mitigate disasters, overcome them, and then create a society with new values “Disaster Mitigation Renaissance."

Note: Please visit our website at http://www.gensai.nagoya-u.ac.jp/ for up-to-date information on the Disaster Mitigation Research Center and Building (Gensai-kan).

Essay

# Gujarat Natural Life Story Vol.1: Animals

ISHIKAWA Teruyuki

## 1. Introduction

It has been three years since I was transferred to KYB Conmat Pvt. Ltd (hereafter referred to as KCPL)in May 2013, the first KYB Group branch in India launched. Out of the first four Japanese representative members including me, three returned to Japan in 2015. Two new members arrived and the total number of members is currently three. The outline of KCPL is introduced in the Technical Review No. 49, and the development of mixer, the production item in the branch, is explained in No. 47.

No. 52 will introduce natural life in Vadodara City, Gujarat in west India, where KCPL is located, in two editions: Animals and Birds.

## 2. Animals

Let's take a look at animals which can be seen in Vadodara City.

### 2.1 Cows and Water Buffaloes

The first animal you can think of in India is cow. There are 1.26 billion population, 200 million cows and 100 million water buffaloes in India.

Cow is a sacred creature ridden by Lord Shiva, a deity of the Hinduism, which is a belief of about 80% of population.

Cows in India have humps and large floppy ears.

Skin under the neck and on the stomach is loose and looks like pleated curtains.

It is outrageous to eat the sacred cows, but milking the cow is acceptable.

**Photo 1** Humped cattle (zebu)

Milk is an important source of animal protein and fat supply as the majority of Indians are vegetarian.

Cows can also be used as draft cattle.

Two oxen with magnificent horns pulling a cart side by side look brave and handsome. Oxen plowing a field can often be seen.

Most of these oxen are spayed.

**Photo 2** Oxen drawing a cart

Many cows in town scavenge for food. Some cows are begging for food in front of a private house until they are fed.

Some are literally "ox-walking" and others are lying on a road. They don't seem to care about traffic jam and they (look like they) live as they like.

They exist as if to say, "I am a God's envoy, and my body says No Problem" - as in Indian cliche. They stroll calmly even when cars and motorbikes pass close by at great speed. Even of cars nearly hit their foot or tail, they stay calm. I'm not sure whether it is because they have guts, poor eyesight, or just a dull sense. When I travel on a car, I not only stumble across cows in my way but also see cars staying still on a passing lane like a cow and women who are driving a scooter parallel to each other getting caught up in chatting loudly. People here probably became like cows as they have lived with them for thousands of years, Although cars in the way are annoying, I was surprised to hear a rain of horns and flashing.

There are as many water buffaloes are as cows in India. They have black body and smaller head compared to cows. The cross-section surface of their horns looks slightly flat.

They are also used for working and milking.

Buffalo's milk contains more fat than cow's milk and yields are higher. Water buffaloes are more useful to people than cows which are said to be God's envoy. Amul, the largest dairy product company (dairy cooperative) in India has one of their factories in Vadodara. A picture of water buffalo is on their delivery track. Buffalo's milk here is called "Gold Milk" and it is slightly expensive.

As for thinking of food safety, these milking cows is doubtful because their food is mainly from garbage. This makes me unease but there is no choice but accept to maintain milk.

**Photo 3** Bathing buffaloes

Cows often go ahead of water buffaloes when they walk in line in town and along the street.

They may have a cate system as human society.

Wire barriers are placed around trees on the side of the line to prevent damages.

While trees that count are in poor growth, weeds and more healthy.

In dry Gujarat, however, many street-side wild shrubs grow long thorns so that they are not eaten by cows and other animals.

Poor water buffaloes ! They are treated unequally although it is the same species as cows. Unlike cows which are worshiped, water buffaloes are considered to be the embodiment of evil and be used as a ride by dead kings. They eventually become edible meat. India exports the largest amount of beef in the world, but this is buffalo's meat. The taste is marginal at best. The meat is tough, stringy and tasteless. This is natural because most buffaloes are not bred for meat, and those which can no longer be used for milk or working are slaughtered for meat.

Cow and buffalo dung are collected, flattened and sun dried to make traditional fuels.

They are often dried along central reservations.

This is a recycling society.

### 2.2 Dogs

Dogs can be seen in every street corner and around town in Vadodara City. Since India is a hot country, many dogs are short-haired and fit like hunting dogs. Most of them have a curled tail. They are lying down on concrete or sand and having a nap. Of course, they are all stray dogs. They live in groups of a few dogs and 6 or 7 dogs are settled in the district where my apartment is. Large iron trash containers are placed in the dumping site in the corner of town, where cows and dogs scavenge for food and make a mess all around. They are wild but are fed regularly. An accompanying tenant is one of those who are feeding the dogs. When he walks in front of the apartment, his favorite dog comes to him. However, it is strange that the dog doesn't try to play begging for food. We need to be careful as they might reserve rabies in India.

**Photo 4** A Dog in front of my apartment and auto-rickshaw

Hygiene of dumping site is somewhat concerned, as caustic lime is often spread as disinfectant.

Pesticide is sprayed like a smoke curtain using a blower attached on the rear deck of a track in order to kill mosquitoes.

Although it doesn't smell so bad, it might affect the health of children who are chasing the smoke.

### 2.3 Squirrels

Squirrel in India is called Indian palm squirrel (Funambulus palmarum) and it is also an animal related to God. They are everywhere from residences to parks as they do not get harmed. Indian squirrels make chattering noise as they wag their tail, which I couldn't recognize at first. Squirrel eating food with both hands are adorable.

**Photo 5** Indian palm squirrel in Sayaji Baug park

### 2.4 Goats and Sheep

KCPL is surrounded by fields and shepherds sometimes take goats and sheep to the field to feed grass. Most of them are goats, and some are sheep. Most sheep are covered in dust . Goats are bred for milk and sheep for wool. After sheep are sheared, they are used as mutton. The majority of meat in India is poultry, followed by mutton. Both goat and sheep meat are called "mutton."

**Photo 6** Sheep and goats walking along the channel next to KCPL

### 2.5 Donkeys

Donkeys look sorrow. They are often stand still on the road side or central reservations hanging their heads, They often stand still on the roadside or central reservations without reason. Although they are in the traffic way like cows, they don't have such presence or dignity as cows. Compared to the smart appearance of horses, they have small body, large head, long nose and big ears. They look as if they are suffering from a sense of inferiority and in despair. Moreover, some of them had their mane colored in pink. Nevertheless, they have an owner and various symbols are marked on the bottom. What are they bred for? I have only seen donkeys on duty of carrying sorted baggages on their back three times. In human society, there are some kinds of person who can be easily bullied. I think donkeys look like such the exist. I hope not.

**Photo 7** Donkeys on top of Pavagadh Hill, Champaner, a world heritage site in Gujarat

### 2.6 Camels

I can't count how many times I see camels before I came to India. I remembered seeing them a few times in the zoos, and the last time I saw them was on the Tottori Sand Dunes. There is no such thing as "camel and wagon." but camels draw big wagon here. When you pass by a camel, you will be surprised to see how tall it is. If you see the nose closely, you will find that their lower part of the nose is long and round. It reminded me of Lucky Dragon in the old film entitled "Never Ending Story." Camels might have been the model of Lucky Dragon.

**Photo 8** Camels being sent to graze

### 2.7 Horses

Although you can see various animals in Vadodara city, chance to see horses are few. Most horses you can see are white horses drawing wedding carriages. Weddings in India are so gaudy that even people from Nagoya (who are believed to be gaudy) would be surprised. Horses and carriages are painted in white and silver, full-dressed and shiny. These carriages are accompanied by a caravan and marching band that hold lightings and decorations in front and back.


**Photo 9** Horse carriage for wedding

### 2.8 Elephants

I have seen two elephants in a wedding caravan once. Many elephants are carved on sculptures in the old sites throughout India, including the front gate of Laxmi Vilas

**Photo 10** Elephants for wedding caravan

**Photo 11** Mugger crocodiles in Vishwamitri River

palace in Vadodara. Battle scenes of elephants with King on the back are depicted in old paintings. I imagine there were many elephants in the past.

### 2.9 Crocodiles

When I commute to work, I cross a few bridges. In the evening, I often see many people in line along the bridge rail looking down the surface of the river. In Gifu, I saw people watching sweetfish in the river in summer. What are they watching here?

I asked the driver. He said in a smattering of English, "they are looking at baby crocodiles." Really? Crocodiles can't be in a river which runs through the middle of town. I think they are large lizards. I lived in Jakarta 10 years ago. There, I saw water monitor (varanus salvator) in the river next to my apartment in the suburb. The driver believed only what he wants to, so I thought that the driver made a wrong assumption or didn't know the right word.

There is a large park called "Sayaji Baug" in the center of the city. Across a road lies a magnificent university with a domed ceiling built by the King 100 years ago. This park was probably also built by the King. There are a large-scale museum that exhibit the King's collections and a zoo in the park. A river runs through the park tortuously. There is a beautiful bridge. The gap between the bridge and the water surface is about 10 m.

As many wild birds can be seen in the park, I often go for a walk on Sunday morning to see them. One day, as I came near the bridge, I bumped into people who are making noise pointing out the river surface. When I looked down, I saw a crocodile sticking up his eyes and nose from muddy water under the tree by the bank. Wow! It's a real crocodile! It was huge. It's length was well over 4 m. Has it escaped from the zoo near here?

Later, I found out that this was a mugger crocodile. This species has a length of 5 meters and a weight of 200 to 500 kg. They inhabit throughout India.

On that day, I saw two mugger crocodiles swimming under the bridge and the area 20 meters downstream . I pass the downstream bridge on my way home from work.

The driver was right. I should not have preconceived ideas.

When I go to the park every Sunday morning, I found myself seeing crocodiles at a rate of 70 - 80%. This is their habitat. I also see tortoises with a 60 - 70 cm shell. Children catch fish without a rod by the river bank. They don't seem to care about crocodiles under the cliff across the river. A newspaper article said that some crocodiles were found, rescued and taken back to the river in the city center when the river flooded from torrential rain during the monsoon season. About 200 to 300 crocodiles live in the river in the city. A local person I met in the park said that he has lived in Baroda (former name of Vadodara City) but they only saw two serious incidents caused by crocodiles. I know he meant that crocodiles hardly pose a threat to people, but it is difficult to judge.

**Photo 12** Mugger crocodiles in river bank, Vadodara city center

Generally Japanese people get in panic when they run into wild big animals like monkeys, wild bores or bears in town. On the other hand, Indian people take it for granted that they live together with them. This is because these animals are sacred in their religion even though they may harm people, and people dislike taking a life.

### 2.10 Snakes

I only saw snakes a few times. Just before finishing work, my driver knocked the window from outside and told me, "come and see, snakes are dancing." In the field right next to the factory, snakes were squiggly, twisting themselves around, raising their upper part and moving their head up and down, side by side. They looked like they were under trance.

This probably continued for around 30 minutes (I kept company with them). Actually, they were mating. It was also a rare scene for local people, so several people asked me for the picture.

**Photo 13** Snakes mating in the field next to KCPL

### 2.11 Monkeys

There are many monkeys in India. They are called hanuman langurs, a group of Old World monkeys. Their arms and legs are long and thin. They have black face, arms and legs, gray body hair, and long tail. These monkeys are considered the messenger of hanuman, God of monkey in Hinduism.

**Photo 14** Young hanuman langurs

Some people feed them as they are an sacred animal. They are not scared of people. Monkeys grooming each other and baby monkeys holding onto their mother tightly are very adorable.

At dawn, I hear a short howling noise. It sounds like it is coming from a spooky jungle. This was from the monkeys. The boss monkey ramps with an electric noise that doesn't seem like it is of an animal to other groups or enemies.

They turn up around the apartment where Japanese expatriates live every 1 or 2 weeks. They move roof to roof in a group in the neighborhood. Individuals that are apart from the group can sometimes be seen. If they turn up on the street in front of my apartment, wild dogs keep watch on them at the corner. After all, they are cats and dogs (monkeys and dogs in Japanese). On the contrary, adult monkeys protect little monkeys. They won't let little monkeys go to dogs by holding their tail. Children in the human world are controlled by adults. Everyone protects their territory.

**Photo 15** A group of hanuman langurs relaxing on top of the roof of a house next to the expatriates' apartment

### 2.12 Mongooses

When I saw this animal, I thought it was a kind of weasel.

After research, I found out that it was mongoose. Thick and long tail stretches from the base.

They can always be found in Sayaji Baug.

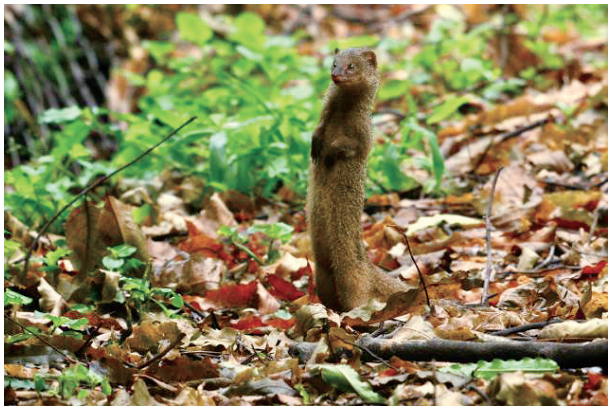

**Photo 16** Mongoose standing to keep watch on surroundings

When you hear about mongoose, you may think of a Habu pit viper vs mongoose fighting show. Although Mongooses were brought to Okinawa and Amami Oshima Island in order to eliminate pit vipers, they didn't eat the snakes. Instead, they grew by domestic chickens, wild birds and small animals. They now show a strong image of troublemakers who are to be expelled as an animal that destroy ecosystems. Are they maintaining biodiversity with other living creatures here in the origin of mongoose?

### 2.13 Cats

You can see various animals in Vadodara City, but not so many cats. I only saw less than 10 cats in 3 years. Skinny cats were in the factory before, but not recently.

**Photo 17** Cat studying its prey in square in front of the mosque

### 2.14 Lizards and geckos

Lizards are crawling in lawn or shrubbery. They look like chameleons and their eyes move round to separate directions. Their color is dry grass and plain. In fact, I don't really know the difference between lizards and chameleons. Geckos are similar in that they stick to walls. I personally like them as they look adorable.

**Photo 18** Lizard climbed on a copperpod tree

**Photo 19** Geckos on the ceiling of expatriates' apartment

### 2.15 Pigs

I sometimes see pigs around town. They might be better called wild pigs. Small ones are boars. I see them playing in mud in a group.

**Photo 20** Boars playing in mud

The number of sheets for this article has reached the limit. In the next issue, I will cover one of my hobbies - "bird watching." I would like to introduce over 80 species of birds that were found here, familiar types of birds and impressive birds.

## Author

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Joined the company in 1982.
Director Finance and Accounting,
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Technology Explanation

# Attenuation Technology Against Poppet Valve 3D Vibration

NAKANISHI Hiroshi

**Abstract**

We investigated the factors that brought about vibrations of the hydraulic poppet valve with numerical analysis and found a solution to stabilize the behavior of said valve for deployment for production.

Analysis was conducted with non-stationary turbulent flow coupled with a rigid poppet charged with flow forces.

If the clearance between the poppet and the valve seat is small, the deformations of the fluid meshes may be excessive and analysis could diverge.

Therefore, we adopted the mesh superposition method capable of avoiding the constraint of the fluid meshes onto the valve seat and noticeable deformations

Occasionally, the poppet vibrations were supposed to be generated due to a hydraulic jet and eddies born from the jet. We found an "edge tone" and "cavity tone", a continual pressure vibrational phenomena, which caused a large energy poppet vibration.

## 1 Introduction

Poppet valves are still widely used for many hydraulic machines. They tend to start vibration but no improvement has been taken against the tendency irrespective of their simple structure. It is supposed that turbulent flow around a poppet generates complex fluid load to it, causing unstable behavior. However the cause for the vibration has not been fully clarified due to unestablished measurement technology.

On the other hand, recent progress of fluid analysis tool has realized estimation of complex flow and poppet behavior and a measure against vibration can be taken based on the analysis result.

In this technical report, we introduce our analysis on a coupled model consisting of non-stationary turbulent flow and rigid poppet for finding causes for the vibration of a poppet valve and improving the valve characteristics.

As a cause for the vibration, vortices in the turbulent flow were focused on, and pressure fluctuation was generated in the analysis to identify the mechanism of the vibration of the poppet.

Influence of other causes for the vibration was also investigated and compared with that of the vortices on the vibration.

## 2 Principle of pressure fluctuation generation by turbulent flow vortex

Here we describe the generating mechanism of pressure fluctuation by a vortex which causes vibration of a poppet valve. The mechanism has been studied as that of sound generation in wind instrument or fluid noise[1)2)].

### 2.1 Edge tone

Edge tone is a generated sound when a jet flow from a plate-type nozzle collides continuously with a sharp edge as shown in Fig. 1.

When the jet flow collides with the edge, vortices are regularly generated and move downstream. The jet flow between the nozzle and the edge receives influence of the vortices and generates regular vibration in a direction perpendicular to the flow. The vibration frequency is determined by the distance between the nozzle and the edge.

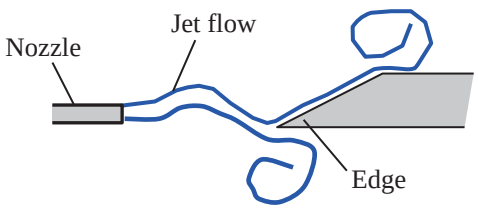



**Fig. 1** Edge tone

### 2.2 Cavity tone

A rectangular empty space in a wall parallel to the flow is called cavity. At the upstream-side edge of the cavity, a vortex is generated when the flow separates from the wall. The vortex moves forward in the free shear layer by the distance of the cavity length and collides with the downstream-side cavity edge. The collision generates a sound wave, which moves backward to the upstream-side edge and generates a new vortex (feedback mechanism). Sounds regularly generated with this mechanism are called cavity tone. Fig. 2 illustrates the cavity and vortices.

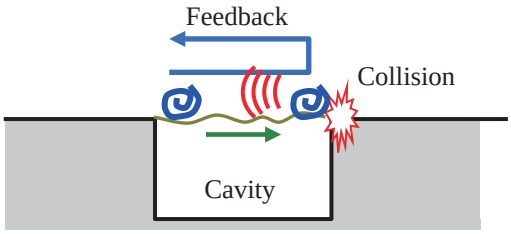



**Fig. 2** Cavity tone

## 3 Coupled vibration model of poppet valve and fluid

In general, a coupled model expresses a poppet and its motion by a boundary surface of movable, deformable fluid mesh set on a flow area. Since all the mesh points on the wall, including the poppet are restricted not to move away from the wall, the mesh deformation could become too large depending on the motion of the poppet and causes calculation failure. In particular, when the poppet is allowed to move in the direction perpendicularly to the axis (hereinafter referred to as transverse direction), interference with a valve sheet located nearby could easily cause the failure. Therefore it is difficult to numerically analyze transverse vibration of a poppet which is observed in actual situations.

In this report, we created a model which does not require constraint on the fluid mesh points on the wall by introducing an overset mesh for the valve sheet independently from the fluid mesh designated in the flow area.

The overset mesh has the following functions and constraints.

(1) It can control the flow as movable wall independent from the flow mesh in the flow area.
(2) Preset motion (such as pump rotation) can be designated to the mesh.
(3) Receiving the fluid force, it can produce a motion according to the force.
(4) Motion constraint due to a mechanical external force, for example when contacting other objects, cannot be made. (The overset mesh slips by the objects.)

This overset mesh realizes analysis of transverse motion and collision with the valve sheet, in addition to the motion along the poppet axis. However, the constraint 4) results in a collision motion constraint on the poppet.

Fig. 3 shows configuration of the fluid mesh and overset mesh and Fig. 4 the model structure of the poppet valve. The poppet valve model in Fig. 4 is the original one, having a shape for which an anti-vibration measure is not taken.

## 4 Estimated cause for vibration

The followings are empirically estimated causes for the vibration of the poppet and their influences to the vibration are analyzed. Fig. 5 shows the parts to which the causes are relevant.

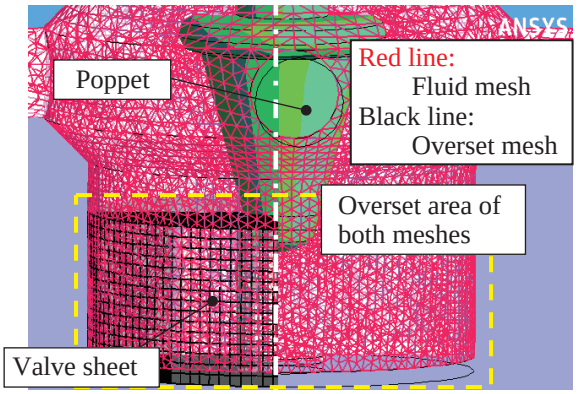



**Fig. 3** Configuration of fluid mesh and overset mesh

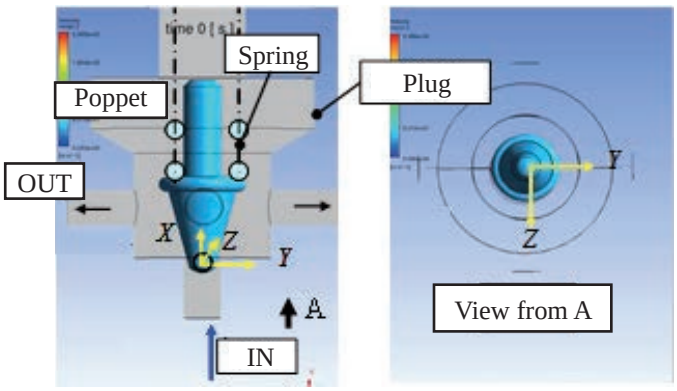



**Fig. 4** Poppet valve model (original model structure)

Cause (1) Collision of jet flow with drain port
Cause (2) Eccentric axis of poppet
Cause (3) Collision of jet flow with the wall of drain manifold block
Cause (4) Collision of jet flow with poppet apex
Cause (5) Occurrence of cavitation
Cause (6) Back pressure fluctuation
Cause (7) Air mixing

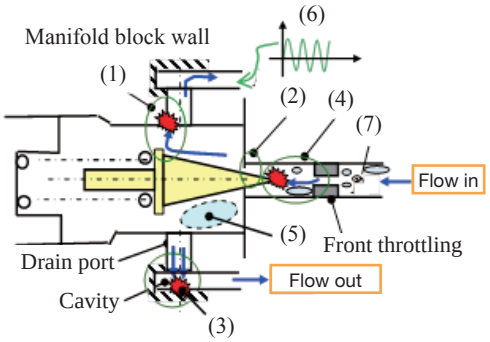
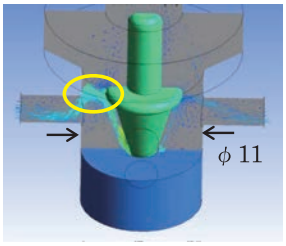



**Fig. 5** Estimated vibration causes (parts of causes (1) to (7))

(a) Original model
$W_m$=18.9[mm²]




(b) Standard model
$W_m$=3.12[mm²]

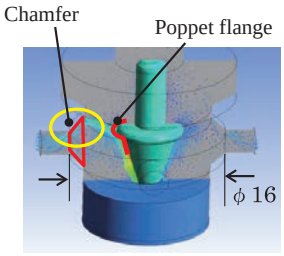



**Fig. 7** Difference of flow velocity distribution between with and without chamfer

## 5 Results of analysis

### 5.1 Cause (1) Collision of jet flow with drain port

Fig. 6 shows analysis results of the poppet displacement as a function of time and a function of frequency. Fig. 7 shows jet flow velocity distribution over the area from the poppet to the drain edge.

With the original model, it was observed that large vibration was generated by the edge tone mechanism due to the jet flow collision from the poppet flange to the drain port. A chamfer was then introduced around the drain port and its anti-vibration effect was studied. The experiment showed that the chamfer suppressed the magnitude and frequency of the transverse vibration. The flow speed analysis indicated that the reduction occurred because less jet flow reached the poppet due to the displacement of the edge position and the distance between the flange and the edge became larger.

The effect of the chamfer was confirmed in experiments and widely used for current type of mass-produced products. Hereinafter we referred to the model with the chamfer as standard model and effects of other estimated causes for vibration (Fig. 5) on the model are investigated.

The vibration energy Wm in Eq. (1) was applied to the evaluation of the poppet vibration magnitude.

$$W_m = \int_0^F \{I_x(f)+I_y(f)+I_z(f)\}df \quad (1)$$

$F$ : Maximum frequency for evaluation (3[kHz])
$I^*$ : Power spectral density of displacement in each direction

### 5.2 Cause (2) Eccentric axis of poppet

One can consider that the eccentric axis of poppet could break the symmetry of the edge tone of the cause (1) and hence cause transverse vibration. Considering the eccentric axis of a spring of actual valve, we assumed

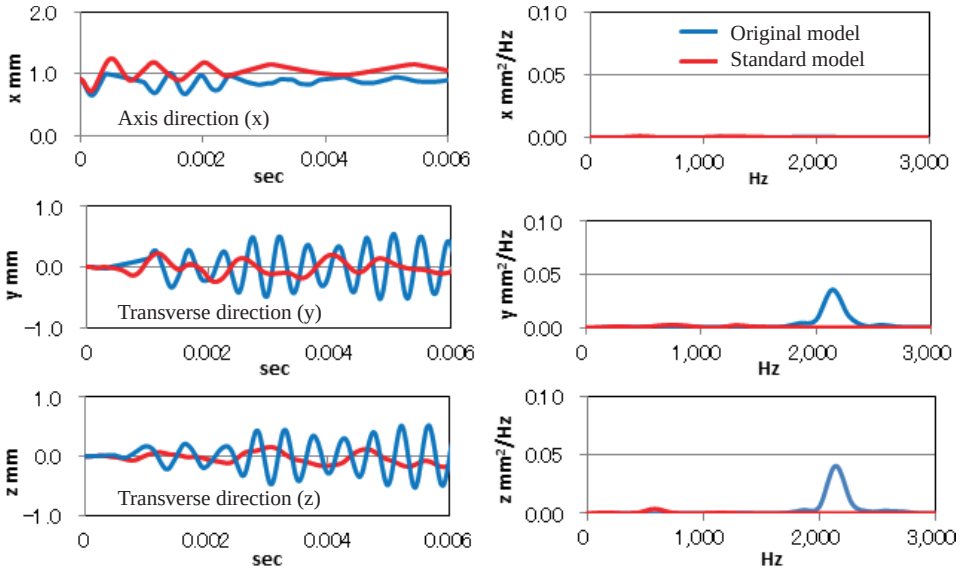



**Fig. 6** Cause (1) Analysis results of poppet displacement

application of a constant eccentric axis load of 10 [N] (which corresponds to the eccentricity of 1.7 [mm]) in the y-direction and analyzed vibration (Fig. 8). The load enhanced the vibration in the direction of eccentricity and the vibration energy increased by about 80%.

### 5.3 Cause (3) Collision of jet flow with the wall of drain manifold block

A manifold block wall was installed in the downstream side of the drain port (Fig. 9), and the effect, on the poppet vibration, of the cavity tone mechanism where a jet flow separating at the outlet of the drain port collided with it was analyzed. Fig. 10 shows the poppet vibration analysis results for the channel gap of the manifold block drain of t0.7, t1.4, and t2.8. For t0.7 and t1.4, the cause (3) gives larger vibration energy of the poppet than the other causes.

For t2.8, on the other hand, the cause (3) gives one third of the vibration energy given by the cause (1) or (2), which indicates the effect of the larger distance to the wall. Namely it was found that large enough gap could effectively suppress the vibration.

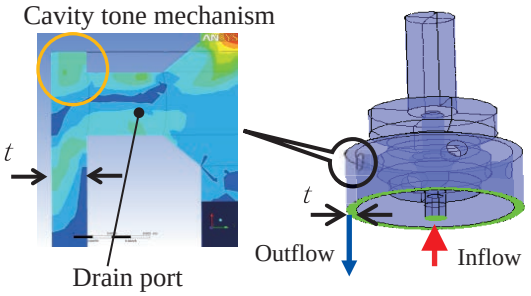



**Fig. 9** Model with manifold block and cavity vortex

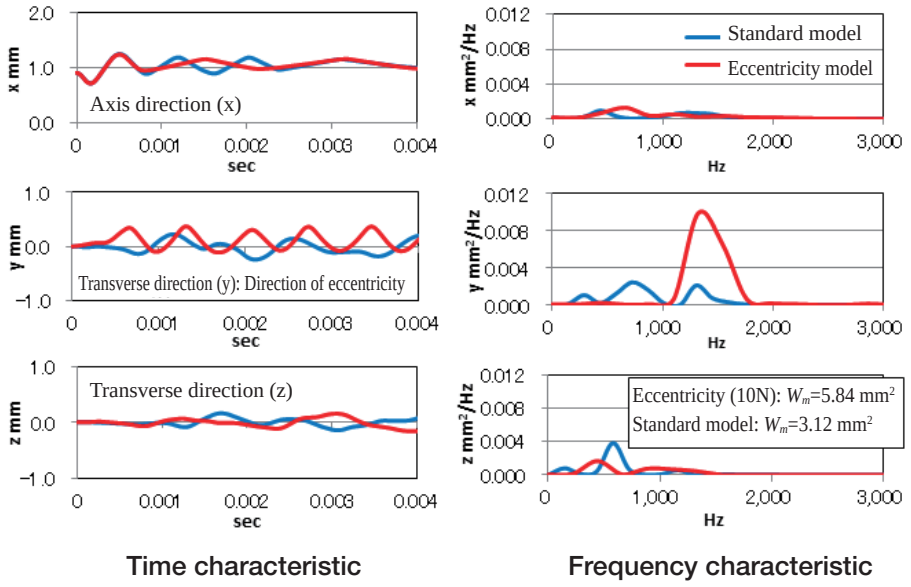



**Fig. 8** Cause (2) Analysis results of poppet displacement

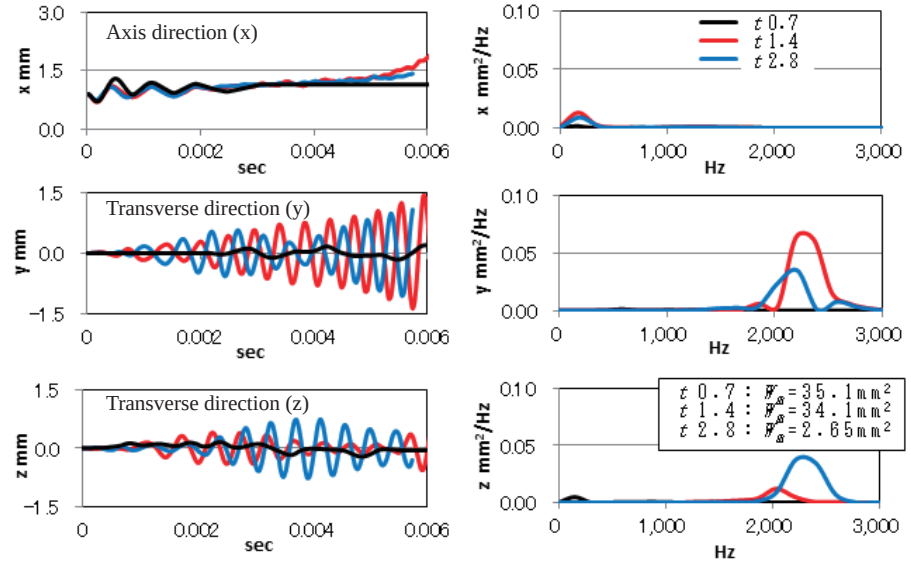



**Fig. 10** Cause (3) Analysis results of poppet displacement

### 5.4 Cause (4) Collision of jet flow with poppet apex

One can easily imagine that a jet flow from the front throttling (orifice on the upstream of the poppet) collides with the apex of the poppet and the edge tone mechanism is generated to cause vibration. Change of the magnitude and frequency of the vibration depending on the distance between the throttling and the poppet can be estimated from the relation with the potential core length of the jet flow (distance from the outlet of the front throttling to the point where the flow speed at the front throttling outlet disappears in the sectional flow speed distribution of the jet flow). In the analysis, the front throttling outlet distance L' was set to 5, 7.5, and 10 [mm] (Fig. 11). The front throttling diameter was not changed from the current type of valve.

Fig. 12 shows the poppet vibration analysis results for different front throttling distances. Transverse vibration was induced by the edge tone and the dependence of the vibration magnitude on the distance L' was determined by the relation with the potential core. (See Wm in the figure. The vibration energy is largest at around the potential core vanishing point L'=7.5 [mm].) However the frequency did not change much and there was no clear indication of the feedback phenomenon.

### 5.5 Cause (5) Occurrence of cavitation

A 3-phase flow (liquid, vapor, air) was assumed in the fluid model and the liquid phase was assumed to have two components, hydraulic oil and dissolved air. For the oil, we assumed paraffin type hydrocarbon. The temperature of the fluid was set to 25 °C in the analysis. Fig. 13 shows the vibration analysis results of the model and the standard model. The occurrence of cavitation did not enhance but slightly suppressed the poppet vibration.

### 5.6 Cause (6) Back pressure fluctuation

A sinusoidal fluctuation of downstream pressure of all the four drain ports was assumed to analyze influence of the fluctuation on the poppet vibration. The back pressure fluctuation in the form of a sinusoidal wave 1±1 [MPa], about the same magnitude as in actual poppet valve, was given to the drain port outlet of the standard model and the poppet displacement was estimated. The vibration energy was largest at the back pressure of about 1,300 [Hz] (Fig. 14).

Two patterns of the back pressure, 0.5±0.5 [MPa] and 1±1 [MPa], at the frequency of 1,300 [Hz] were given to analyze the influence on the poppet vibration. The upstream pressure was fixed to 29 [MPa]. The result is shown in Fig. 15. The vibration along the axis was large with large pressure fluctuation amplitude because

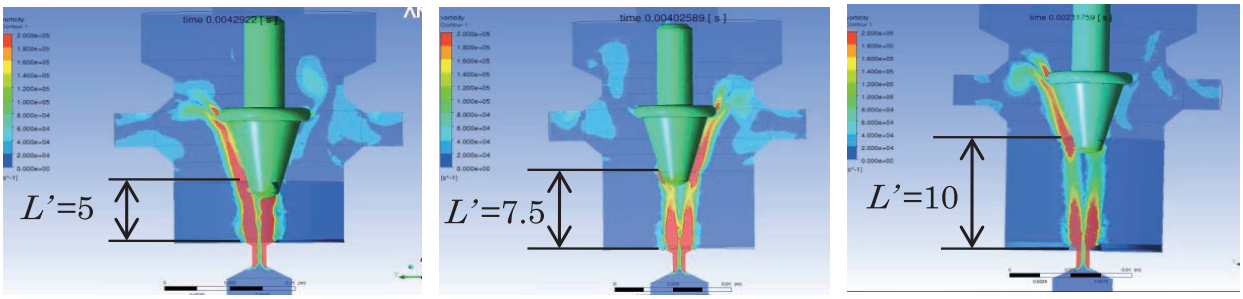



**Fig. 11** Front throttling outlet distance and example of vorticity distribution analysis result

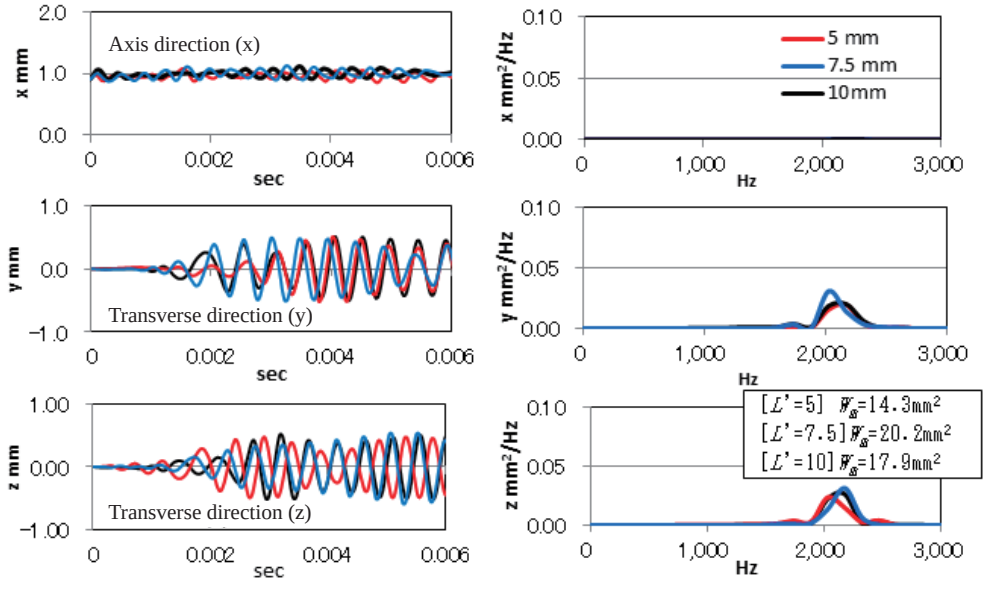
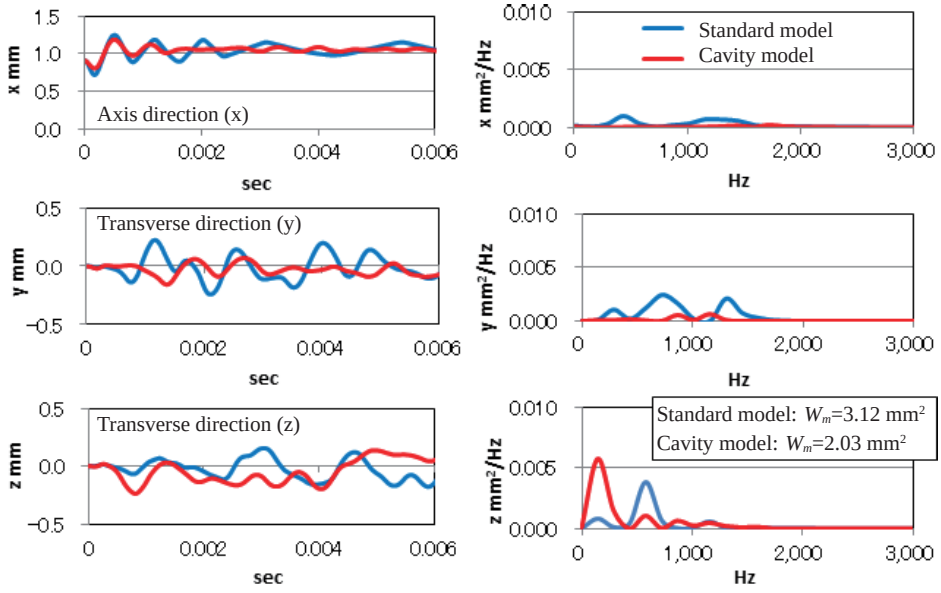



**Fig. 12** Cause (4) Analysis results of poppet displacement




Time characteristic　　Frequency characteristic

**Fig. 13** Cause (5) Analysis results of poppet displacement

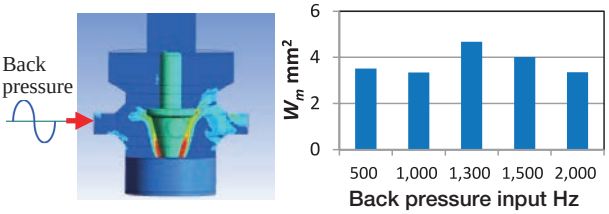
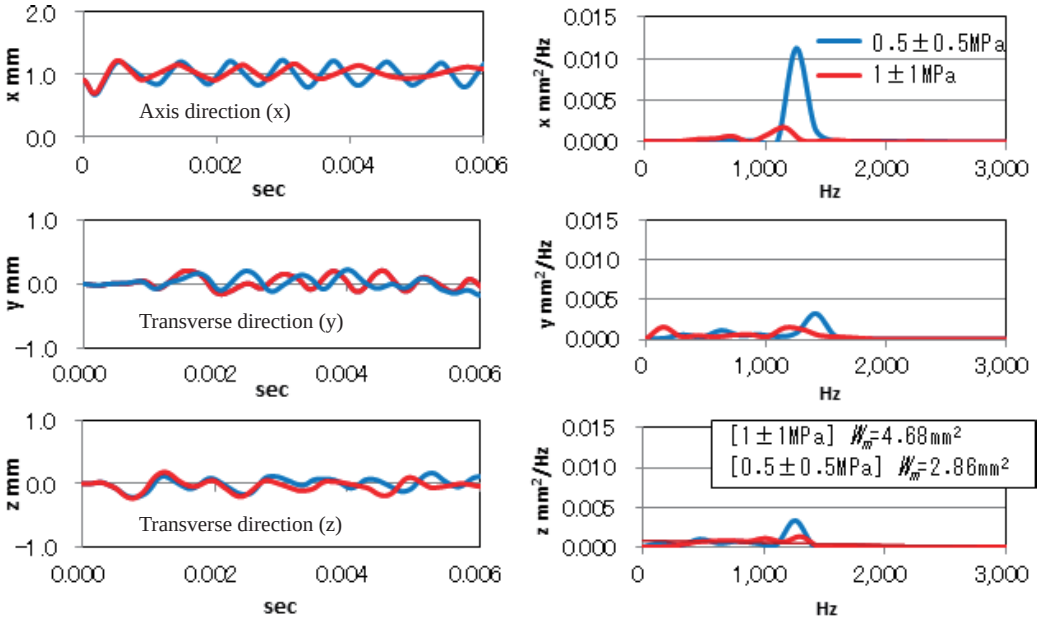



**Fig. 14** Input of back pressure fluctuation and vibration energy

a large change in the differential pressure could make a large change in the balanced position along the poppet axis direction. The vibration energy Wm with the back pressure 1±1 [MPa] was about 1.5 times as large as the one in the standard model.

### 5.7 Cause (7) Air mixing

The poppet motion was analyzed by assuming that the two phase flow with the hydraulic oil and air mixed flows in from the upstream side (Fig. 16). It was assumed in the present model that bubbles had the polydisperse diameter and united with and separated from each other repeatedly. Fig. 16 shows the analysis results with the air volume ratio γ being 0.3 and 0.5 at the inlet boundary. The vibration was larger for larger γ. When γ =0.5, the vibration energy was slightly larger than the energy Wm of the standard model but did not have a large influence. The energy was




Time characteristic　　Frequency characteristic

**Fig. 15** Cause (6) Analysis results of poppet displacement

also not very large for γ =0.3. Therefore, the vibration could be suppressed depending on the air mixing rate.

## 6 Comparison of vibration energies caused by estimated causes

Fig. 17 compares the poppet vibration energies caused by the estimated causes, including vibrations generated by vortices discussed above.

From the comparison, one can see the following characteristics.

1. The poppet vibration energy in the original model where drain port collision occurred was 6 times larger than the energy in the standard model where a chamfer was introduced in the port, and had a large influence on the edge tone vibration.
2. The eccentric axis of the poppet caused large vibration in the eccentricity direction, making the energy 1.8 times larger.
3. With the manifold block wall, the cavity tone mechanism was established in the area from the port outlet to the wall surface and caused large vibration (about 10 times larger than that in the standard model) when the wall distance was small (t0.7, t1.4). On the other hand the mechanism's influence was negligible for t2.8, indicating that the vibration was largely dependent on the wall distance.
4. The relation between the distance from the front throttling to the poppet and the poppet vibration energy could be determined by the characteristics of the jet flow and the vibration energy was largest at around the potential core vanishing point (L'=7.5). However a frequency change which indicated occurrence of feedback was not observed.
5. The occurrence of cavitation had little influence on the vibration. It rather suppressed the vibration.
6. The back pressure fluctuation slightly affected the poppet vibration. With the amplitude of 0-2 [MPa] made the vibration energy 1.5 times larger than the energy in the standard model.
7. In the study of the 2-phase model to find the influence on the poppet vibration, the vibration was found larger with larger air volume ratio at the model inlet although it was not very large for γ=0.3 and 0.5.
8. In general the vibration induction effect of the edge tone (causes 1) and 4)) and the cavity tone (cause (3)) was found large. However vibration due to the causes 1) and 3) can be reduced by changing the shape to suppress the jet flow collision.

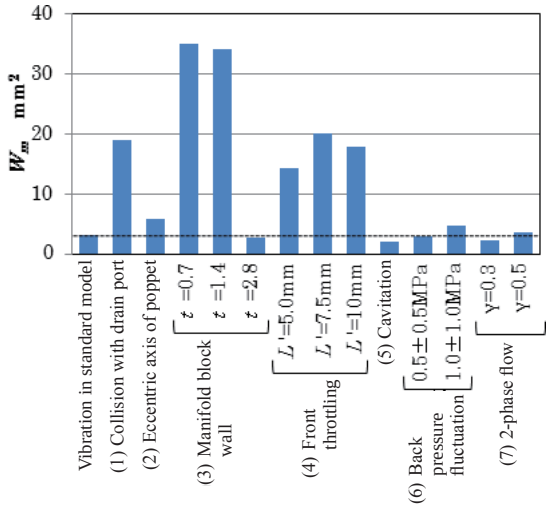



**Fig. 17** Energy comparison of vibration generated by estimated causes

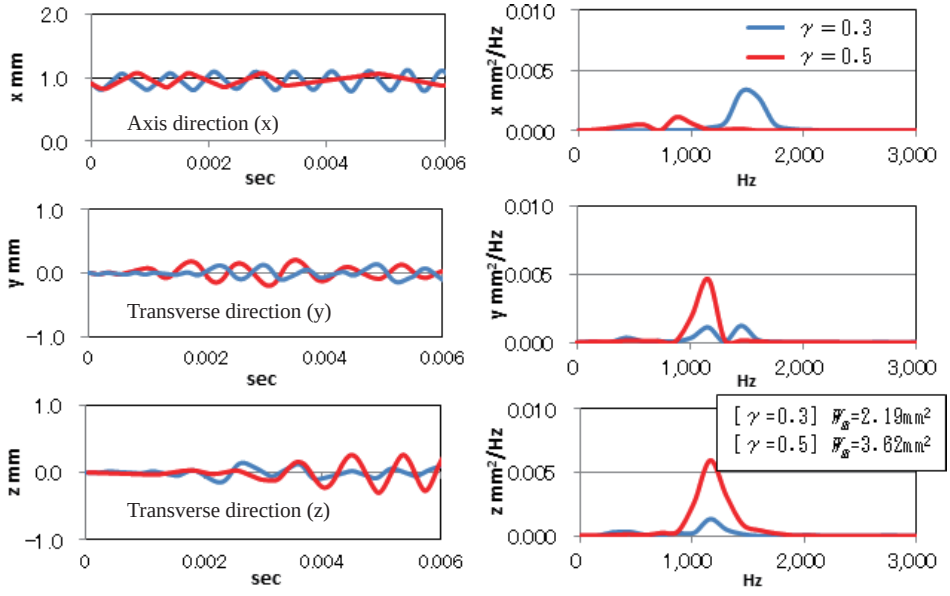



**Fig. 16** Cause (7) Analysis results of poppet displacement

## 7 Conclusions

A coupled model consisting of a poppet valve and non-stationary turbulent flow for three-dimensional vibration analysis with degrees of freedom in the axis and normal-to-axis directions was created and used to identify the causes for vibration, including external disturbance such as back pressure or air mixing. As a result, it was found that the cause (1), cause (4) (edge tone mechanism), and cause (3) (cavity tone mechanism) could generate 4.5-11 times larger vibration energy than the standard model without those causes. As a countermeasure against the vibration, a jet flow collision suppression shape was found. Also, since the overset mesh was found effective on the analysis of three-dimensional vibration, it will be applied to hydraulic machines which require similar analyses.

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Product Introduction

# Development of Light-Weight Electronically Controlled Mixer Truck "MR5040EL"

OKANO Tetsuya

## 1 Introduction

Plans for the Tokyo Olympics and redevelopment of Central Tokyo in recent years have increased the needs for products with better transportation efficiency.

"Light-weight mixer truck (Photo 1)" refers to trucks, in which the weight of the mounted mixer feature has been reduced in response to the low-floor-type chassis Note 1) (hereinafter referred to as "low-floor truck"). They can transport more ready-mixed concrete at a time due to the increased load of wet concrete.

Light-Weight Electronically Controlled Mixer Truck "MR5040EL" (hereinafter referred to as "MR5040EL"), which is introduced in this review, is made even more lightweight than the Low-floor Light-weight Mixer Truck "MR5020L" that has been in mass production since 2009. In addition, MR5040EL employs the urban-type computerized control "eMixer-II" Note 2)", which is quiet and was not installed in the conventional light-weight mixer trucks.

Note 1) The back tires are small in diameter, resulting in lower height than common large trucks. In addition, due to its medium truck-class engine, the chassis weight is lighter by approximately 1,500kg.

Note 2) Computerized hydraulic drive control for concrete mixer trucks (Refer to KYB TECHNICAL REVIEW No. 44 Model Change of the Electronic Control Concrete Mixer Truck "eMIXER")


**Photo 1** Light-weight mixer truck

## 2 Development Background

### 2.1 Issue in achieving the load

The total weight of a light-weight mixer truck is 20 tons, and it had achieved the load of 11,500 kg, which was the standard specification as per the original requirement. However, the purification unit, which was installed as a result of increased exhaust gas regulations, increased the chassis weight, thus reducing the load to approximately 11,450 kg. In addition, special features to satisfy customer requests increase the weight, which further reduces the load.

In this development, we aimed to reduce the weight of the mounted mixer feature by more than 150 kg with the aim of achieving the load of 11,600 kg in the standard specifications for low-floor trucks.

### 2.2 Issue in reducing the assembly man-hours

As previously mentioned, demands are expected for light-weight mixer trucks. However, light-weight mixer trucks require more assembly man-hours in KYB production lines than large mixer trucks, which have more orders, preventing us from increasing the production. Light-weight mixer trucks take approximately 1.3 times more assembly man-hours compared to large mixer trucks. Therefore, our aim was to reduce the assembly man-hours of light-weight mixer trucks to the same level as large mixer trucks in order to increase the production. In addition, the assembly line requires welding when mounting the feature. However, spattering may damage the vehicle, and deteriorated atmosphere due to welding may also lead to contamination, etc. Our aim was to simultaneously improve the quality by discontinuing the welding process in the assembly line as well as reduce the assembly man-hours by changing the structure.

## 3 Overview of Weight Reduction

### 3.1 Newly developed special frame

As previously mentioned, low-floor trucks are designed so that the height is lower than large trucks. Therefore, when the mounted feature for large trucks is installed on a low-floor truck as is, it lowers the hopper (Photo 2), from which wet concrete is injected, resulting in a gap in height

with wet concrete manufacturing plants. In addition, it also lowers the chute (Photo 2), which releases wet concrete, compared to large trucks, meaning that user-friendliness is compromised for customers in terms of use with concrete pumping trucks [Note 3]. Furthermore, since low-floor trucks are medium class trucks, their chassis frame strength is weak and cannot withstand the weight of the mounted feature, which is intended to be installed on large trucks.

In order to respond to such issues, conventional light-weight mixer trucks have one "sub-frame" from the front to the back of the mounted feature under the front frame/rear frame on each side. Sub-frames enabled these trucks to have the same height as large trucks, increased the strength on the mounted feature side, and compensated for the frame strength on the chassis side, thus enabling the mounted feature to be installed on low-floor trucks (Fig. 1).

The weight of MR5040EL, which is introduced in this review, has been made light by removing these sub-frames. First, we changed the design so that the height from the ground is made the same as the conventional light-weight mixer trucks by increasing the height of the front/rear frames to address the height issue. Next, we installed a middle frame between the front frame and rear frame by using a square pipe to address the strength issue. By securing these components with bolts, we integrated them into one frame structure, increasing the strength along with the frame on the chassis side (Fig. 2). To determine the form, we used the Finite Element Method to analyze the structure in order to satisfy the strength and optimize the structure by limiting weight increase (Fig. 3). With these changes, we were able to reduce the weight by approximately 100kg without changing the user-friendliness for customers.

Note 3) Vehicle used to pressure-feed wet concrete to a far location or high location via a boom.

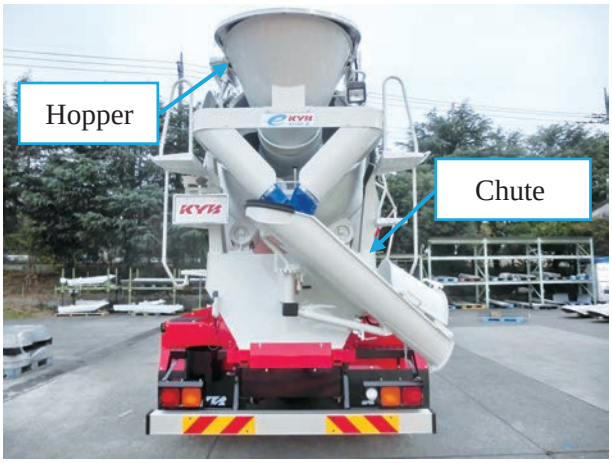



**Photo 2** Hopper and chute

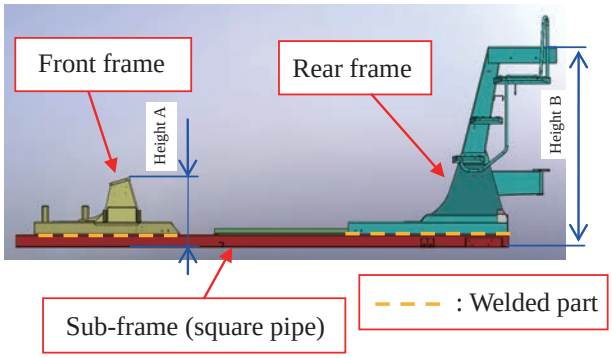



**Fig. 1** Conventional mixer frame

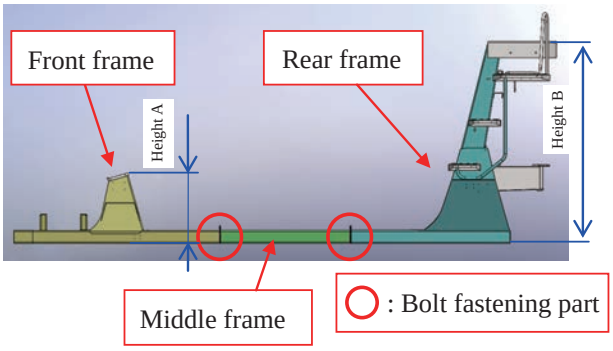



**Fig. 2** Newly developed special mixer frame

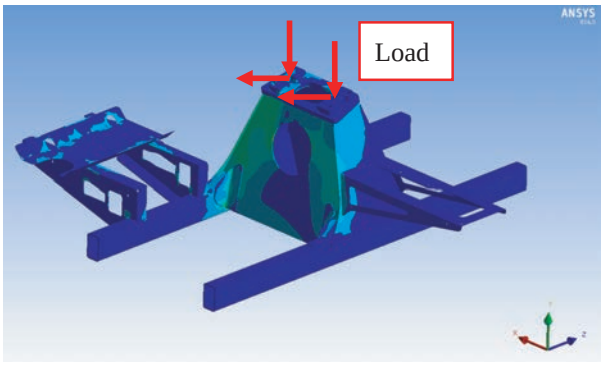



**Fig. 3** Mixer frame FEM analysis

### 3.2 Reducing the thickness of the roller ring

Roller ring touches the drum roller, which rolls the drum (Fig. 3), and it integrates with the drum along the rolling plane. The drum touches the roller ring in 2 places in the back, so the roller uses a reinforced material due to the fact that it bears the load when wet concrete is loaded.

Strength, conductivity, and durability are aspects to consider when reducing the thickness. Therefore, we performed analyses and experiments for each consideration step and aimed to achieve the limit design. Due to this, we were successfully able to reduce the weight by approximately 20 kg.

### 3.3 Using the oil cooler

KYB's mixer trucks use hydraulic pump/hydraulic motor. Hydraulic drive rolls the drum, but an oil tank is originally installed to maintain the heat balance.

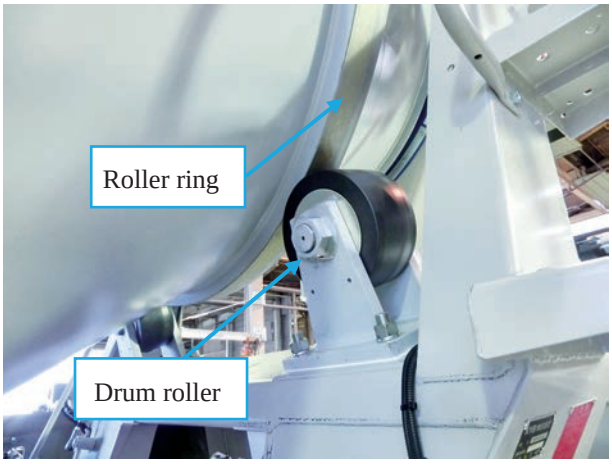



**Photo 3** Drum roller and roller ring

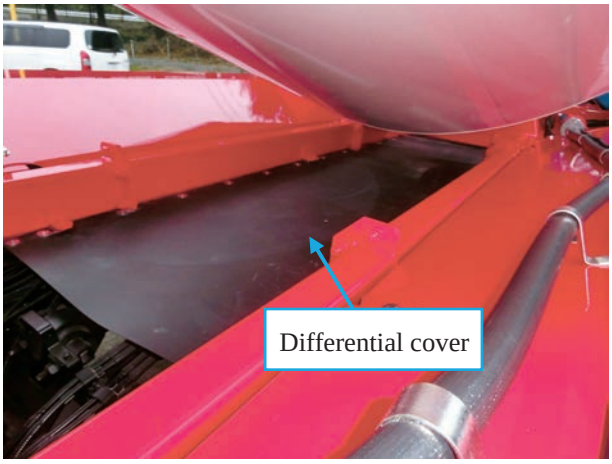



**Photo 5** Resin material differential cover

We used an oil cooler, with which the oil tank is integrated, for MR5040EL. This is the first time for this oil cooler to be used for domestically manufactured mixer trucks. The oil cooler (Photo 4) has a fan for forced cooling, which can efficiently cool down with a small amount of hydraulic oil. In addition, reducing the used hydraulic oil amount also leads to weight reduction.

Due to this, we reduced the used hydraulic oil amount by 80% without reducing the cooling efficiency and successfully reduced the weight by approximately 30kg.


**Photo 4** Oil cooler

### 3.4 Using resin for the differential cover

The differential cover is used to prevent the grease, which sprays from the differential gear on the chassis side, from spattering on the drum.

The differential cover used in KYB's mixer trucks, which are manufactured in Japan, is made with iron. We aimed to reduce the weight of MR5040EL by changing the material for the differential cover to resin (Photo 5). This is used for KYB's overseas mixer trucks, and it performs sufficient functions as a cover. Due to this, we were successfully able to reduce the weight by approximately 10kg.

### 3.5 Using aluminum material

We used aluminum exterior parts, which are also used as standard parts for the conventional light-weight mixer trucks, on MR5040EL as standard parts in order to also reduce the weight. Some of the exterior parts using the aluminum material are side guard to prevent people from getting caught, fender/splash board to prevent spattering of mud during traveling, and rear cover to prevent wet concrete from spattering over the rear part of the vehicle (Photo 6).

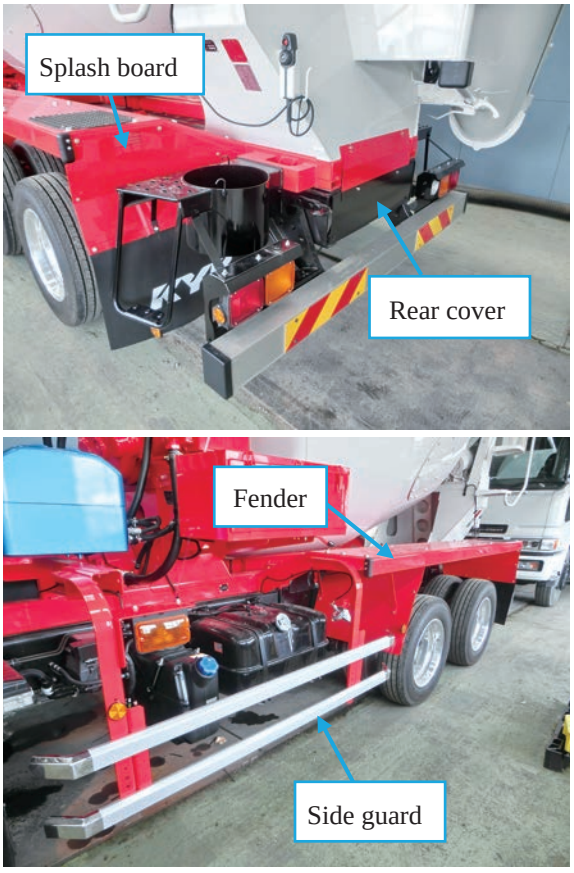


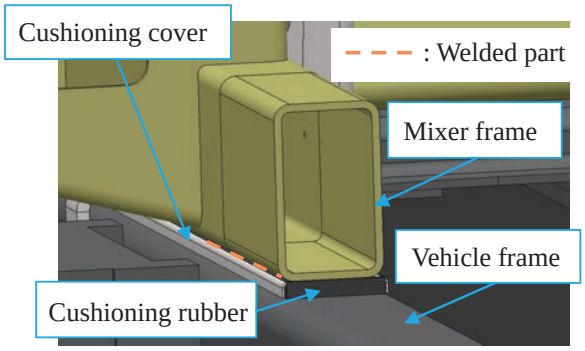

**Photo 6** Aluminum exterior parts

## 4 Simplifying Assembly

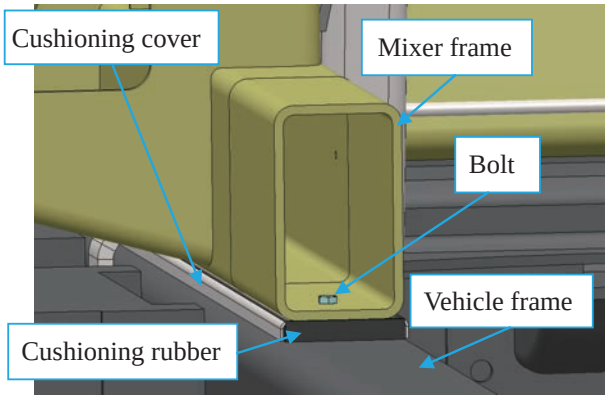
In this development, we considered the design so that we could discontinue the welding process in the assembly line and reduce the assembly man-hours on the mounted feature side.

### 4.1 Reducing assembly man-hours with the newly developed special frame

As previously mentioned, sub-frames were installed on the conventional light-weight mixer trucks. With MR5040EL, we discontinued the sub-frames and secured middle frames with bolts, thus successfully discontinuing the welding process in the line and drastically reducing the assembly man-hours.




(a) Conventional mixer




(b) MR5040EL

**Fig. 4** Cushioning cover bolt fastening

### 4.2 Discontinuing the welding process to prevent the mounted feature and the cushioning material for vehicle from falling out of place

Rivets are installed on top of the vehicle frame. If the mounted feature is installed directly on the vehicle, it would sit on the rivets. Therefore, we install cushioning rubber in between as a cushioning material. Furthermore, we install a cover on the cushioning rubber so that it would not fall out of place while traveling. The cushioning cover is welded onto the mixer frame in the assembly line (Fig. 4-a). However, with MR5040EL, we tapped the mixer frame and secured the cushioning cover and the cushioning rubber with bolts with the aim of preventing them from falling out of place and discontinuing the welding process (Fig. 4-b).

## 5 Conclusion

We have reduced the weight of the mounted mixer feature by more than 150 kg in this development and succeeded in achieving the load of over 11,600kg in the standard specifications.

The assembly man-hours have drastically reduced and have become the same number of man-hours as large trucks, which has enabled us to increase production. Furthermore, we have also been able to discontinue the welding process within production lines.

## 6 In Closing

This was exhibited in the Tokyo Motor Show, which was held in October of 2015, as part of our development activities. It was well-received by many visitors.

Our plan for the future is to have customers perform monitor assessment and develop this into a mixer truck, which is even more user-friendly.

Finally, I would like to express my deepest gratitude for everyone involved in this development who has provided great support, within and outside of the company.

## Author

**OKANO Tetsuya**

Joined the company in 2013.
Engineering Dept., Kumagaya Plant,Special Purpose Vehicles Div.
Engaged in designing mounted mixer features and development design.

Product Introduction

# Flow Control Valve-Less Vane Pump for CVT

SHIMONO Hiromi

## 1 Introduction

In recent years, the requirements for better fuel efficiency, lower carbon emissions and exhaust emission levels, are becoming more demanding in automotive industry. In response to meet such market needs, more and more models of car are equipped with an automatic transmission, continuously variable transmission (hereinafter referred to CVT) that provides the highly-efficient transmission ratios Variable Transmission This newly developed vane pump (Photo 1) is installed onto the Jatco's new model CVTunit for compact car and its production in KIMZ (KYB Industrial Machinery (Zhenjiang))has been started since July 2015.

## 2 New CVT

Photo 2 shows the appearance of CVT newly developed by Jatco. This new model CVT has the following features:

(1) Improved drivability
(2) World's best ratio coverage of 8.7 for CVT
(3) Improved fuel efficiency

Our vane pump functions as the hydraulic source for the new CVT and contributes to better fuel efficiency.

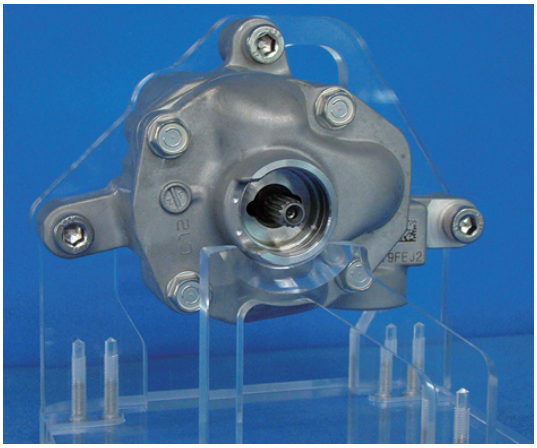


**Photo 1** Appearance of Vane Pump for New CVT

## 3 Description

### 3.1 Structure and Main Specifications

The main specifications of advanced vane pump are shown in Table 1, and the structures of both existing and advanced pumps are shown in Fig. 1. The flow control valve is eliminated for the advanced pump unlikely as compared to the existing model. The flow control valve, which suppresses cavitation, is an important structural element in CVT for dealing with highly aerated hydraulic fluid. For advanced vane pump, even the torque rotation

**Table 1** Main Specifications for Vane Pump

| | |
|---|---|
| Basic Discharge Rate | 10.5cm$^3$/rev |
| Cavitation Speed | 7000rpm |
| Discharge Pressure | ～6MPa |
| Oil Temperature | -40～140°C |
| Hydraulic Fluid Type | Nissan NS-3 |
| Wight | 1000g |

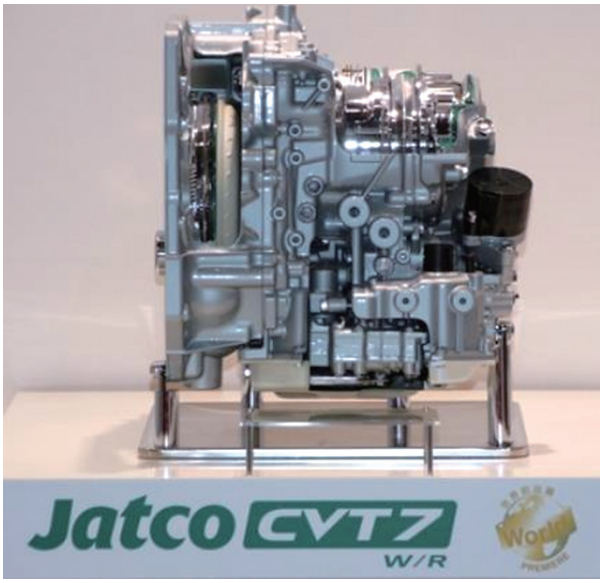



**Photo 2** Appearance of New CVT

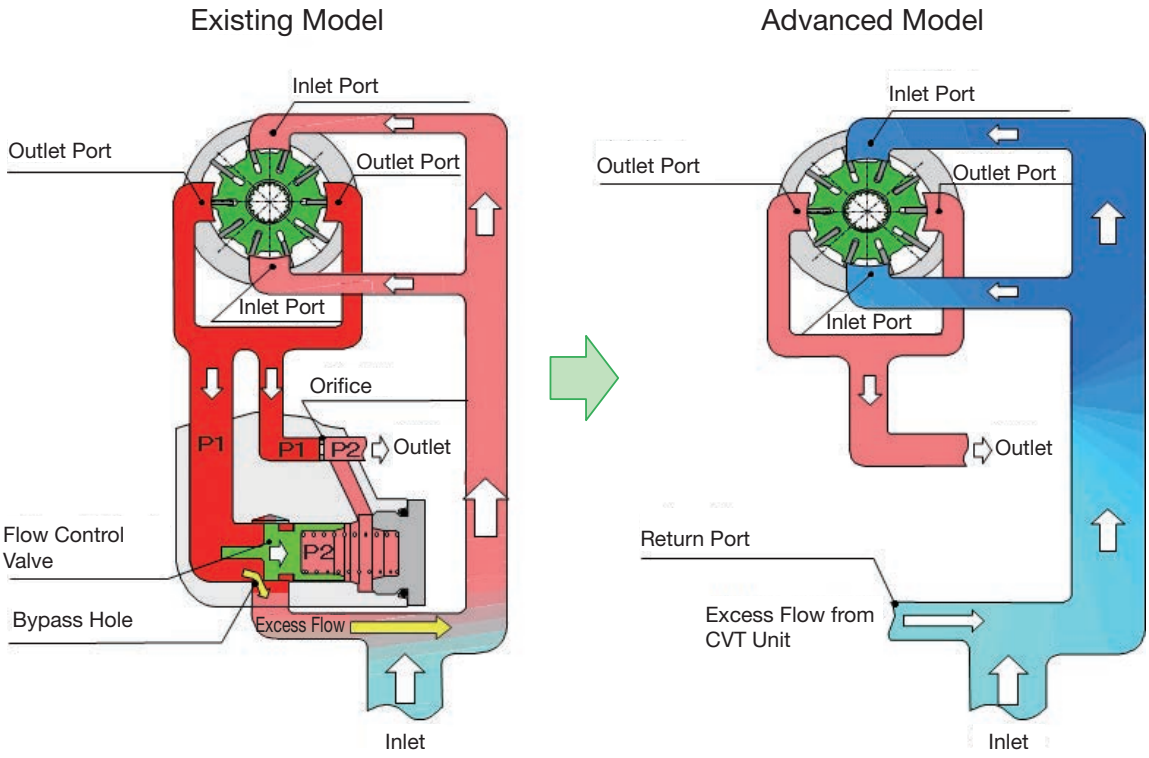



**Fig. 1** Comparison of Existing and Advanced Models

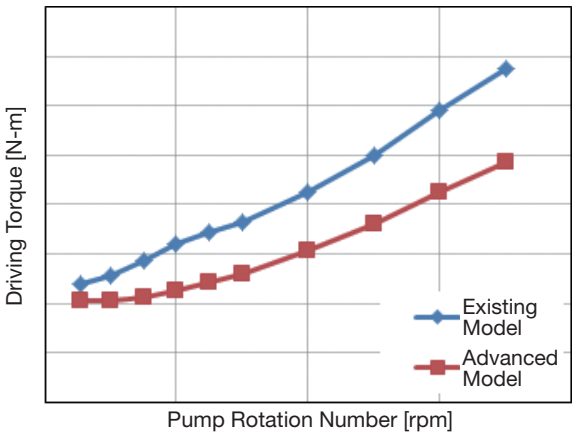



**Fig. 2** Driving Torque of Existing and Advanced Models

caused by hydraulic fluid's pressure was reduced in order to achieve a reduction of rotational torque, which resulted in the contribution to better fuel efficiency.

### 3.2 Reduction of Driving Torque

The driving torques for both existing and advanced models is indicated in Fig. 2. The advanced model successfully prevents the differential pressure and reduces the pressure applied to the pump by eliminating the flow control valve. Furthermore, the absence of flow control valve resulted in eliminating fluid leakage from the flow control valve and could achieved reductions both in the basic discharge rate and torque rotation while the previous model utilizes the differential pressure given by an orifice to drive the flow control valve.

### 3.3 Cavitation Prevention

Flow control valve offers the function to prevent cavitation by circulating of the excessive flows at high pressure during the highly aerated hydraulic fluid condition. An alternative measure for cavitation prevention was required for the newly advanced model since it is not equipped with flow control valve. As the prevention measures, both the oil inlet channel and the pressure rise of vane chamber were optimized.

#### 3.3.1 Adjustment of Oil Inlet Channel

The result of the negative inlet pressure analysis is shown in Fig. 3. The cavitation was successfully prevented with a larger size of oil channel and additional cutting port on cam-ring (Fig. 4) which reduced a negative pressure generated in oil suction. The optimum shape that prevents

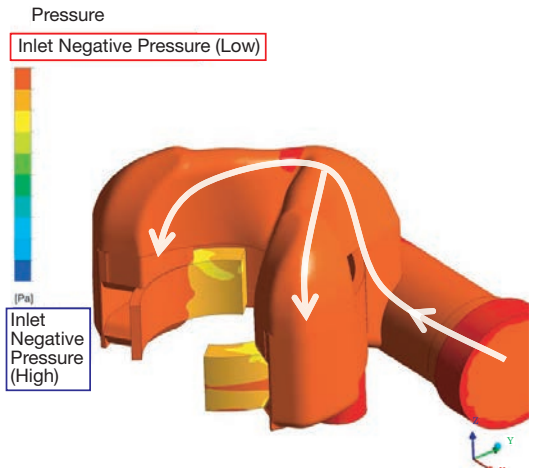



**Fig. 3** Result of Negative Inlet Pressure Analysis

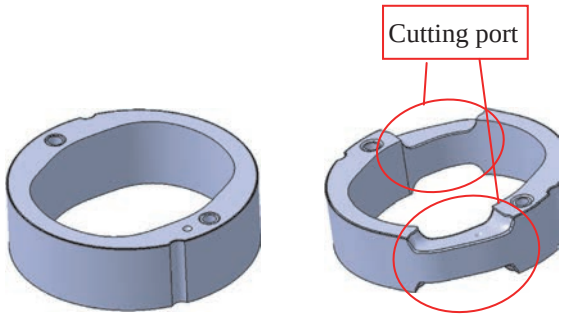



**Fig. 4** Shape of cam-ring

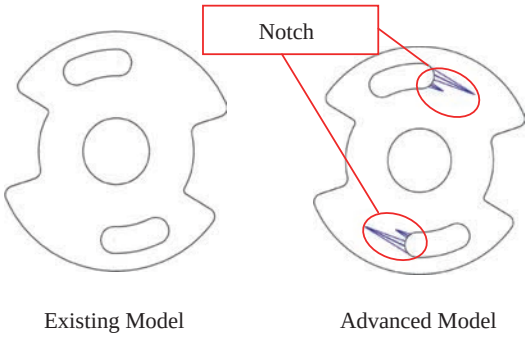



**Fig. 6** Shape of side plate

the pressure loss was determined through a flow analysis.

### 3.3.2 Adjustment of Pressure Rise in Vane Chamber

The adjustment of oil inlet channel has reduced the negative inlet pressure potential due to elimination of flow control valve. However, the inlet pressure is still negative. The existing model can maintain a positive pressure by circulating of the excessive flows at high pressure. On the other hand, a delay in the pressure rise is experienced in the vane chamber of the advanced model due to its negative inlet pressure. The pressure fluctuation and the cavitation erosion caused by this delay may result in the noise and the damages to the pump. The measurements of vane chamber pressure are shown in Fig. 5. The supply of high-pressure oil was increased and the delay in the pressure rise during the highly aerated hydraulic fluid condition was reduced to almost same level with the flow control valve equipped model by additionally created notches (Fig. 6).

Quick voltage boosting indicates an improvement in performance. A faster voltage boosting ensures the performance that is equal to that of the current model.

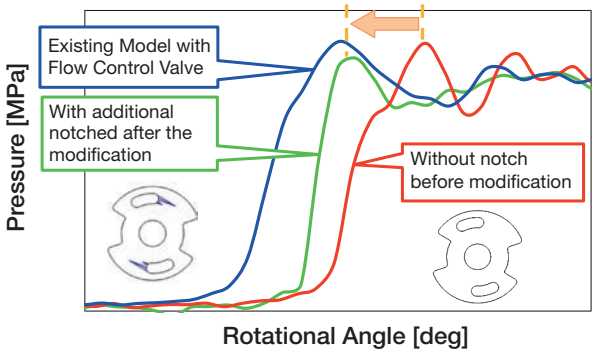



**Fig. 5** Measurements of Vane Chamber Pressure

### 3.4 Localization

Since the newly developed flow control valveless pump would be produced locally in China, the materials available locally were preferably used, achieving local procurement rates of over 85 %. Improved localization of existing model allowed successful localization at production start-up.

### 3.5 Cost Saving and Weight Reduction

The structures of both existing and advanced models are shown in Fig. 7. Elimination of flow control valve enables up to a 27 % reduction in number of components comparing to the existing model, reducing processing positions to facilitate process, and body weight as well as a reduction in torque. Actively use parts common with existing model. The cost saving and weight reduction (9 % down) could be achieved through above mentioned practices.

## 4 In Closing

Newly developed flow control valveless pump has achieved the reduction in the torque rotation, weight, and cost, and its local production is established in KIMZ. With considerable cooperation and prompt actions given by everyone, including the project members of Jatco and relevant personnel within company involved in this product, the development of mass production in KIMZ has come to successful completion. I would like to take this opportunity to express my sincere gratitude to the relevant parties for their cooperation for this development.

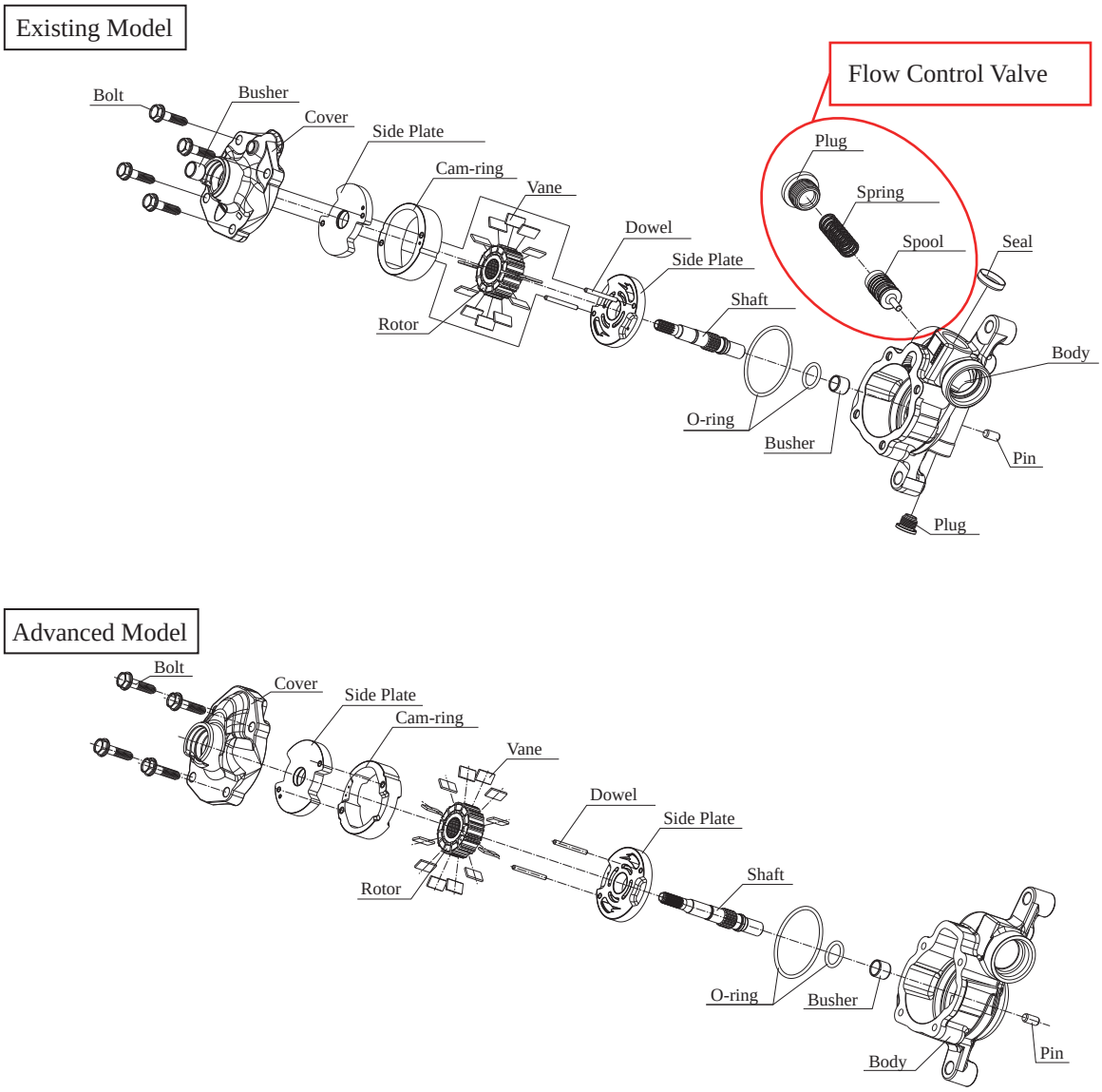



**Fig. 7** Structures of Existing and Developed models

## Author

**SHIMONO Hiromi**

Joined the company in 2006.
Pump Engineering Dept.,
Engineering Headquarters,
Automotive Components Operations.
Engaged in the work of vane pump design.

Product Introduction

# Passive Switching Type Oil Damper (Seismic Isolation Damper for Narrow Land in City)

NAKAHARA Manabu

## 1 Introduction

There are a number of measures taken to protect people and buildings from earthquake-related damage. "**Quake resistant** structure" reinforces "resilience and strength of buildings" to withstand the seismic force given to the buildings.

"**Vibration control** structure" weakens the seismic force given to the building with vibration suppression devices. We can say that they are both technologies used to respond to seismic force given to the building as much as possible.

On the other hand, "**seismic isolation** structure" refers to "evading (isolating itself from) the force itself that is given to the building" and drastically reduces building vibrations. Seismic isolation structures change strong and severe vibrations caused by earthquakes into big and slow vibrations. It not only prevents the building itself from being damaged but also prevents furniture and facilities/equipment within the building from moving/falling over. Seismic isolation has also been confirmed to be effective in actual earthquakes.

**Quake resistance/vibration control/seismic isolation** (Refer to Glossary "Quake Resistance, Vibration Control, Seismic Isolation" on P44)

The device called "isolator" is used to insulate the building from the ground. Isolator is made of seismic isolation rubber, slide bearing, and rolling bearing. By constructing a building on top of these isolators, they prevent the vibrations of the ground from directly affecting the building. However, it is not that they can completely float the building in the air like a magic carpet, so slow vibrations still affect the building, even if the seismic isolation structure drastically reduces the strong and severe vibrations of earthquakes. Isolators cannot stop the vibrations even after the earthquake stops.

KAYABA SYSTEM MACHINERY Co.,Ltd. manufactures dampers to quickly stop such vibrations in case of major earthquakes (Photo 1).

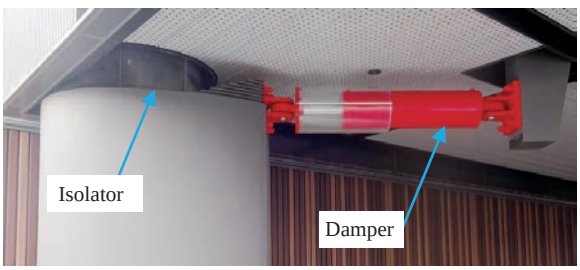



**Photo 1** Example of a seismic isolation structure (KYB's plant)

## 2 Issues in Applying the Structures to Narrow Land

In order for buildings to evade earthquakes, seismic isolation structures help buildings to freely move in isolation from the ground; however, but this means that the buildings would move from the ground. The conventional seismic isolation structures require at least 60 cm margin around the building (movement limit for the current isolator - especially seismic isolation rubber for buildings - is 60cm). However, it is difficult to secure the margin that is required by seismic isolation structures in urban areas, due to the fact that high-rise buildings are built closely together.

In general, a building's movement can be reduced by increasing the number of dampers and increasing the stopping force (damping force), but the building movement and acceleration have an antinomic relationship (quickly stopping the movement within a small distance creates larger reaction). If you increase the number of dampers to reduce the margin around the building, it doesn't achieve the effect of not transmitting the vibration of small to medium earthquakes, which are relatively frequent, which is the purpose of seismic isolation.

## 3 Objectives of the Product

"Passive Switching Type Oil Damper (Seismic Isolation Damper for Narrow Land)", which is introduced in this review, was jointly developed with Taisei Corporation. With the aim of resolving the aforementioned antinomic relationship, we aimed to improve the seismic isolation structure with the following objectives.

### 3.1 Objectives of seismic isolation structure for narrow land

1. Provide buildings with the optimal seismic isolation structure with the margin of 30cm or less. (Half of what is conventionally required as margin)
2. Sufficiently exert the functions of seismic isolation, which prevents vibrations from earthquakes from being transmitted to the building, up to intensity 5.

3. In major earthquakes, it bring out great damping force to control the vibrations before the building hits the walls of a narrow isolation layer.

Fig. 1 shows the comparison of earthquake scale and effect between the conventional seismic isolation structure and seismic isolation structure for narrow land.

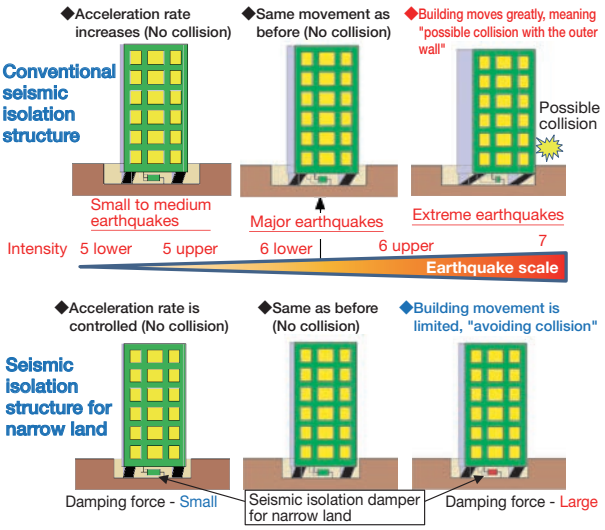



**Fig. 1** Comparison of earthquake scale and effect between regular seismic isolation structure and seismic isolation structure for narrow land

### 3.2 Requirements for seismic isolation damper for narrow land

1. One damper must possess the 2 properties of high damping force, which is brought out to prevent buildings from collision during major earthquakes, and low damping force, which is effective in small to medium earthquakes.
2. Switching of the above high damping force and low damping force must be mechanically done in the given displacement (damper stroke) without using electric signals.

By using this damper, the maximum seismic isolation effect can be achieved in small to medium earthquakes, which are frequent. It can also prevent damage from building collision in areas with less margin around the building in case of major earthquakes, which are rare.

## 4 Structure of the Developed Damper

Fig. 2 shows the basic hydraulic circuit diagram for this developed damper. You can switch between 2 types of damper force. (Although this circuit diagram has been simplified for this review, this has already been released as Japanese Unexamined Patent Application Publication No. 2014-159850)

The area in the two-dot chain line indicated in (1) uses the same damper as KYB's standard seismic isolation damper BDS-type oil damper (Building Damper hi-Speed type). We call the state, in which the damping force is brought out solely by this section, “high damping mode”.

The area in the two-dot chain line indicated in (2) is the valve block that is specially installed on this damper. This

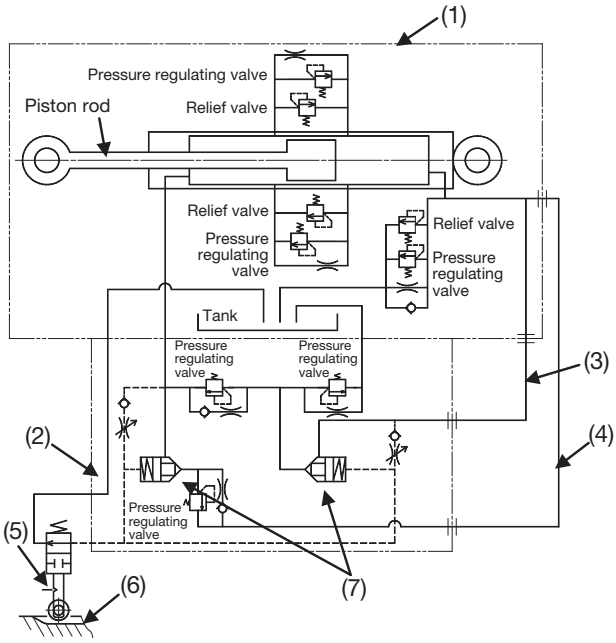



**Fig. 2** Hydraulic circuit diagram

valve block is connected to (1) damper via the (3) and (4) pipes.

When oil runs through the (2) valve block, the amount of oil that runs through the valve for damping force installed on the (1) damper is reduced, resulting in smaller damping force even if the damper functions in the same speed. We call this state the “low damping mode”.

The valve that switches between the “high damping mode” and the “low damping mode” is the (5) shut-off valve (mechanical). This switches the oil flow by pressing the plunger sticking out of the valve chassis.

In this damper, this is normally open to let oil flow. However, it is set so that oil flow is shut off when the plunger is pressed. (6) Detection rod is installed to pair with this (5) shut-off valve.

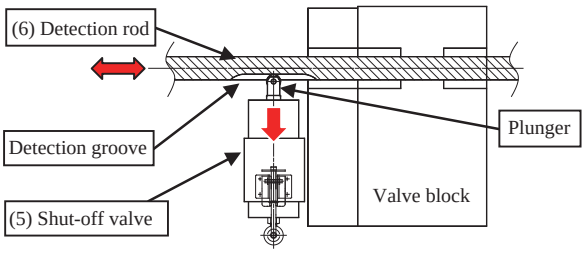



**Fig. 3** (5) Shut-off valve and vi. detection rod

Fig. 3 shows how the (5) shut-off valve and (6) detection rod are installed. The detection rod comes with a groove (detection groove) in the middle. The tip of the plunger rests within this detection groove in a normal state, and the plunger is not pressed. So this is in the “low damping mode”. The (6) detection rod is installed on the damper's piston rod and moves in the same movement as the piston rod. When the piston rod moves more than the length of the detection groove (in major earthquakes), the part of the (6) detection rod without the groove moves to where the

plunger is. When this happens, the plunger is pressed by the outer surface of the (6) detection rod, switching the (5) shut-off valve and shutting off the oil flow.

The (5) shut-off valve comes with the detent mechanism and maintains the switched state.

(5) Shut-off valve only shuts off the flow channel in the back of the (7) logic valve. This flow channel leads to the tank room, and oil normally flows without resistance. In this state, the (7) logic valve moves freely and guides the oil, which comes from the (3) and (4) pipes, to the valve within the (2) valve block.

Since (5) shut-off valve shuts off the oil channel in the back of the (7) logic valve, (7) logic valve can no longer move. It stops the oil, which comes from the (3) and (4) pipes, and stops the oil flow to the valve within the (2) valve block.

As a result, force is only created with the (1) internal valve, switching from the “low damping mode” to the “high damping mode”.

Below is the summary:

1. Damper's piston rod in the low damping mode moves more than the length specified for the detection groove due to a big earthquake.
2. The detection rod, which is attached to the piston rod, presses the plunger for the shut-off valve.
3. The shut-off valve switches and stops the logic valve's movement by shutting off the oil flow.
4. Due to the fact that the logic valve cannot move, the flow of the oil, which was flowing in the low damping mode, to the valve within the valve block stops.
5. Since oil does not flow to the valve within the valve block, the valve within the damper alone processes the oil flow, bringing out damping force.

Photo 2 shows the appearance of the damper. You can see the valve block, pipe, and the detection rod on the outside of the damper.

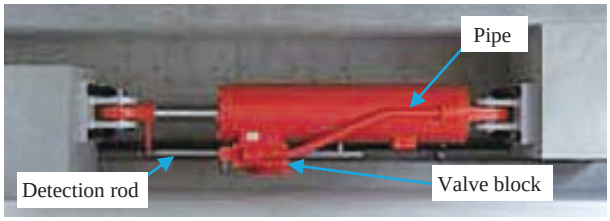



**Photo 2** Appearance of a seismic isolation damper for narrow land

## 5 Comparison of Damping Capabilities

I would like to compare the difference in the effect between this developed damper, which possesses the function to switch the damping force, and KYB's standard damper.

Fig. 4 shows how a standard damper works. This diagram shows a graph, which is part of the analysis drawing. It indicates the movement (displacement/damper stroke) gradually being increased. When the displacement increases, the speed also increases, resulting in greater damping force; therefore, the analysis result looks like a swirl.

Fig. 5 shows a graph comparing the developed damper and standard damper.

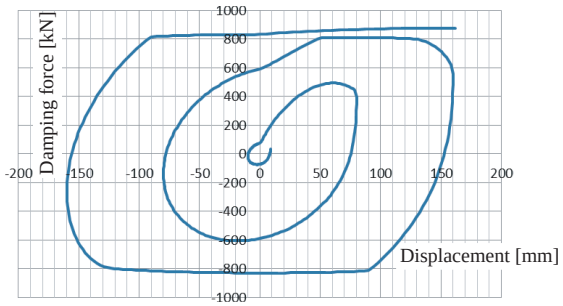



**Fig. 4** Diagrammatic drawing for displacement - damping force of a standard damper

The graph was drawn under the same condition as Fig. 4. However, unlike Fig. 4, this shows a section immediately after the vibration start in which the damping force was low. This is the “low damping mode” segment. In this graph, the switching point to the “high damping mode” is 50mm, so you can see that the damping force suddenly increases where it is indicated with a red circle.

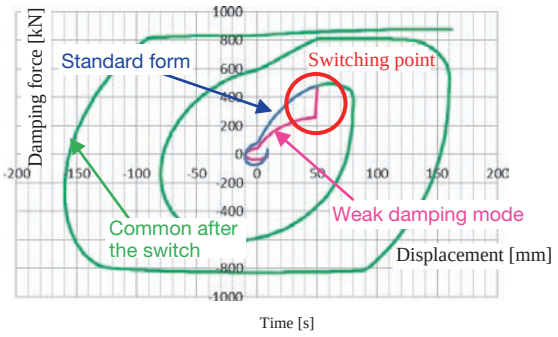



**Fig. 5** Diagrammatic drawing for displacement - damping force to compare seismic isolation damper for narrow land and standard damper (overwritten)

Fig. 6 indicates the horizontal axis in the result of Fig. 5 shown in terms of time. The graph shows the displacement and damping force. You can see that the damping force greatly increases halfway, while the displacement change is constant (in other words, the speed is consistent).

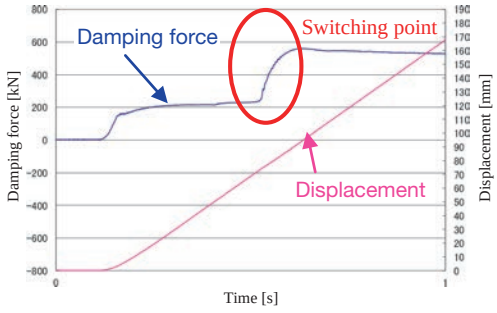



**Fig. 6** Diagrammatic drawing for damping force and displacement

## 6 Installed Buildings

There are several buildings in which this developed damper was used. I'd like to introduce some examples.

### 6.1 ZEB for the Taisei Technology Center of Taisei Corporation (Photo 3)

This building is the evaluation/experimentation facility “Zero Energy Building”(ZEB) of Taisei Corporation, which is a joint developer, and Taisei Corporation received

**Photo 3** Appearance of ZEB for the Taisei Technology Center of Taisei Corporation

the 16th Japan Society of Seismic Isolation Prize with this building.

### 6.2 Hulic Shinjuku Building (Photo 4)

This "urban seismic isolation" utilizes a seismic isolation structure that enables them to effectively use the valuable land in Central Tokyo.

It is the building at the center of the picture, but you can see that the surrounding buildings are close.

This building uses a natural ventilation system as a means to care for the environment and uses only natural ventilation between seasons. It also takes in sunlight via the ceiling of the rooms at all times regardless of the changing seasons/time (position/height of the sun) by using the natural lighting system (specially-designed fixed louver) without using power.

This building received "5 stars" from the Development Bank of Japan Inc., which is the highest ranking of the "DBJ Green Building Certification".


**Photo 4** Hulic Shinjuku Building appearance

## 7 In Closing

I would like to express my deepest gratitude for everyone who has provided support for this development, including departments of KYB, relevant affiliates, and the Engineering Research Institute of Taisei Corporation.

The developed damper was approved by the Ministry of Land, Infrastructure, Transport and Tourism as a seismic isolation component at the end of last year (certificate number: MVBR-0498). If you are considering buildings with seismic isolation structures in areas with closely built buildings, please don't hesitate to contact KYB.

Finally, I would like to express my appreciation for those who kindly gave me the permission to use these pictures.

## Author

**NAKAHARA Manabu**

Joined the company in 1991.
Joined Engineering Dept. in KAYABA SYSTEM MACHINERY Co.,Ltd.
Engaged in oil damper development work.

Glossary

# "Quake Resistance, Vibration Control, Seismic Isolation"

Printed on page 40 "Passive Switching Type Oil Damper (Seismic Isolation Damper for Narrow Land in City)"

KYB TECHNICAL REVIEW editor ITO Yoshifumi

The following structures are considered for recent building structures in order to protect the building itself, household goods, and residents in earthquakes.

## 1 Quake resistance

Quake resistance (structure) refers to the conventional structure to withstand quake energy by reinforcing the strength of pillars and joists, etc. for building structures.

Fig. 1 shows the image diagram of the quake resistance structure.

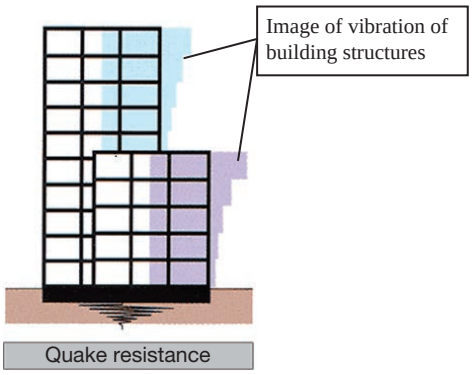



**Fig. 1** Quake resistance structure image diagram

## 2 Vibration control

Vibration control (structure) refers to the structure, in which dampers are installed on pillars and joints, etc. of building structures to absorb/disperse quake energy to reduce deformation.

Fig. 2 shows the image diagram of the vibration control structure.

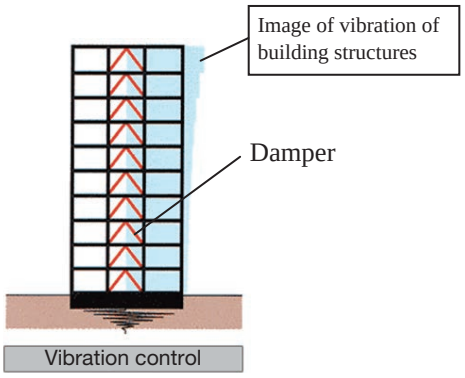



**Fig. 2** Vibration control structure image diagram

## 3 Seismic isolation

Seismic isolation (structure) refers to the structure, which reduces vibrations of the building structure by installing the device called isolator (seismic isolation rubber, slide bearing, rolling bearing, etc.) between the building structure and the ground.

Isolators cannot stop the vibration that have been transmitted to the building structure, so dampers are also installed to stop the vibration.

Fig. 3 shows the image diagram of the seismic isolation structure.

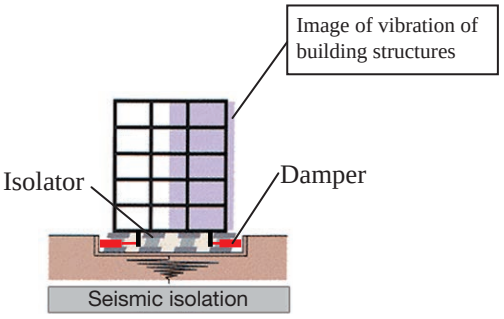



**Fig. 3** Seismic isolation structure image diagram

Product Introduction

# Introduction of Development of KYB K'lassic (SD-2)

SAWANISHI Toshiyuki, HOSHINO Yuta, YAMAOKA Koji, ISHIMARU Nozomi

## 1 Introduction

Aftermarket shock absorbers (hereinafter referred to as aftermarket SA) now produce a core profit of KYB.

In this article, outline of the development of KYB K'lassic*1), a new series of low-price range products which KYB has not manufactured before, is explained.

*1) Coinage of KYB+Classic

## 2 Background

### 2.1 Market of aftermarket SA and aim of new product

At KYB, the production volume of aftermarket SA is about one fourth of the total volume and most of the aftermarket SA products are shipped to foreign repair markets.

After market SA products can be classified by type of markets. Those for general-price product markets are called SD-1 and those for low-price range product markets are SD-2 (Fig. 1). The market size of SD-1 is 63,000 thousand pcs/year and that of SD-2 is 19,000 thousand pcs/year. KYB has a share of about 30% of the SD-1 market but has no share in the SD-2 market since KYB has not manufactured SD-2 products.

Demand for SD-1 arises in three years after a vehicle begins to be sold, reaches a peak in three years after the sales of the vehicle ends, and almost disappears in 15 years after the end of the vehicle sales (Fig. 2). Since the vehicle is still new during the period of 5 years after the end of the vehicle sales, general price products are demanded in many cases. This is the SD-1 market.

As the vehicle becomes old and the vehicle price decreases, customers tend to choose lower cost products. Also in case of low-price Korean and Chinese vehicles, low-price range products tend to be chosen even for new cars. This is the SD-2 market.

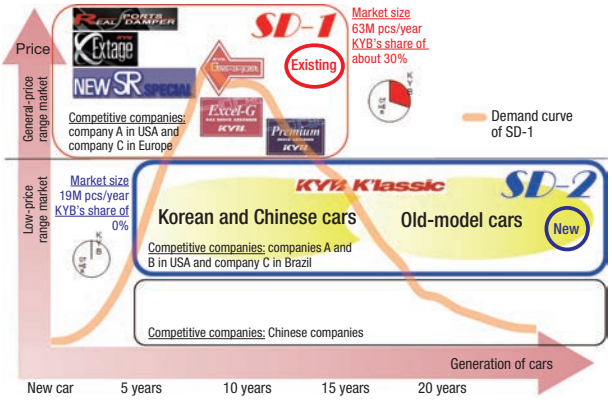



**Fig. 1** Aftermarket SA market

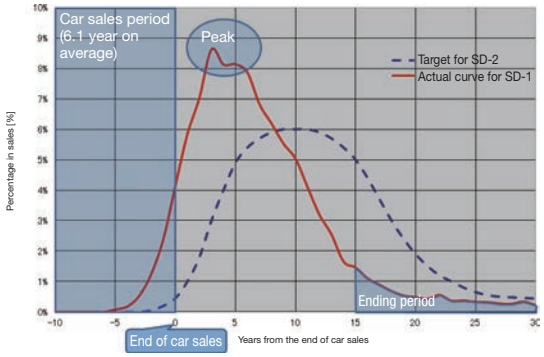



**Fig. 2** Demand curve

So far KYB had to make price adjustment to compete with low-price range products of other companies but has begun to develop SD-2 products to cover the low-price range market. The company began to develop products for the SD-2 market while ensuring the reliability and quality but reducing the cost, and aimed to achieve 1,800 thousand pcs/year and share of about 10% by 2020.

### 2.2 Cost reduction of aftermarket SA

To follow the market price, KYB continues the cost reduction activity every day, which is the basis for the SD-2 development. Part of the activity is explained below.

#### 2.2.1 Improvement activity for low profit models

"Improvement activity for low profit products" is the cost reduction activity with focus on the profitability of a product. Based on the sales record of the previous year, about 10 models having low profitability are selected and cost reduction is aimed at for each of the models. Drawings, unit prices of parts, and production processes are reviewed to solve problems in the production and

replace high-price parts with lower-price ones. By doing this, items having a large cost reduction effect per product are identified. Also, price adjustment for individual models is made by taking account of the market prices.

### 2.2.2 Cost reduction activity for SD-1

Cost reduction activity for SD-1 is the activity for whole aftermarket SA products conducted with an aim at a wide effect of cost reduction by, for example, changing damping force valve or standard parts. To accelerate the effect, items with higher feasibility are prioritized.

## 3 SD-2 product development

### 3.1 Requirements for SD-2 products

There are three requirements for SD-2 products: 30% reduction of sales price, ensuring minimal functions, and differentiation from conventional products.

SD-1 products are manufactured to have the same quality as the one achieved by OEMs but such quality is not necessary for old vehicles in many cases. Therefore, the existing design specifications needed to be significantly revised for the development of SD-2 products.

For the 30% reduction of the sales price, the reduction target of the variable cost was set to 10% to secure the profit. Previous cost reduction activities focused only on the cost reduction while keeping the product functions. However since the previous cost reduction method shown in 2.2 is not suitable to reaching the cost reduction target of SD-2, it was necessary to decrease the variable cost by limiting the functions to necessary ones (like removing excess fat from body). Minimal but necessary functions for ride quality, controllability, strength, durability, and noise prevention were ensured.

It is also necessary to differentiate low-price range products from the previous ones. The differentiation is made by adjusting the damping force. Namely, the damping force is adjusted so that the new products can be clearly differentiated from the previous ones while the deterioration of ride quality is allowed.

### 3.2 Setting of target performance

A target for each required performance, designated to ensure minimal functions and differentiate the new products from the previous ones, is summarized in Table 3. The ride quality and controllability were allowed to decrease by 25% from those of the previous products. In particular, for the ride quality, clear difference from the previous products was demonstrated with appropriate setting of the damping force. The product strength was maintained in the same level as that of the previous products. The durability and noise prevention were set to an appropriate level as low-price range products.

As mentioned above, the previous cost reduction activities cannot reduce the cost to meet the target. Therefore, a study meeting for cost reduction items was held and the items were identified based on unconventional idea of design (Fig. 4). Next, for each of the items pointed out in the meeting, compatibility with the required performance is checked (Table 1) to establish

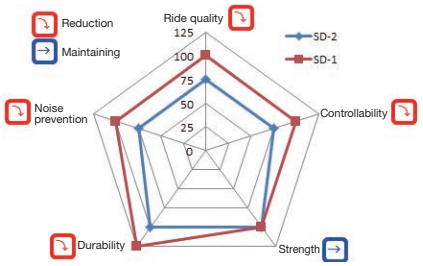



**Fig. 3** Setting of target performance

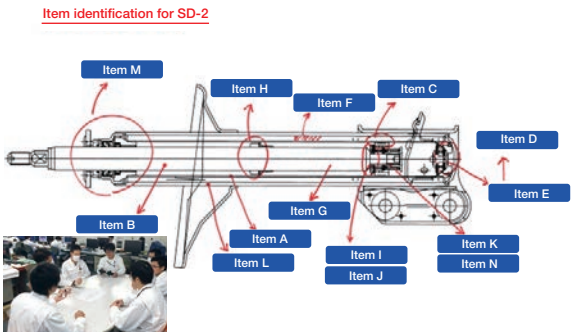



**Fig. 4** Item study meeting

**Table 1** Check of compatibility with required performance

| Item | Cost (◎Large effect ○Medium effect △Small effect) | Performance: Ride quality (Differentiation Minimal) | Performance: Controllability (Minimal) | Reliability: Strength (Unbreakable) | Reliability: Durability (No leakage Minimal) | Reliability: Noise prevention (Minimal) |
|---|---|---|---|---|---|---|
| Item A | ◎ | — | — | ★ | — | — |
| Item B | ◎ | — | — | ★ | ★ | — |
| Item C | ◎ | ☆ | ☆ | — | ★ | □ |
| Item D | ◎ | ☆ | ☆ | — | — | □ |
| Item E | ○ | ☆ | ☆ | — | — | □ |
| Item F | ○ | □ | — | — | — | □ |
| Item G | ○ | — | — | □ | — | — |
| Item H | ○ | — | — | — | — | □ |
| Item I | ○ | — | — | — | ★ | — |
| Item J | ○ | — | — | — | ★ | — |
| Item K | ○ | ☆ | — | — | — | □ |
| Item L | △ | — | — | ★ | ★ | — |
| Item M | △ | — | — | — | ★ | — |
| Item N | △ | — | ★ | — | — | — |

★Has to be fulfilled.
☆Needs to be checked.
□Performance to be checked.

design specifications. In particular, for the damping force valve, the number of parts was decreased considerably.

### 3.3 Tuning of damping force

The damping force valve was also simplified for SD-2 and there could be difference in the following points from the previous products.

(1) Harshness Note 1)
(2) Roll Note 2)
(3) Shock absorption on bad road

Note 1) Vehicle motion when it moves over a joint, protrusion, or step of paved road.
Note 2) Rolling motion to right and left around the traveling direction

The reduction of shock absorption capability on bad road was allowed but the increase of the harshness and roll was adjusted by tuning the damping force to prioritize

the ride quality and controllability (Fig. 5). The positive damping force of SD-2 at around 0.02 m/s was set lower than that of the previous products and the force at around 0.1 m/s was maintained in almost the same level as that of the previous products in order to ensure the ride quality and controllability. The evaluation score was 75.9 with the score of the previous products SD-1 being set to 100 and it was confirmed that the targets of the ride quality and controllability were almost met (Fig. 6). It was also confirmed that the ride quality was clearly distinguishable from that of the previous products.

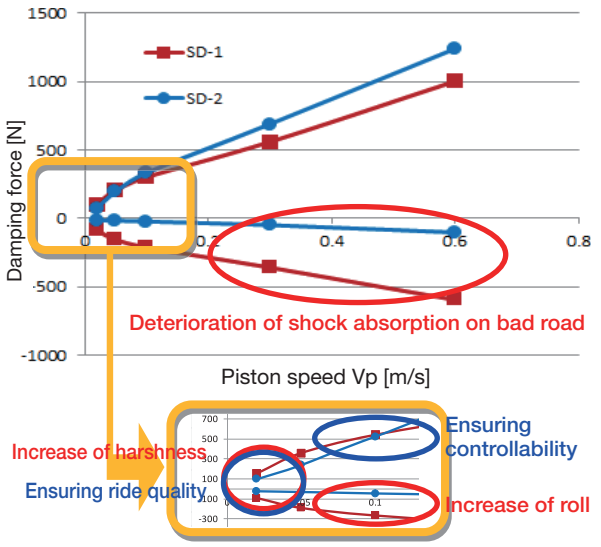



**Fig. 5** Characteristics of damping force

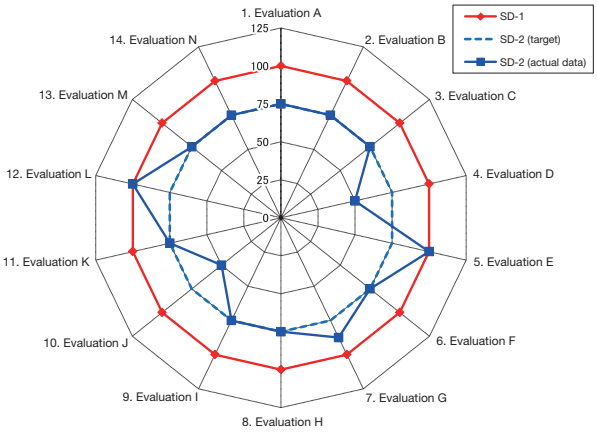



**Fig. 6** Evaluation result with actual cars

### 3.4 Quality check

The durability was tested on actual vehicles to see whether the target quality was secured for each product size. The test result indicated that the target durability was actually achieved. The noise performance was also checked for each product size and found to have no problems (Table 2).

**Table 2** Result of quality check

| | Quality check items | C25ST | C30ST | C25SA | C30SA |
|---|---|---|---|---|---|
| Durability | Item C | Sliding durability test ○ | Sliding durability test ○ | Mass-produced | Mass-produced |
| | Item I | Check with C25SA | Check with C30SA | High speed durability test ○ | High speed durability test ○ |
| Noise | Noise evaluation A | Noise level measurement Evaluation with actual cars ○ | Noise level measurement Evaluation with actual cars ○ | Noise level measurement Evaluation with actual cars ○ | Noise level measurement Evaluation with actual cars ○ |
| | Noise evaluation B | Noise level measurement Evaluation with actual cars ○ | Noise level measurement Evaluation with actual cars ○ | Noise level measurement Evaluation with actual cars ○ | Noise level measurement Evaluation with actual cars ○ |

### 3.5 Driving test in actual conditions

Samples were sent to KYB's sales sites over the world and on-site check of the samples mounted on actual vehicles was conducted (Table 3). The aim of the test was to check the marketability and points of design modification. For the driving test in actual conditions in Iran and Germany, KYB's designers went to the countries and checked the products as well as actual use environment. The driving test in actual conditions in Iran is described in Sec. 3.6.

**Table 3** Test result with actual cars

| Sales company | Model | Evaluator | Comment from sales company | Conclusion |
|---|---|---|---|---|
| Germany | European A | Staffs from sales company<br>Designer from KYB | Front product has no problem.<br>Rear product is too soft. | △ |
| | | Sent to re-test in Germany | | |
| China | Japanese A | Staffs from sales company and agency | Low controllability but high ride quality<br>Can be commercialized. | ○ |
| Asia | Japanese B | Philippines, Myanmar, Sri Lanka | High ride quality with no problem | ○ |
| | | Thailand, Indonesia, Vietnam | Front product has no problem. Rear product has low ride quality on bad road.<br>Can be improved. | △ |
| Brazil | European B | Staffs from sales company<br>Car owner | Improved stability<br>Slightly soft but no problem in Brazil | ○ |
| Mexico | Japanese C | Staffs from sales company | No problem in ride quality<br>Also suitable for taxi companies | ○ |
| Middle East | Korean A | Staffs from sales company and agency<br>Designer from KYB | No problem in ride quality, controllability, or noise | ○ |
| | | Sent to test in Iran | | |

### 3.6 Driving test in actual conditions in Iran

In August 2015, a prototype SD-2 was tested on actual car in Tehran, Iran (Photo 1). The car is one of major models frequently found in Iran.

The prototype SD-2 was mounted on the car and it was confirmed that there was no clearance problem between the product and the car. A driving test was conducted and the ride quality and controllability were found to be higher than those of the product previously used for the car.

The total driving distance of the test vehicle was very long (350,000 km) and the products used for the vehicle were extremely deteriorated. Many old cars was found in the city. SD-2 products would be quite suitable in the market of this country to be used for these cars. The market seemed to have a great potential when the economic sanctions had been lifted.

**Photo 1** Driving test in actual conditions in Iran

### 3.7 Cost check

It was confirmed that the target of 30% reduction of sales price and 10% reduction of variable cost could be achieved by taking account of the cost reduction items discussed above. Fig. 7 shows an example of the result of the cost check.

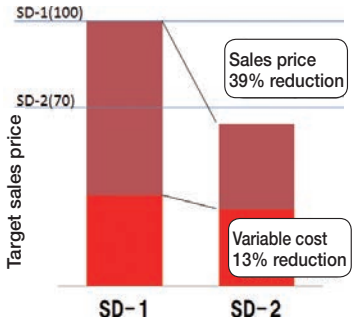



**Fig. 7** Cost check

## 4 Future development

Products developed as SD-2 will be sold as KYB K'lassic and the market target as of 2020 is 1,800 thousand pcs/year (Fig. 8). To achieve this target, more than 400 models of products need to be designed by 2019 and coordination with relevant divisions and departments is being made now. In future, this activity will be developed to foreign production sites.

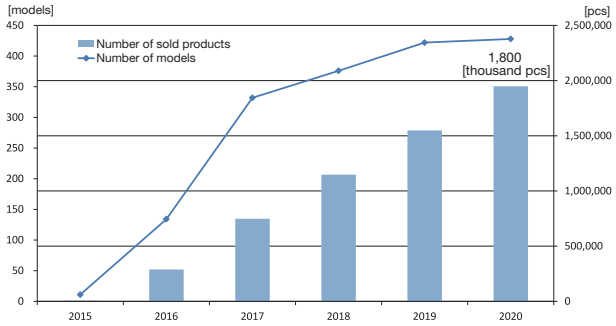



**Fig. 8** Future sales plan

## 5 Conclusions

The outline of the development of KYB K'lassic was explained in this article.

The present activity could develop products suitable for old cars and highly competitive in the low-price range market.

The authors would like to express sincere thanks to those who supported us for the development of the products.

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Technology Introduction

# Application of MBD to Development of ECU Prototype for EPS

KOBAYASHI Masayuki

## 1 Introduction

Conventionally, most of the embedded control systems have been developed, using a document-based design and hand-coding. However, the high quality, low cost, and shorter development lead-time are expected, while increasing demand for higher performance and more diversified functionality in electronic control systems mainly in automotive industry. Since efficiency improvement in product development is expected also for one of KYB's major electronic control systems, the electric power steering (hereafter referred to as EPS), innovative process and methods differing from that of the past are needed .

In recent year, The model-based development (hereafter referred to as MBD), which enables the visualization of design and implementation, has drawn attention as a development method of embedded system. Note 1) This method in fact has been widely used and established a considerable track record in the automotive industry.

This document describes our approaches for MBD implementation in ECU prototype development for EPS.

Note 1) An abbreviation of "Model Based Development."

## 2 Moves to MBD Implementation

### 2.1 Issues in a previous development method

Specifications are always required in the development of embedded systems, however it is difficult to make users fully understood the the contents of document. For example, there is a risk of experiencing unwanted iterations when some requirements are misunderstood by a user, resulting in a failure detected in test process. Actually, this type of problem had been seen frequently in a manufacturing floor, and solved by spending numerous resources. However, the present method is no longer able to sufficiently respond the demand for improved efficiency in product development today.

### 2.2 MBD Overview

MBD is the development method that uses the CAE tool with it's simulation capabilities Note 2) during the development process of embedded control systems in

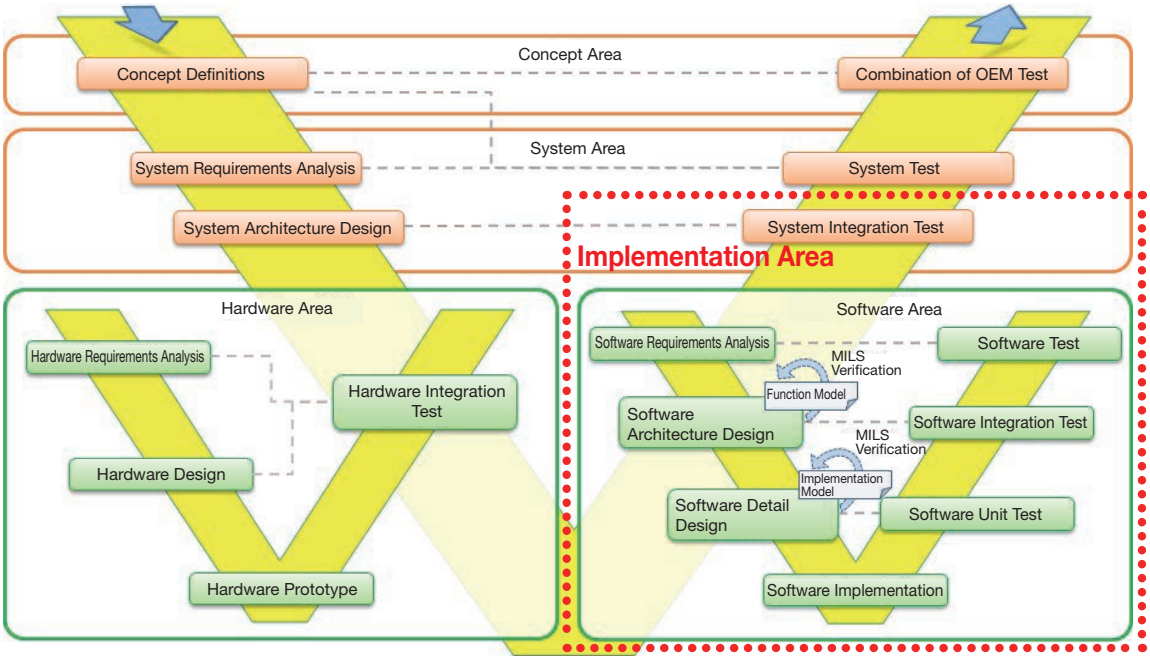


**Fig. 1** V-Shape model of development life cycle

order to improve quality and development efficiency throughly in the development life cycle as illustrated in Fig. 1. The left half of V shape illustrates the design phase while the right half illustrates the test phase. Function model is created/verified in software architectural design. Implemented model is created/verified in a detailed design. In this development, focusing on the software, the system integration test was conducted as software verification.

Features and advantages of MBD implantation are described as follows:

(1) Clarification of specifications

An intuitive, easy-to-understand specifications can be created by using common language, "model" in place of two different words such as "specification" and "function." This also helps communication with overseas affiliates.

(2) Front Loading

The validity of specification is verified in each simulation since a specification is feasible model. This is called MILS, Note 3) and the combination of control model and plant model Note 4) enables an operation check for the developing product even from its design phase. A risk of experiencing unwanted iterations can be reduced by giving special emphasis to the upstream processes of development.

(3) Automatic Code Generation

Since source codes can be automatically generated from the model, a consistent level of quality, such as readability and execution efficiency, can be maintained with regards to human errors and variation in skills of programmers. Furthermore, the manpower required for coding can be significantly reduced. The specification and software prepared in equal without fail by code generation facilitates the management.

(4) Reuse

The past developed models are stored in library so that they can be easily reused at the specifications level. As a result, the accumulation of expertise and asset enhancement can be achieved as well as improved development efficiency. The above explanations can be applied to the plant model as well as the control model.

Note 2) Defines a series of processes, ranging from design through development, operation, and maintenance.

Note 3) An abbreviation of "Model In The Loop Simulation." Simulation performed by combining a control target model and a controller model .

Note 4) A physical model in which the motion of the control target such as a motor is substituted into the motion equation.

## 3 Software Area

In order to limit the effect of developing model to an application part for this software, AUTOSAR Note 5) -compliant software components was used (Fig. 2).

Application Layer is the application part, where the model-based development is applied.

BSW Layer realizes the connection between software and hardware, and consists of Service Layer and MCAL Note 6) that provide OS services, including complex drivers that is required for using sophisticated functions.

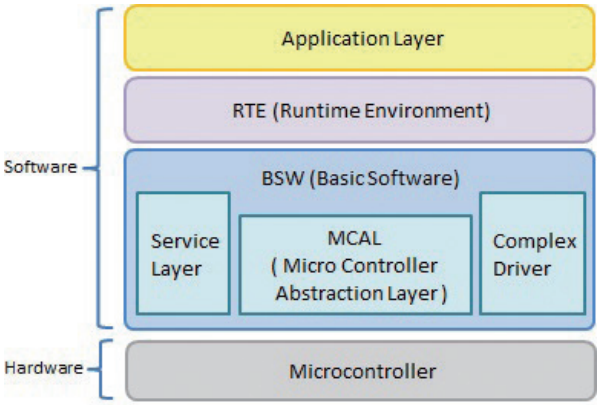


**Fig. 2** AUTOSAR Configuration

RTE is a communication layer that realizes the connection between BSW Layer and Application Layer.

Having layer components as described above, applications is treated as one reusable module, and the development can be performed without awareness of Hardware.

Note 5) An abbreviation of "Automotive Open System Architecture." The organization and specifications that standardizes automotive software platforms.

Note 6) An abbreviation of "Microcontroller Abstraction Layer." Software module that provides an access to inside of microcontroller.

## 4 Developing Process

The work carried out in this development based on the development process is described as follows.

### 4.1 Requirements Analysis

Extracts requirements from the concept to be developed, and reflects the specific methods for realizing requirement to the software specifications (Fig. 3).

### 4.2 Function Model

Converts the function into a model based on the output of requirements analysis in the architecture design (Fig. 4). MILS is performed in this function model in order to verify/confirm the feasibility of the system operation, including fail-safe and requirements. To increase readability of model, the modeling guidelines were created in modeling process to ensure the description rule based on MAAB Note 7).

For modeling tool, the MathWorks MATLAB®/ Simulink® Note 8) that has already been used in our company was used . The model which has been developed by our company was used for plant model.

Note 7) An abbreviation of "Mathworks Automotive Advisory Board". Guidelines which provides the rules such as description rules for Mathworks product.

Note 8) Graphical environment for algorithm development and system simulation. MATLAB®, Simulink® are registered trademarks of the MathWorks.

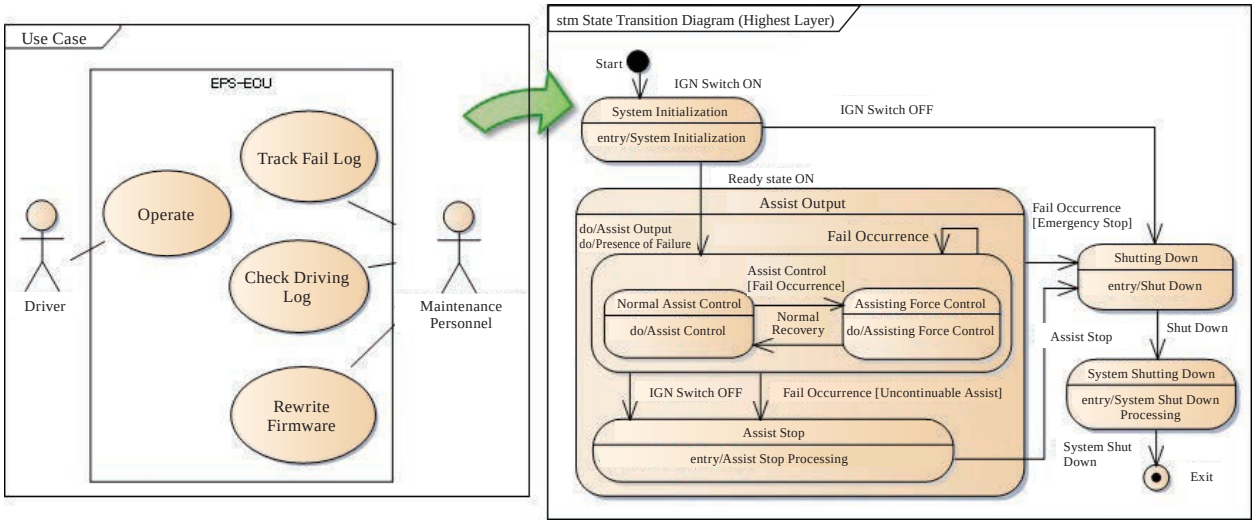


**Fig. 3** Software requirements analysis

### 4.3 Implementation Model

Modifies the function model consciously of the memory performance of the program with an ECU equipped. The discretization of continuum model and the separation of individual component, the modification including the optimization of the variable type are performed. Then, the equivalency between function model and implementation model were verified by Back-to-Back test (Fig. 5).

### 4.4 Implementation

Provides code generation for implementation model. For generated C code, the conformance of MISRA-C [Note 9)] rules are checked by using a static analysis tool and appropriate corrective measures are implemented for nonconforming items.

Note 9) Coding standard for securing the security, portability, and reliability of software (C language).

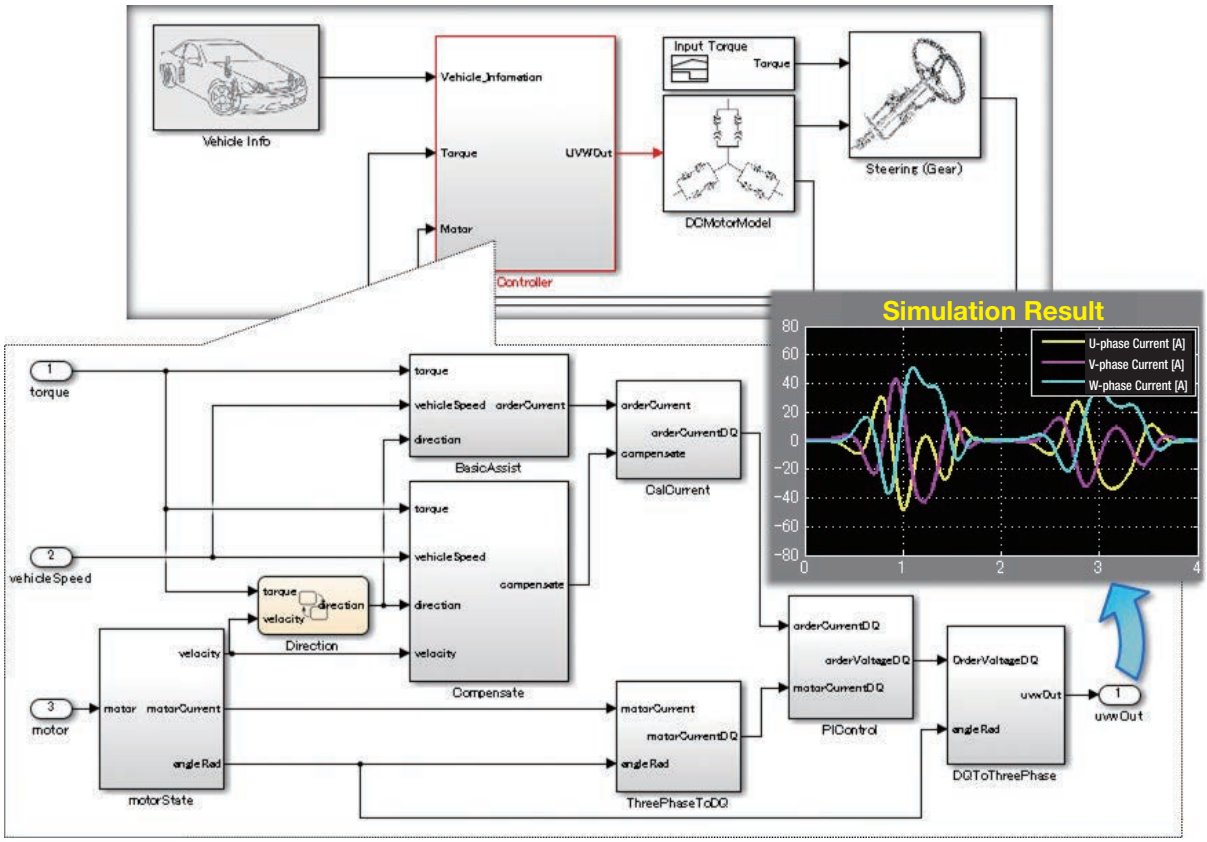


**Fig. 4** Function model created by MATLAB®/Simulink®

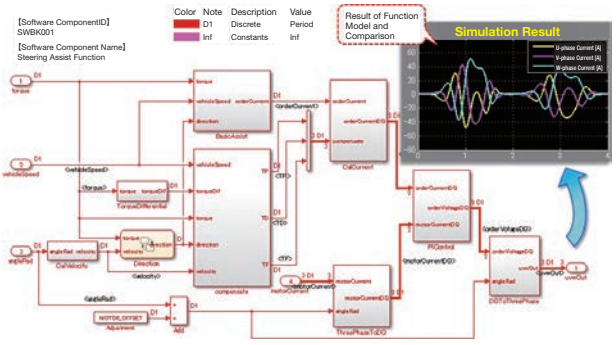


**Fig. 5** Implemented model created by MATLAB® / Simulink®

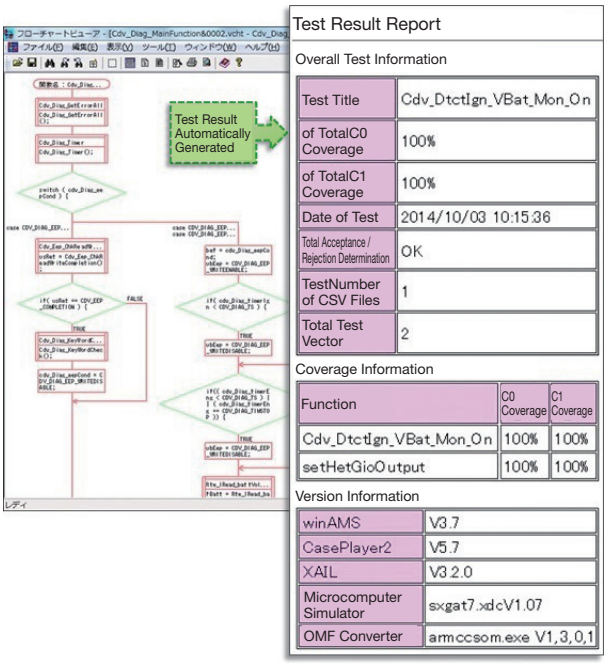


**Fig. 6** Coverage Measurement

### 4.5 Test

Tests required during this development is described as follows:

#### 4.5.1 Software Unit Test

Conduct the unit test for each software unit by using microcomputer simulator. A consistency with the detailed design is verified by Back-to-Back test and coverage measurement (Fig. 6). Also, an ISO26262 Note 10) compliant unit test tool is used to automatically generate the evidence.

Note 10) Specification of safety requirements for all automotive electronic and electrical systems.

#### 4.5.2 Hardware integration test

Software units are rationally integrated to conduct a test using the microcomputer simulator in combination with test program. The proper operation of integrated software is confirmed, and its compatibility with the software architecture design is verified (Fig. 7).

#### 4.5.3 Software Test

A sensor and a control target are combined with ECU equipped with the integrated software to conduct a test. Also, the memory usage and CPU shares in a microcomputer are measured to verify the consistency with software requirement.

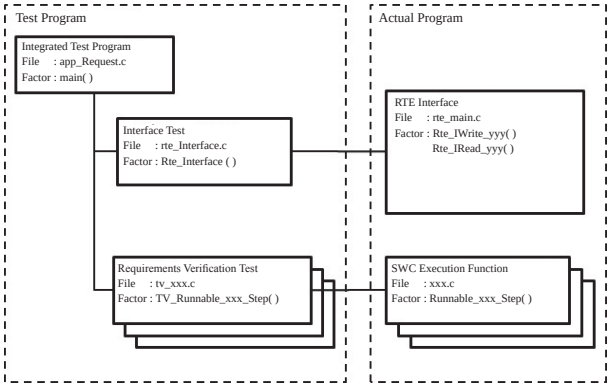


**Fig. 7** Program configuration in software integration test

#### 4.5.4 System integration test

Provides rational integration of the individual components of the system Besides the basic functions, the robustness was evaluated by using the bench test device, which is equipped with a steering and gear box (Photo 1). The system operating waveform generated in the steering operation of bench test device is shown in Fig. 8.

Its compatibility with system architecture design is verified, and the completion of system is confirmed from the evidence of test result.

## 5 Summary and future tasks

Using the model in the upstream process enables the early verification of required specification validity in the design phase, resulting in quality improvement. Also, the common understanding among project members was successfully improved and the communication in the development process was facilitated by utilizing the model as communication tool. Consequently, the work efficiency has been improved, and the benefits of using MBD in a multiple people development project were confirmed. Efforts were also made to the preparation of the operation environment such as development of guidelines and improvement in fundamental activities for full implementation of MBD. We would like to horizontally spread expertise that can be adopted in development of the EPS-derived products and other project.

However, there are some obstacles. Since multiple tools are often used for MBD, the basic overall knowledge about each tool must be acquired. Therefore, it may be a time consuming to train the MBD engineers. Also, the environment construction such as HILS Note 11), and the overall development process, including development of valuable human resources, require considerable funding. Therefore,the hurdle for utilizing this technology is fairly high.

Note 11) An abbreviation of "Hardware In The Loop Simulation." Simulation using an actual ECU with a model that simulates an actual vehicle.

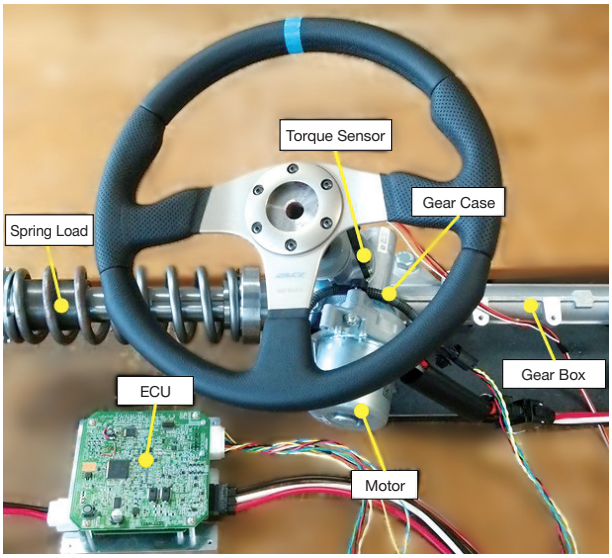


**Photo 1** Bench test device

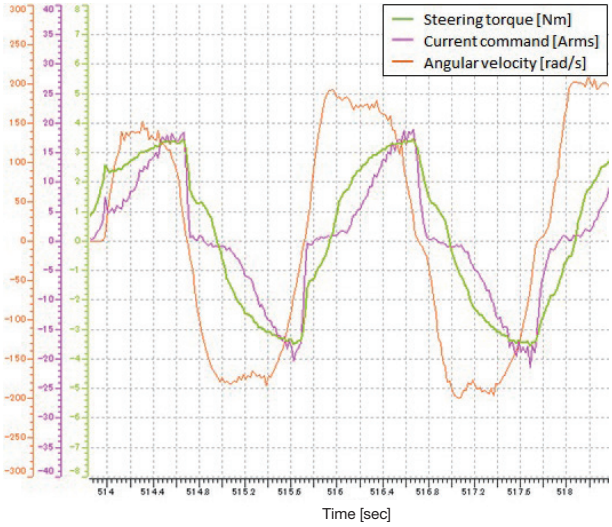


**Fig. 8** The operating waveform when rotating the steering by 90° to the left and the right

## 6 In Closing

In recent years, remarkable progress has been made in automotive technology, and the vehicles equipped with driver assistance systems are no longer unusual. Most driver assistance systems, typically the lane keeping assist, are closely related to EPS. When function of "steering assist +α" is added to EPS, the complexity of systems will be increased, leading to bloated software. Under these circumstances, it would be a necessary consequence that MBD is more commonly used in standard processes.

Besides MBD, there are always new topics in automotive industry such as AUTOSAR and ISO26262, which are applied in our project, and the fault tolerant [Note 12)] design. To respond to such changes in needs, and standards, we, as engineers, should always pay careful attention to the industry trend and prepare the appropriate environment and system.

Note 12) This enables a continuous operation without stopping in the presence of faults in some of its components.

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Technology Introduction

# Development of Driving Safety Support System

HASEBE Atsutoshi, HARA Yasuhiko

## 1 Introduction

KYB currently manufactures drive recorders to record and analyze accident images. In recent years, the automotive industry has been actively developing driving support systems utilizing sensing technologies, such as cameras and radars, with the aim of preventing accidents. KYB must also develop driving support functions utilizing sensing technologies in order to add greater values to drive recorders.

Due to this, in this "Development of Driving Safety Support System" (hereinafter referred to as "this development"), we developed an in-vehicle device with driving safety support functions. This device detects lanes during driving with image recognition based on images taken by a monocular camera and comes with the lane departure warning function, which warns the driver when the vehicle may depart from the lane.

## 2 Lane Departure Warning System

We mention below the defi nition, development goals, and issues in the development of the Lane Departure Warning System.

### 2.1 Definition

The Lane Departure Warning System (hereinafter referred to as "LDWS") refers to a system that detects the lane, in which the vehicle is driving, through sensing or other means and warns the driver when the vehicle departs from the lane.

LDWS definition is provided in "JIS D 0804: 2007 Intelligent Transport Systems - Lane Departure Warning Systems - Performance Requirements And Test Procedures". Fig. 1 shows the operation image of LDWS.

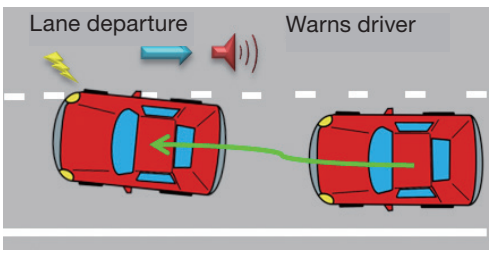



**Fig. 1** LDWS operation image

### 2.2 Development goals

(1) Lane recognition rate of 90% or above
(2) Pass the JIS D 0804 test
(3) System structure, which can easily be transferred to other products

### 2.3 Issues in the development

Upon developing the LDWS, we extracted potential issues. Since it was difficult to respond to all natural conditions, such as weather and time, in this development, we first extracted issues by limiting to stable conditions. Table 1 shows the list of issues in this development.

**Table 1** List of issues in the development of LDWS

| No. | Issue | Description |
|---|---|---|
| 1 | Respond to broken lines | Detect in the same manner as solid lines |
| 2 | Respond to lines on one side | Interpolate the line on the other side |
| 3 | Respond to curves | Detect in the same manner as straight lines |
| 4 | Determine lane departure | Establish the detection method |
| 5 | Respond to lane changes | Withhold warning during lane changes |
| 6 | Differentiate expressways | Withhold warning on general roads |

## 3 Algorithm

This development utilized a monocular color camera as a sensing means. By processing the images of the traveling direction, which are taken by the camera, the device detects lane markings. By calculating the distance between the lane markings and the sides (tires) of the vehicle, it determines the risk of lane departure. Fig. 2 shows the LDWS algorithm summary flow, which was established in this development.

### 3.1 Preprocessing (Identifying the lane region)

While this development used a camera that can acquire HD-size (1280×720 pixel) images, processing this size would take a long time. Therefore, we reduced the processing time by identifying the region, which applied

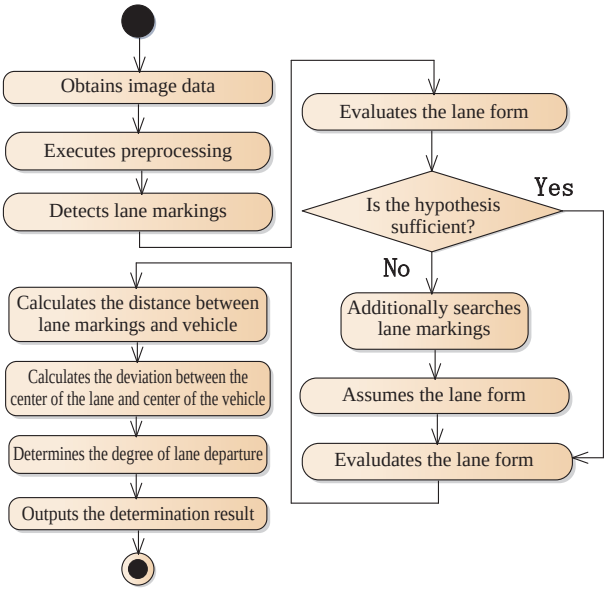



**Fig. 2** LDWS algorithm flow

to the lane, from the acquired images, performing the search process in this region, and finally overlapping the search result on the original image. Fig. 3 shows the concept of lane region identification.

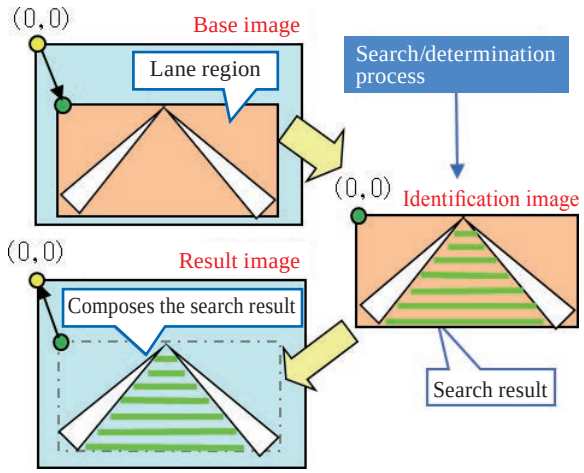
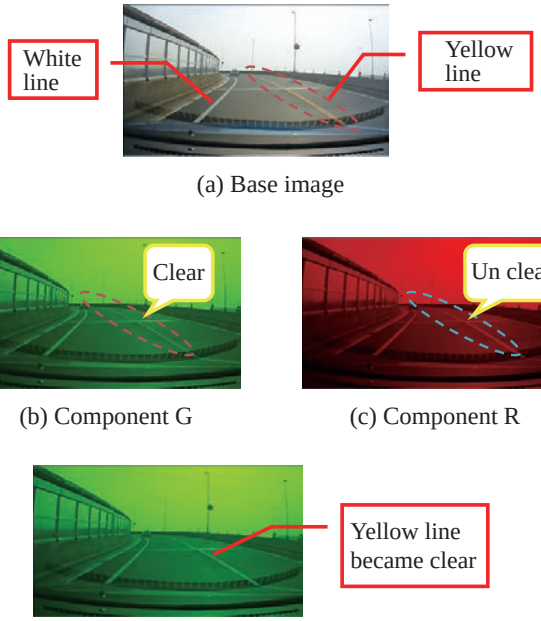



**Fig. 3** Identifying the lane region

### 3.2 Preprocessing (Composing color components)

Regular methods perform binarization in gray scale, in which images are converted into black and white. However, gray scale uses all of the red (hereinafter referred to as "R"), green (hereinafter referred to as "G"), and blue (hereinafter referred to as "B") components, which are the 3 primary colors of light, increasing the process time. Therefore, this algorithm performs binarization by only using specific color components. There are 2 types (white and yellow) of lane markings, which are the detection targets. While only component G is required to detect white lines, component R greatly contributes to the detection of yellow lines. Therefore, we made it possible to detect both white lines and yellow lines by comparing the pixel values of component G and component R and preparing a composite image with a greater value. Fig. 4 shows the composition result of component G and component R.




(a) Base image

(b) Component G

(c) Component R

(d) Example of color component composition process result (Integrated with component G)

**Fig. 4** Composition of color components

### 3.3 Detecting lane markings

In order to detect lane markings, the device first searches for edges, which are used as candidate points for lane markings, on both sides from the center of the search (=center of the vehicle). Fig. 5 shows the concept of the search for candidate points. Detection of lane markings follow the following process.

(1) It searches change points in brightness from the center of the vehicle toward both sides and uses the discovered change points in brightness as candidate points for lane markings.

(2) Points that greatly differ from other candidate points are excluded.

(3) It determines the linearity of the remaining candidate points and detects them as lines. Capturing lane markings as groups of candidate points instead of straight lines enables the device to make detection that doesn't differentiate solid lines/broken lines, which was issue No.1.

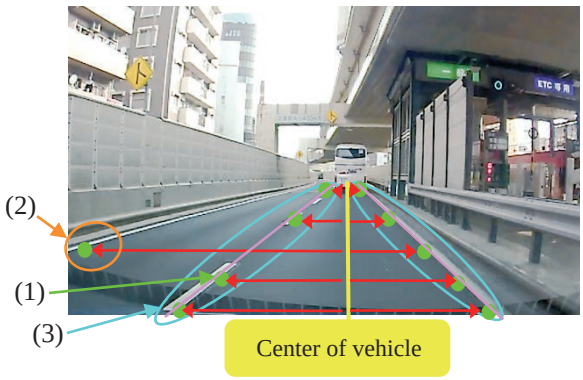



**Fig. 5** Detecting lane markings

### 3.4 Assuming lane forms

Lanes are recognized by forming multiple hypotheses according to the lane forms (straight line/curve) and obtaining the optimal solution by evaluating each hypothesis. In this algorithm, curves are approximated in polygonal lines. Table 2 shows the list of hypotheses. By assuming the form and employing the optimal hypothesis, line on one side as well as curves, which are issues No. 2 and 3, in Table 1 can be recognized with high accuracy.

**Table 2** List of lane form hypotheses

| No. | Form |
|---|---|
| 1 | Form employed in the previous process |
| 2 | Straight line approximation |
| 3 | Polygonal line approximation |
| 4 | Straight line approximation (one-sided prediction) |
| 5 | Polygonal line approximation (one-sided prediction) |

Form that was previously employed is entered as hypothesis No.1 in case there is no appropriate hypothesis. Hypothesis No.2 assumes based on the presupposition that lanes are straight. Hypothesis No.3 assumes based on the presupposition that lanes are curved. When doing so, curves are approximated in polygonal lines. Hypotheses No.4 and 5 use the form, in which the opposite line is assumed based on the detected lane markings in case the lane markings on one side does not exist or cannot be detected due to poor condition in each of hypotheses No.2 and 3.

### 3.5 Evaluation of lane forms and determining the solution

In order to obtain the optimal form among the form hypotheses, which were obtained in section 3.4,evaluation is conducted on each item shown in Table 3. The results are scored. Each result is summed, and the hypothesis with the highest points is determined as the correct form.

**Table 3** Evaluation items for lane form hypotheses

| No. | Item |
|---|---|
| 1 | Lane width |
| 2 | Lane smoothness |
| 3 | Brightness difference between lane markings and road surface |
| 4 | Lane tilt |
| 5 | Temporal change in lane width |
| 6 | Temporal change in lane position |
| 7 | Road surface texture (pattern) |
| 8 | Lane marking texture (pattern) |
| 9 | Position for lane marking candidate point |

### 3.6 Determining lane departure

Fig. 6 shows the concept of lane departure. "Wr" represents the detected lane width, and "Wc" represents the vehicle width. Lane departure is determined based on the remaining distance "d" between the side of the vehicle and the lane markings. Below items were employed in order to respond to the lane departure determination, lane changes, and differentiation of expressways under issues No. 4, 5, and 6 in Table 1.

1. Composite determination process for the deviation of the vehicle and the center axis of the lane by assuming a large vehicle
2. Lane change determination process by blinker signal
3. Warning issuance control process based on the vehicle speed information

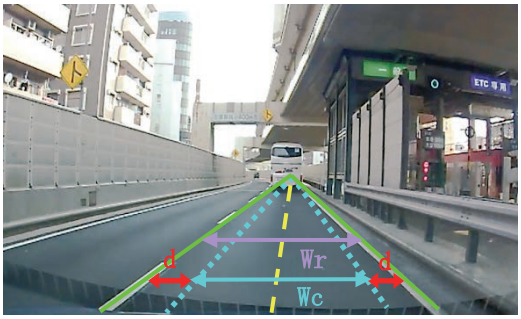
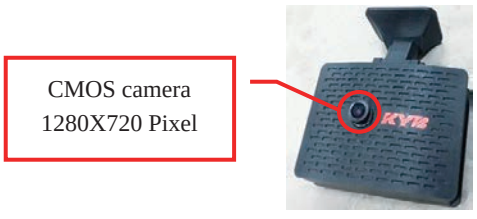



**Fig. 6** Lane departure determination based on the remaining distance to the lane marking

## 4 Prototype

We manufactured a prototype of the lane departure warning device in order to install the developed algorithm on actual vehicles for evaluation. Photo 1 shows the appearance of the prototype.

As a characteristic of the hardware, we used Visconti2™, which is an image recognition processor made by




(a) Front appearance


(b) Back appearance and each function

**Photo 1** Prototype for the lane departure warning device

TOSHIBA CORPORATION, as the processor to perform recognition processes. Since this processor comes with the hardware to perform general image processes, it achieves faster processes compared to general processors. In addition, by using an another IC to control the peripheral hardware, we made the processes, which are required to recognize images, independent for better portability with other products.

## 5 Result

We installed the manufactured prototype on actual vehicles to measure the lane recognition rate and conduct the performance evaluation tests based on JIS D 0804. We colored traffic lane according to the recognition status, as shown in Fig. 7, in these tests to determine the lane recognition status. When the lane markings on both sides are recognized, it shows the image in green. When the prediction is for one side, it shows in blue. When it determines lane departure, it shows in red. Since this algorithm assumes the use on expressways, we performed the driving evaluation on expressways, using vehicles with the prototype installed. As a result, it achieved the high lane recognition rate of over 90%, including recognition on both sides and prediction on one side. In addition, the prototype also passed the performance test based on JIS D 0804 and safisfied the specified perfonmance below.

1. Reproducibility test to confirm variations in the warning points
2. False alarm test to confirm that warning is not issued during normal driving

(a) Line recognition on both sides

(b) Line prediction on one side

(c) Departed state

**Fig. 7** Differentiation of the lane recognition state

## 6 In Closing

In this development, we performed the system evaluation by limiting the field to expressways, in which the lane marking condition is relatively stable. However, we must also respond to issues in general roads, due to the fact that general roads (especially arterial roads, etc.) also have needs for lane departure prevention.

In addition, since adjustment of various parameters in this development was mostly the so-called "sensory evaluation adjustment" based on actual vehicle driving results, we must establish indexes that would enable us to evaluate the recognition results and performance in a quantitative manner in the future.

## Author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Technology Introduction

# Production Transfer of MSG Swing Motor to KHIZ on Installation of High-quality Assembly Line

UGAJIN Yuta

## 1 Introduction

Traveling motor MAG-33 Note 1) and turning motor MSG-27, 44 Note 2) for mini/compact hydraulic excavator are currently manufactured in KYB Sagami plant and shipped to the international destinations, including China. Japanese manufacturers of mother machines have already shifted their productions to emerging countries such as China and many of them requested the local production/supply.

For traveling motor, the MAGassembly line, which used to be located in Sagami plant was transfered to KHIZ Note 3) (KYB Hydraulics Industry Zhenjiang Ltd.)last year in response to our customer requests. For turning motor, the new assembly line has just been established in KHIZ.

In new assembly line, there will two different setups, one is for MSG-27 (Photo 1) and the other is for MSG-44 (Photo 2). This may cause a wrong-assembly and requires the precision of quality assurance better than that of Sagami plant. The low-cost washer was developed and the in-house production was increased to reduce the equipment cost. Furthermore, the hazardous work has been eliminated aimed at avoiding work-related injury.

As a consequence of considering those measures, the assembly line of superior quality and safety was successfully developed.

Note 1) Type of Motor Axial piston with a gear reducer
Motor Axial piston Gearbox-33cc/rev

Note 2) Type of Motor Swashplate with a gear reducer
Motor Swashplate Gearbox-27, 44cc/rev

Note 3) KHIZ has been integrated with KIMZ(KYB Industrial Machinery (Zhenjiang) Ltd.)in April 2016.

**Photo 1** MSG–27

**Photo 2** MSG–44

## 2 Outline of Plan for Assembly Line

The assembly line processes flow is designed to be Large component Cleaning→Assembly→Inspection→All paint. Small components are cleaned in sub-assembly process and later charged in an assembly line (Fig. 1).

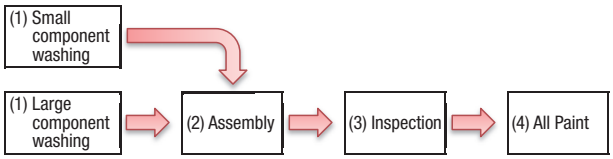


**Fig. 1** Outline of Plan for MSG Assembly Line in KHIZ

## 3 Purpose

Establish the high quality MSG assembly line in KHIZ.

## 4 Objectives

(1) Production line claim 0 case (as of December 2015)
(2) Work-related injury 0 case (as of December 2015)
(3) Start of Production December 2014

## 5 Requirements

(1) MSG-Establishment of high quality assembly line that enables set-up of 27 and 44.
(2) Reduction of equipment cost in order to achieve the budgetary objectives in investment.
(3) Securing the safety by elimination of hazardous work.

## 6 Descriptions

### 6.1 Improved precision of quality assurance through error-proofing system

#### 6.1.1 Establishment of Picking System for Selection of Shim Note 4)

From multiple shims available in various sizes, one should be selected for assembling based on the amount of the clearance created between components during the bearing

assembly process. At this point, there is a potential risk of wrong assembly caused by misselection of shim. Once the wrong part is assembled, the play of roller inside bearing may become excessive and cause vibration, resulting in shorter life time of bearing.

When the clearance determined by a measuring apparatus, was wirelessly transmitted (Photo 3), the indication lamp of a part box, in which appropriate shim is stored, illuminates (Photo 4). The system is designed to prevent a product from proceeding to the next step until an operator presses a picking sensor after picking out the specified shim.

The technique which allows the correct picking regardless of the operator's skill was established in this improvement.

Note 4) Spacer used in adjusting the height of component and extra clearance

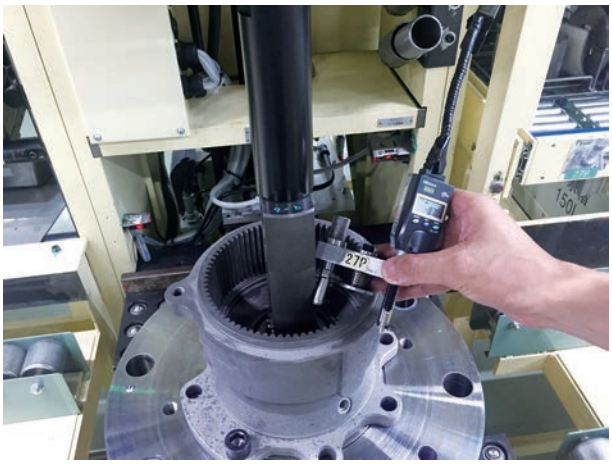

**Photo 3** Clearance Measuring Apparatus

**Photo 4** Shim Storage Rack

### 6.1.2 Establishment of Grease Quantification System

Since the grease application to bearing is a manually performed process, the amount of grease applied to each machine may vary. Also, a product may proceed to the next process, skipping grease process. Insufficient grease application may cause the shorter lifetime of a bearing.

Grease gun, which provides grease amount control, was adopted (Photo 5) in order to quantitatively provide the one-push amount of grease. The system is designed to prevent a product from proceeding to the next step when the amount of applied grease is insufficient.

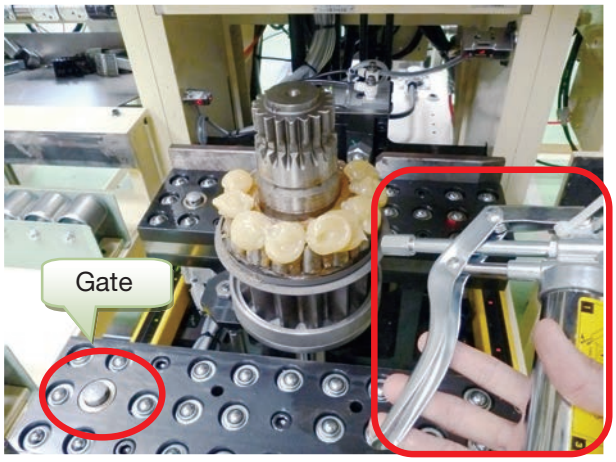


**Photo 5** Quantitative Grease Filling Gun

The technique which enables an application of grease quantitatively on each machine regardless of the operator's skill was established in this improvement.

### 6.2 Mechanical Efficiency (Torque Efficiency) Stability Measurement

The variation of mechanical efficiency (torque efficiency) may occurs in a performance test equipment due to unstable torque measurement. Since the rotational shaft of the performance test equipment is equipped with contact type torque-meter, the zero point drift easily occurs due to wear of the contact portion which can cause the unstable torque measurement. In addition, since the torque is controlled by a hydraulic motor (Fig. 2), its rotational speed is destabilize due to the oil pressure pulsation, leading to unstable torque.

Non-contact type torque-meter is currently equipped on rotational shift of the performance test equipment as a substitution. Also, the inverter controlled motor is used for torque control. Consequently, the rotational speed, and then torque speed were stabilized.

The technique which enables the stable measurement of mechanical efficiency regardless of the operator's skill was established in this improvement.

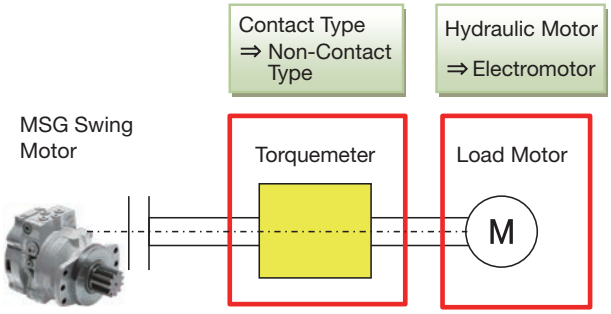


**Fig. 2** Performance Test Equipment rotational shift

### 6.3 Development of Filter Selection Simulator

For MSG performance test, the hydraulic fluid is supplied to MSG by the hydraulic pump installed on performance test equipment to rotate the motor. This causes the initial wear particles over the contact surface, which lower the fluid cleanliness level.

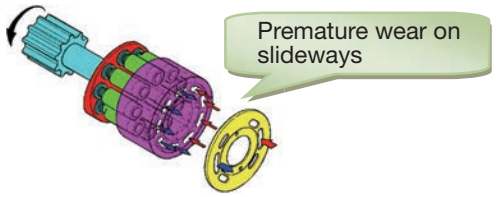


**Fig. 3** Rotary Parts of MSG turning motor

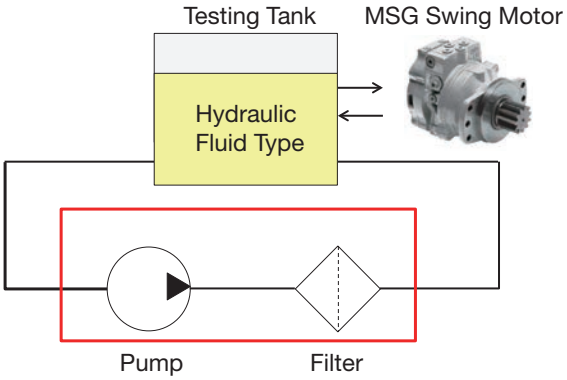


**Fig. 4** Offline Filter Circuit

The fluid cleanness levels were set out in our internal standards. The low fluid cleanness level results in the risk of premature wear or failure on MSG (Fig. 3). In order to prevent decrease in fluid cleanness, a filter was installed (Fig. 4). However, the determinations of filtration accuracy (filter mesh) and pump flow rate were only based on engineer's experience in production, who had decided the specifications of the performance test equipment, and the selection criteria were not clearly defined.

A simulator which outputs the particle count inside the performance test tank upon entry of the required data, including filtration accuracy and pump flow rate, was internally developed this time (Fig. 5). The filtration accuracy and pump flow rate were determined by using this simulator in order to maintain the fluid cleanness level of the performance test equipment to be within our internal standard.

The technique which enables the determination of appropriate filter regardless of the operator's skill was newly established in this improvement.

### 6.4 Development of Low-cost Bubbling Washer

The machine time of the washer preciously used in Sagami plant was too short in regard to the target cycle time and over-specified (requires a high equipment cost) . Meanwhile, the cleaning accuracy was set out in our internal standard and thus must be complied with.

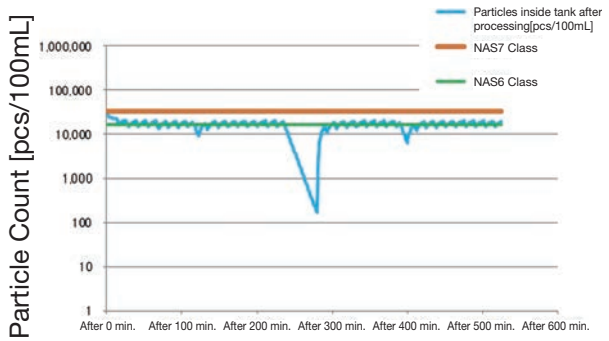


**Fig. 5** Simulator Output for Particle Count

The low-cost bubbling washer was newly developed in order to keep expenses within investment budget (Photo 6). The previous bubbling washer requires two pumps, one for the circulation and the other for bubbling. This time, one pump can provide both the circulation and bubbling functions and successfully contribute to reduce the cost of equipment (Fig. 6). For further reduction of equipment cost, a local manufacturer in China was selected as a source of this washer.

The specification of the equipment was developed in Sagami plant. Then, the subsequent process from the acquisition of estimation through equipment installation, test-run, and check for cleaning accuracy were conducted mainly by KHIZ local staffs.


**Photo 6** Bubbling Washer Appearance

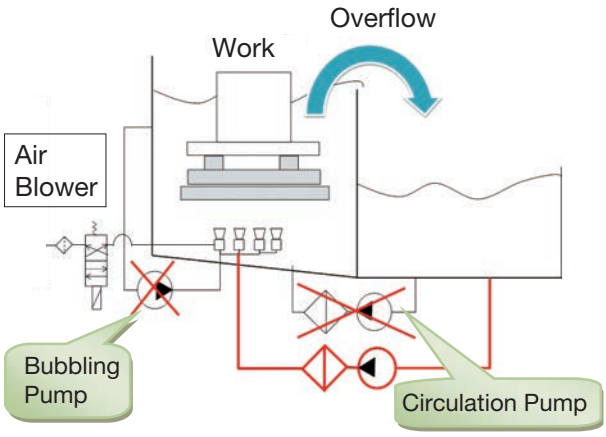


**Fig. 6** Circuit Diagram of Washer

### 6.5 Internally Developed Control Software for Performance Test Equipment

The control software for the performance test equipment was previously outsourced.

Since the performance test equipment is a core facility, the control design was developed in our machine tools center. As a result, the equipment cost was successfully

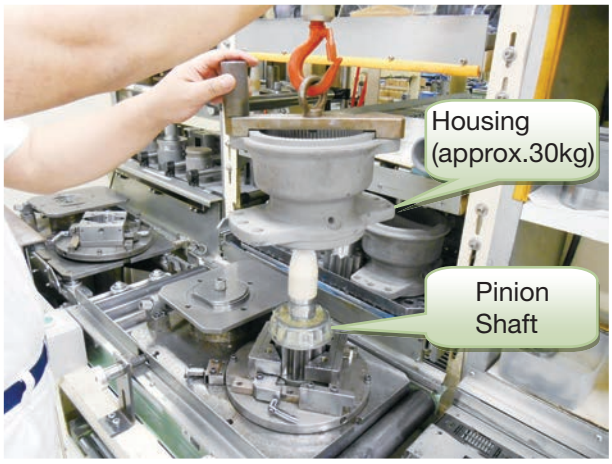


**Photo 7** Crane Operation

reduced by internally developing the electrical circuit of the performance test equipment and control software.

### 6.6 Safety Measures

#### 6.6.1 Craneless Preload Control Device Note 5)

The previous preload control method requires a crane, which lifts a housing of mass approx. 30 kg. and place it on pinion shaft for installation (Photo 7). Use of crane was considered as one of hazardous work, in which materials falling or caught-in may occur.

Note 5) Press equipment, which apply load on taper roller bearing.

The equipment has the structure for which the pinion shaft can be installed onto the bottom of housing in order to achieve the craneless operation (Photo 8).

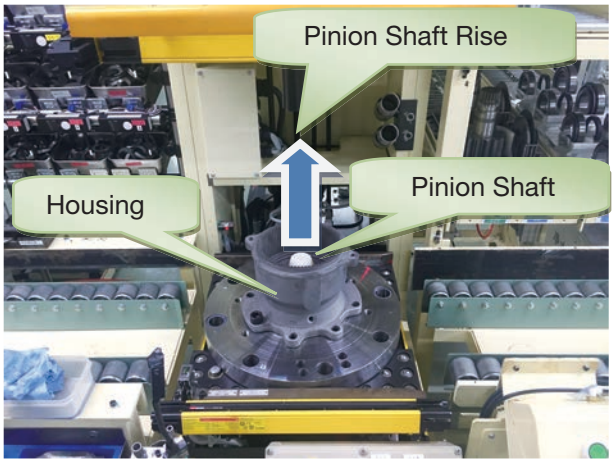


**Photo 8** Preload control device

#### 6.6.2 Craneless Performance Test Equipment

In the process using the previous performance test equipment, the material assembled in a longitudinal attitude was suspended by crane in a laying sideways condition to be install on the rotational shaft. Use of crane was considered as one of hazardous work, in which materials falling or caught-in may occur.

This time, the material was secured in a pallet, and gripped in a conveying loader. The work pallet was clamped, and tilted 90 degrees so as to be a horizontal attitude in order to achieve the first craneless operation for MSG (Photo 9).

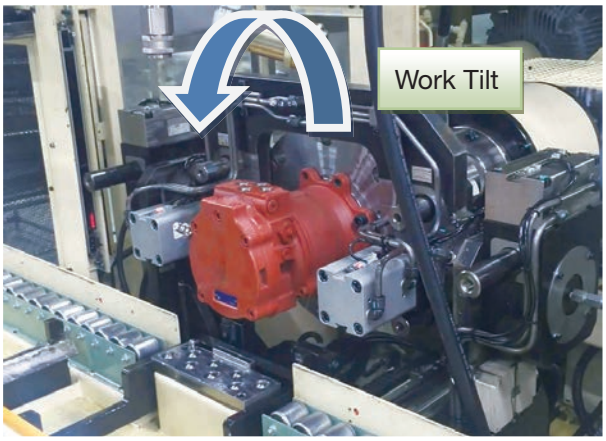


**Photo 9** Performance Test Equipment

## 7 Results

All objectives were achieved.
(1) Production line claim 0 case (as of December 2015)
(2) Work-related injury 0 case (as of December 2015)
(3) Start of Production December 2014

## 8 Summary and future tasks

The assembly line was successfully developed not only for MSG assembly in KHIZ but also for achieving superior quality and safety.

We plan to share and improve this technology in other production lines.

## 9 In Closing

I would like to take this opportunity to express my deepest gratitude to everyone involved and provided support in the establishment of MSG assembly line.

## Author

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Production Engineering Sect.,
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Technology Introduction

# Technological Development of Mass Production of Injection-Molding Worm Wheel

OGURA Shogo, FUJINAMI Taro

## 1 Introduction

Pinion type Electric Power Steering System (hereafter referred as EPS) is the EPS, which assist mechanism on the pinion shaft. The output torque from an electric motor is increased by a gear reducer and transmitted to pinion (output shaft). Worm wheel is used for this reduction gears (Photo 1). The resin material is used for making tooth of worm wheel in order to reduce the gear meshing sound.

A worm wheel is engaged with the worm in each steering, the contact stress was caused on the tooth base, creating friction on the tooth surface. If a gear is deformed or worn out, the backlash of worm and worm wheel will

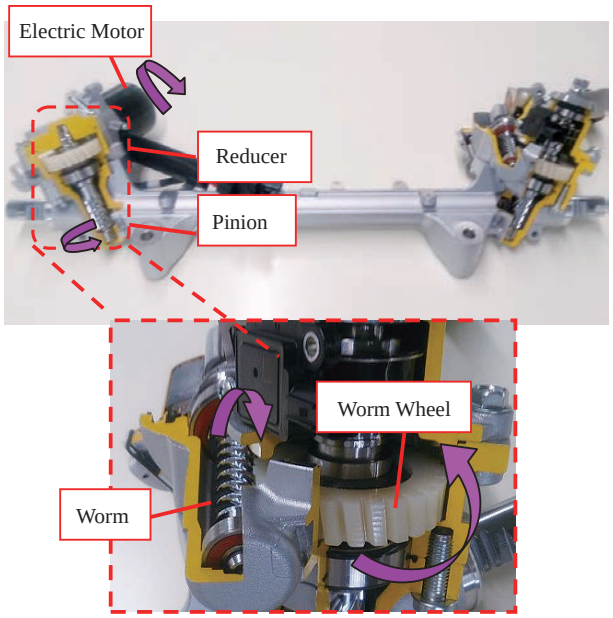


**Photo 1** EPS Structure

be increased, causing gear meshing sound. Therefore, excellent strength and wear resistance are required in worm wheel.

As well as high product quality, the improvement of the productivity must be ensured to meet demands for cost reduction these days.

Therefore, this section introduces the innovative production line, which was developed to satisfy high quality requirements while ensuring the high productivity.

## 2 Purpose

Establish a mass production that satisfies all the elements required for functional components, including high strength, durability, and productivity.

## 3 Objectives

(1) Inner defect rate 0%
(2) Ensure resin material properties that meet required strength.
(3) Operational Availability 85 % or greater

## 4 Description of Applicable Product

The worm wheel, which is object of this project, consists of a resin made tooth and a metallic core bar (Fig. 1).

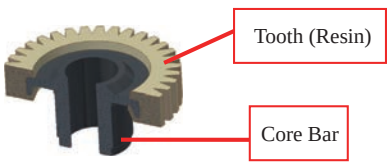


**Fig. 1** Cross Section of Worm Wheel

## 5 Overview of Production Line

### 5.1 Process Flow

Process flow developed for Injection molding line is shown in Fig. 2.

In order to achieve high quality and productivity, the

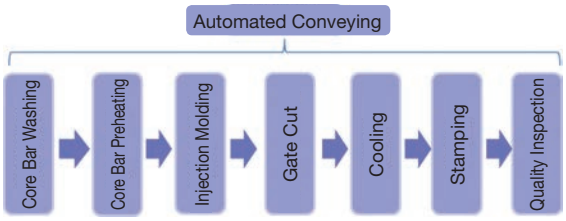


**Fig. 2** ProcessFlow

production line was developed based on the fundamental philosophy described as follows.

### 5.2 Quality

(1) Defect occurrence prevention
Determine the manufacturing control conditions that can ensure the targeted quality.

(2) Defect outflow prevention
When defect occurs, automatically dispose the defective parts, avoid decision making by an operator, and prevent the defect outflow.

(3) Traceability System Development
The traceability system should be developed, which enables tracking the impact range in a short time when defects occurs after market introduction.

### 5.3 Productivity

(1) Automation
A self-driving robot is used to convey workpieces between presses in order to reduce conveyance loss and variation.

(2) Multi-product manufacturing
Measures effective to reduce change-over time should be taken to ensure the operational availability thorough multi-product manufacturing.

The description and result of development is partly described as follows.

## 6 Descriptions and Results of Development

### 6.1 Thermal stability of core bar

When changes in resin filling properties occurs due to fluctuations in core bar temperature, there will be a possibility of dimensional variation. Therefore, the relationship between the temperature of the core bar during molding and its quality was examined, and the temperature range wherein the variation in dimensional change is suppressed (Fig. 3).

In order to maintain the core bar temperature within the targeted range, a preheater, which offers the low-frequency induction heating method was installed. Thereby, a rapid and uniform heating were also achieved. This method can be used for a core different in shape by changing the heating conditions, and the need of changing set-up, such as coil exchange, was eliminated.

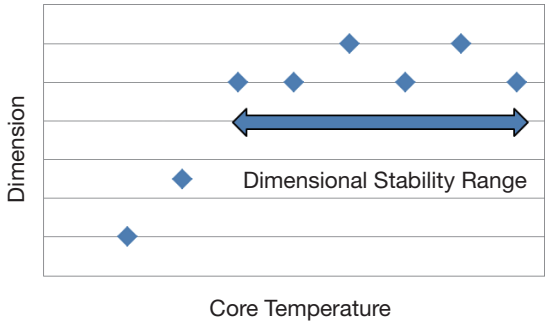


**Fig. 3** Relationship Between Core BarTemperatureand Dimension

### 6.2 Injection Molding

Injection molding is a manufacturing process whereby the molten resin is injected into a mold, and then cooled and solidified. It is suited for high volume production of complex shaped parts. Injection molding machine is shown in Photo 2.

The molded products by injection molding vary in their size, appearance, and strength due to differences in melting temperature, injection speed, and injection pressure.

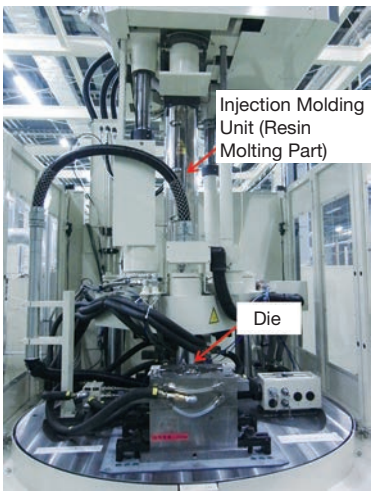


**Photo 2** Appearance of Injection Molding Machine

#### 6.2.1 Balancing Inner Defect Prevention and Cycle time

Earlier in development, air bubbles were formed in the resin. The temperature profile during injection was examined, using flow analysis in order to determine the cause of air bubbles (Fig. 4).

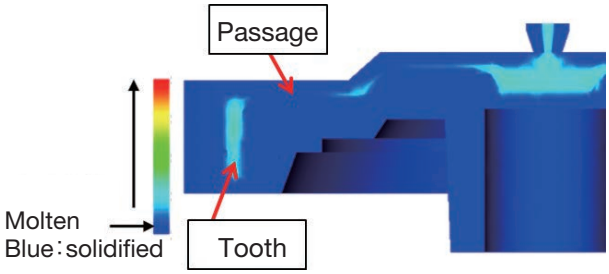


**Fig. 4** Temperature Profile During Injection

Since a resin was first solidified in a flow passage half way to the tooth, the sufficient resin was not filled into the tooth, causing air bubbles. The injection molding condition was optimized in order to delay the solidification in the flow passage, and the delay of the solidification in the flow passage was confirmed by the temperature profile (Fig. 5). When manufacturing under optimum molding conditions, the air bubbles were prevented.

The multistage control of the injection speed and injection pressure enables the air bubble prevention and shorter cycle time.

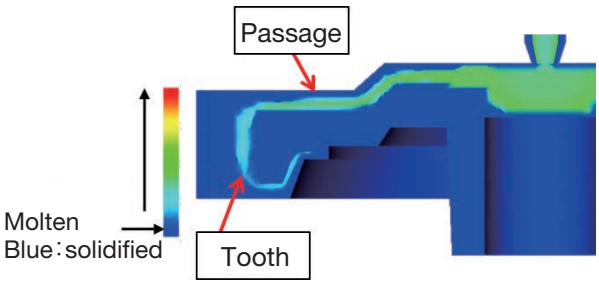


**Fig. 5** Temperature Profile During Injection
(After Injection molding conditions optimized )

### 6.2.2 Management of Quality Requirements

The injection molded products vary in their strength and size due to differences in the temperatures of resin and dies even if the same material is used. This is similar to the metallic materials, which vary in their mechanical properties after their system and crystal structure are changed in the processes of machining and heat treatment. Considering the above, the correlation between molding conditions and the overall quality is clarified, centering the resin material properties. The schematic chart is shown in Fig. 6.

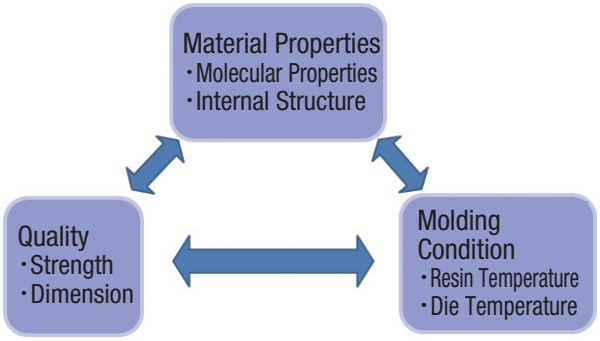


**Fig. 6** Schematic Chart of Injection Molding

Determination method for the control value of molding condition which can meet the required strength is described in this report.

First, the relationship between strength and material properties is examined to determine the material properties that can meet the required strength.

Then, the impact to the material properties upon changes in the molding condition was observed to determine the control value of conditions, which satisfies the target value. Example of resin temperature is shown in Fig. 7.

The control items such as the resin temperature are monitored for each mold shot during production. If values do not go beyond a given control range, the product will be disposed into NG chute automatically by a self-driving robot. This can prevent prevent the defect outflow.

Moreover, the serial numbers associated with the above mentioned control item data was stamped on each molded product. This allows confirmation of each molding conditions.

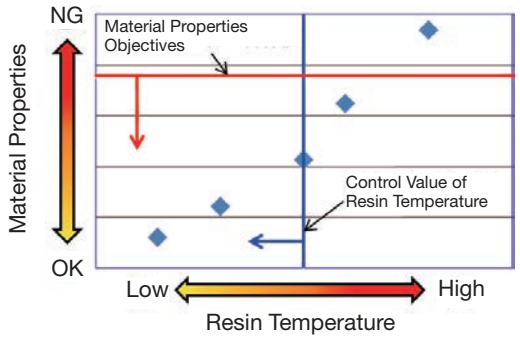


**Fig. 7** Relationship Between Material properties and Resin Temperature

### 6.2.3 The reduction of time and material loss after stoppage of equipment

Once the equipment stops, the molten material inside injection unit will be deteriorated by heat, resulting in the strength reduction of the molded product . In such case, the deteriorated resin is typically purged by test shot. However, excessive test shooting may cause the decrease in operational availability and material loss.

The level of strength resulting from machine downtime was examined to determine the downtime that would not adversely affect strength and a required purge resin amount.

In the event of an abnormal stop, the downtime measurement will be automatically started. A mechanism was developed for, when a downtime exceeds the specified time period, automatically purging an amount of resin that was determined from the total amount of downtime, and then starting re-operation.

Thereby, an accidental outflow to a subsequent process of a mold product, which contains the deteriorated resin and excessive test shooting were eliminated and both high quality and operational availability were achieved.

### 6.3 Development in Gate Cut Method

The gate cut method wherein a gate portion (Fig. 8) is cut and removed after molding would cause an equipment abnormality due to resin chips, blade wear, and variations of shape generated during machining process. A highly reliable gate cut method was newly developed.

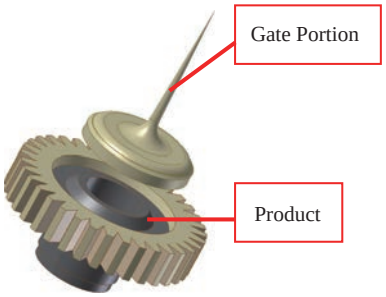


**Fig. 8** Gate Cut Portion

By step-feeding, [Note 1)] resin chips which were generated during machining process were sequentially parted

into more fine chips, and recovered by air blowing and vacuuming in order to prevent winding of the chips on a blade.

Note 1) The feeding method that enables a blade moving back to the mouth of hole after cutting a certain amount.

By monitoring the load torque of a shaft, the points of blade contact on the core during machining process was detected, and the detection signal was utilized as an operation completion signal (Fig. 9). Thereby, the variations in work dimension and in shape, which is resulted from blade wear were eliminated to prevent the stoppage of equipment caused by the gate remaining. Moreover, the blade wear was mitigated by reducing the core cutting portion.

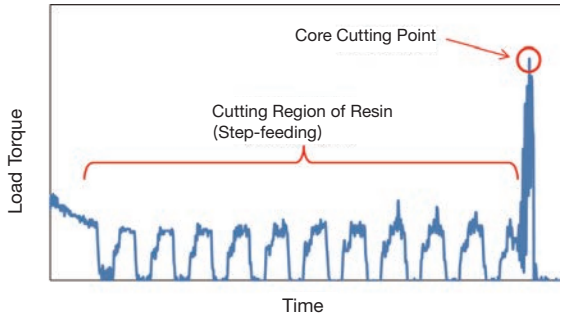


**Fig. 9** Load torque of Shaft During Gate Cutting

### 6.4 Change-Over Time Reduction in Multi-Product Manufacturing

In order to achieve high productivity in multi-product manufacturing, the change-over time must be reduced.

Measures used to reduce the change-over time are described as follows:

(1) Reduce die changing time
For an injection molding machine, a die exchange is required based on the product shapes. The die structure that enable the shortening of the exchange time was developed, and the setup time was significantly reduced.

(2) Commonize parts shape
By using a part with a same shape, where technically feasible, during design phase, the setup work involved in die exchange for each product shape was minimized as far as possible.

(3) Incorporate into equipment and process specifications
In order to reduce setup time losses, the method and equipment that can be utilized only by changing machining condition, and the system wherein data, typically machining condition, is automatically changed under communication between robots and controlling facilities were incorporated as new features in specifications.

## 7 Achievements

(1) Inner defect rate 0%
(2) Determination of manufacturing conditions, which can ensure the material properties.
(3) Operational availability 88%

## 8 In Closing

The mass production line of resin mechanical component where high strength is required was successfully developed. The automated line that enable the multi-product manufacturing, and the facilities that provide the determination of abnormality and recovery system controlled by facilities are developed, achieving the high quality.

I would like to make continuous effort to contribute in improvement of resin processing technologies, that allows the weight reduction by using resin product for metal replacement, and the achievement of higher function and lower cost.

At last, I would like to take this opportunity to express my sincere gratitude to the relevant parties for their cooperation for this project from the start to the end.

## Author

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Joined the company in 2012.
R & D Sect. No.1, Production Technology R & D Center, Engineering Div.
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Technology Introduction

# Development of Multi-metal Paint Coating Treatment

SAWANO Takeshi

## 1 Introduction

KYB motor cycle suspension (hereafter referred as KMS) manufactures the front fork (hereafter referred as FF) and the rear cushion unit (hereafter referred as RCU), the main components of a motorcycle. Especially, the superior appearance quality is required in painting process.

Two lines have been required for the painting process in KMS to satisfy the different specifications of chemical conversion coating (pretreatment) depending on the type of material. The non-chromate treatment (used to be hexavalent chromium) is required for aluminum parts while the zinc phosphate treatment for metal part .

However, there were the issue and losses associated with equipment investment and running cost for having two painting lines.

As a solution of this problem, the newly developed multi-metal paint coating treatment that can be used for both aluminum and metal parts are described in this report.

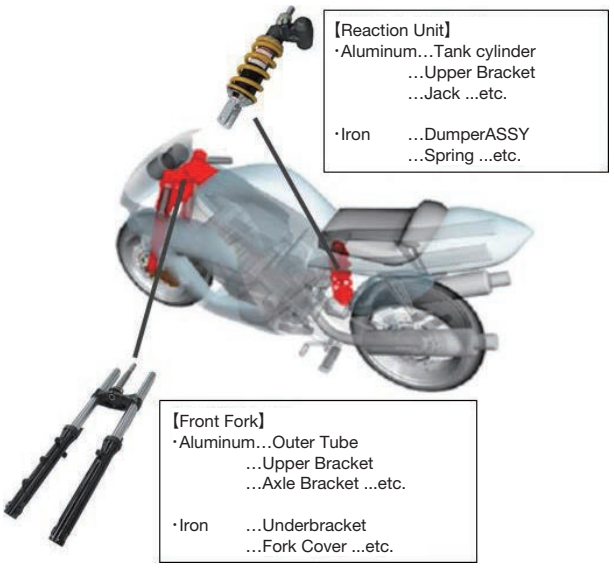



**Fig. 1** Outline of Motorcycle Components and Painting Components

## 2 Function and Previous Methods of Chemical Conversion Coating (Pretreatment)

Chemical conversion coating provides the chemical reaction on the material, especially metal surface in order to create a surface with corrosion resistance and affinity character differently from its original surface. The followings are used in KMS.

1. Non-chromate treatment

The chromate treatment which can provide the corrosion resistance and the painting property had been widely used for the aluminum alloy material. However, The non-chromate treatment (zirconium phosphate conversion coating) was rapidly becoming the method of choice once the chrome used for this treatment was designated as restricted substance and prohibited to be contained.

The low pH (pH 2-4) and a heavily etched would be caused by using non-chromate treatment on surface. If used for iron surface, it would lead to excessive surface roughness and uneven condition.

The non-chromate solution infiltrated in the recessed and prevent a film forming on the surface, leading to rusting.

2. Zinc phosphate coating

This is primarily composed of phosphate ions and zinc ion. A crystalline film will be formed.

This treatment is widely used as an undercoat on iron, and improves excellent corrosion resistance and adhesion. However, if this treatment is used for aluminum, a film may not be formed due to a rise in pH (pH 4-6) and a weak etching.

## 3 Multi-metal Paint Coating Treatment Characteristics

This treatment enables a suppression of etching and a film forming on iron by lowering pH to pH 3-5 based on zirconium phosphate conversion coating suitable for aluminum substrates.

Since the etching of aluminum surface will be weaken due to a lower pH, organic acid may be added to zirconium phosphate conversion coating, and an amorphous film coating is obtained to thereby compensate the etching power on aluminum.

## 4 Our Issues to be Solved

Two lines have been required for the painting process in KMS in order to coat the different materials. Only because their pretreatments are distinguished each other, many losses are created such as more personnel and running costs to fulfill each task in 2 lines (Fig. 2).

For example, even if one line was overloaded due to variations in production volume for aluminum and iron, the tasks cannot be transfered to the other line because of only difference in coating material. In such case, over work was required everyone in one line while the other line works less straight hours.

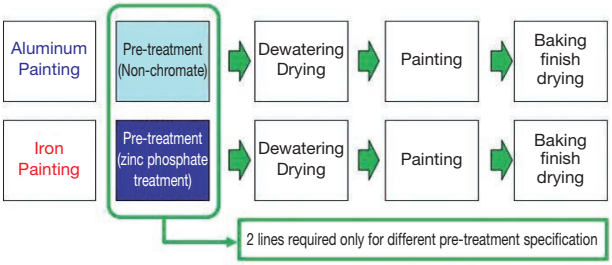



**Fig. 2** KMS Painting Process Flow

Also, during the project for developing a painting process in the affiliate overseas, funding for equipment of 2 lines was very challenging, especially when the in-house production of aluminum and iron products was being promoted in most affiliates.

Therefore, KMV(KYB Manufacturing Vietnam Co., Ltd) in 2006, accompanying with a shift to in-house production for aluminum and iron, two types of pretreatment process (non-chromate treatment, zinc phosphate coating) were integrated by arranging them in series and having pretreatment system capable of switching shower depending on the material (Fig. 3).

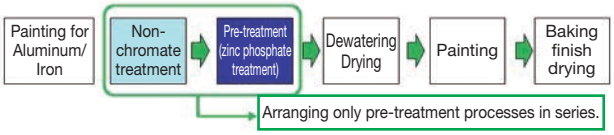



**Fig. 3** KMV Painting Process Flow

This enabled the reduction in equipment investment cost and the elimination of losses for production volume of each material. However, there is the potential risk by changeover of process specifications, and unless the mist of a material is completely purged at changeover, the other materials cannot be flowed in. Therefore, the 30 min. of changeover loss occurred (at every material changeover).

Such problems were remain unsolved.

Under such conditions, the development of multi-metal paint coating treatment, which is applicable for both aluminum and iron was provided. The verification is performed to clarify whether it is applicable to KMS products or not.

## 5 Verification with KMS Products.

### 5.1 Properties Comparison of Previous Process

Test pieces for each test were pretreated with both previous chemical conversion coating and multi-metal paint coating respectively before top painting. Then the coating performance test was performed to compare their capabilities.

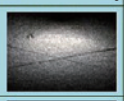
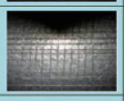
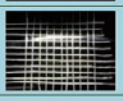
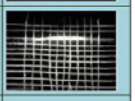
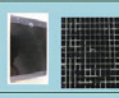
1. Material
   Aluminum…AC2B material
   Iron …SPCC material
2. Coating film performance Test Requirements
   (1) Corrosion resistance test …SST 96h→Allow1h
   (2) Adhesion test…1mm width square ×100
   (3) Water resistance test …40°C・Immersed 120h
   (4) Moisture resistance test…50°C・95% or greater ×96h→Allow 2h

Note that the highest requirements in each motorcycle manufacturer shall be applied as test criteria .

3. Comparison Test Result

Since the performance was equal to or higher than the previous chemical conversion coating both on aluminum and iron substrates and determined to be employed in KMS (Table 1).

**Table 1** Test Result of Coating Performance Comparison

| Material | Aluminum (AC2B) | | Iron (SPCC) | |
|---|---|---|---|---|
| Film Coating | Non-chromate Coating | Multi-metal Paint Coating | Zinc phosphate coating | Multi-metal Paint Coating |
| Salt Spray Testing (SST) |  |  |  |  |
| Adhesion test (square) |  |  |  |  |
| Water Resistance |  |  |  |  |
| Moisture Resistance |  |  |  |  |
| Determination | Equal to or greater than OK | | Equal to or greater than OK | |

### 5.2 Toward Utilization in KMS

No abnormality found in performance test, using test pieces. However, the following concerns were found by in record by tracking the issues before the adoption of the treatment method into actual production line. The Mass production evaluation was performed.

(1) Impact from excess film
(2) Impact from Penetration into coating solution
(3) Coloration to clear painting item by coating

## 6 Obstacles for Mass Production

### 6.1 Impact From Excess Film

Excessive shower due to the stoppage of convener and downtime during production may cause an increase in the weight of chemical conversion coating, the adhesion failure between a transfer films, leading to the separation of painting.

The newly introduced multi-metal paint coating solution is capable of forming a layer that is relatively stable. Once the weight of coating film exceeds the control value 1.0, the separation of coating may be generated (Fig. 4).

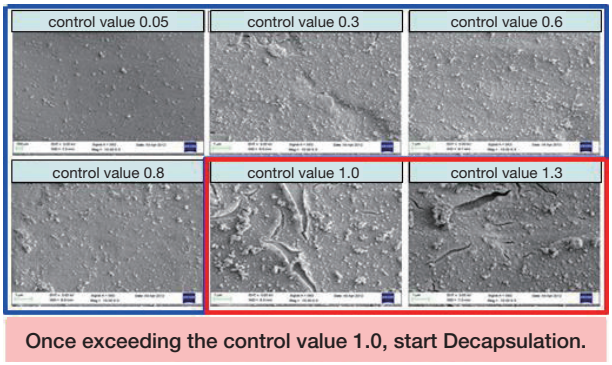



**Fig. 4** Enlarged Picture of Coating

The actual work was coated by multi-metal paint coating solution, and checked for mass to the lapse of time. The saturation started after the processing time 10. The coating film was gradually increased, and then exceeded the control value (Fig. 5).

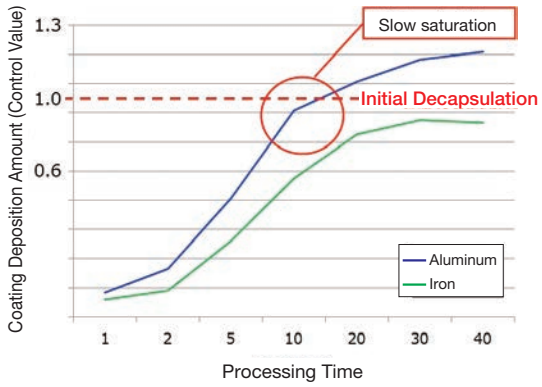



**Fig. 5** Processing Time and Film Weight for Each Material

Our needs were given to a chemical maker, again in order to request the improvement that allows a saturation before reaching the control value, 1.0 that the separation of coating was initiated without impact to the processing time.

As a result, a saturation started approx. 5 minutes after the process and successfully maintain the film condition the 0.6 or under (Fig. 6). This eliminated excessive film coating.

No abnormality found during coating film performance test after the improvement.

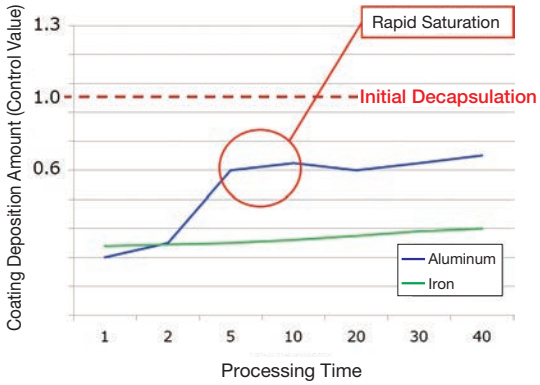



**Fig. 6** Film Weight Profile after Modification

### 6.2 Impact from Penetration into coating solution

When chromate treatment was shifted to non-chromate treatment for aluminum in a past, no abnormality was found earlier during coating film performance test, however, the aluminum was penetrated into the coating solution each time it is used, adversary affecting the painting quality.

The coating film performance test was performed for each work by using an aged solution equivalent to the amount of one year use that was provided by a chemical maker.

1. Manufacturer's Control Value and Penetration
   (1) Amount of aluminum penetration
   Max.=Control Value 150
   Aged solution=control value 98
   (2) Amount of iron penetration
   Max.=control value 750
   Aged solution=control value 470

As s result, the coating film performance test were equal and no abnormality found (Table 1).

### 6.3 Coloration to clear painting item by coating

KMS offers some aluminum outer tubes coated by a clear painting film for utilizing material's visual appeal. However, the coloration may occur depending on its components and processing times (weight of coating film). Only aluminum was verified.

When the appearance to processing time (weight of coating film) was checked, no abnormality found and the film weight is low with the official processing time 2. However, it was hazed once the film weight exceeded the control value 0.5 (Table 2).

Based on the above, it is difficult to maintain the control value 0.3 or less even with the solution that was modified for lighter weight. For clear painting film, we intend to continue our development.

**Table 2** Coating processing time and Appearance after Process

| | | Zirconium deposition amount | | | | Appearance Check After Coating※ |
|---|---|---|---|---|---|---|
| | | N=1 | N=2 | N=3 | Average | |
| 1 | 1 | 0.09 | 0.12 | 0.11 | 0.11 | ◎ |
| 2 | 2 | 0.20 | 0.21 | 0.24 | 0.22 | ◎ |
| 3 | 5 | 0.57 | 0.52 | 0.53 | 0.54 | △ |
| 4 | 10 | 0.92 | 0.95 | 0.96 | 0.94 | × |
| 5 | 20 | 0.99 | 1.18 | 1.06 | 1.08 | × |
| 6 | 30 | 1.20 | 1.24 | 1.08 | 1.17 | × |
| 7 | 40 | 1.27 | 1.19 | 1.17 | 1.21 | × |

At this point, the coating solution effectively works for the product other than the transparent.

## 7 Establishment of KMSI(Plant in India)

With respect to this, upon the establishment of KMSI (KYB Motorcycle Suspension India Pvd. Ltd) in 2015, the in-house painting of aluminum part and iron part were officially decided. Then the estimate amount was approximately twice the amount of budget for equipment investment, and installation of both lines for aluminum and iron has become a great issue.

Since there was no clear painting specification in overseas, and the multi-metal paint coating, which is under development, if it is adopted, can suppress the investment cost within FS budget, KMS has decided to implement the multi-metal treatment throughout KMS group.

It has been 8 months from its launch in May 2015, and the project is turning out great with no coating-related issue found all this time.

We are still in progress for the modification in other coating that has no record. The update cycle should be determined based on the penetrating quantity measurement performed every month by a chemical maker. (Fig. 7).

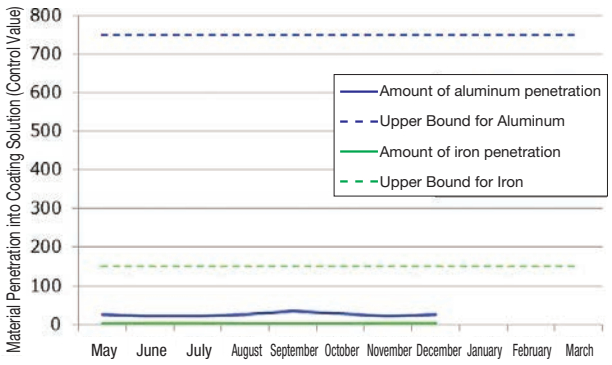



**Fig. 7** Penetrating Profile for Aluminum/Iron coating solution

## 8 Future development

The newly developed multi-metal paint coating process enable the painting capability for both aluminum and iron substrates.

For the future update needed in KMS facilities due to obsolesce and development of new production lines in our affiliates overseas, KMS should develop its original compact painting process line that can be directly connected with subsequent process (Fig. 8).

Also, we will continue to work on the further development in clear painting products.

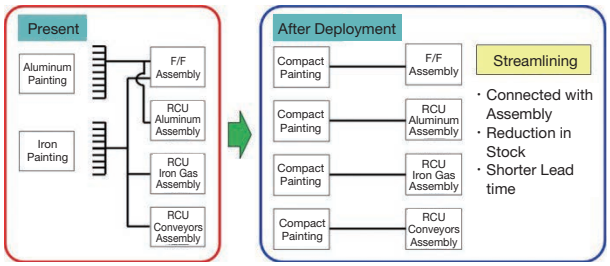



**Fig. 8** Our Ideal Structure

## 9 In Closing

In this development, multiple factors, such as processing time, material, and concentration, should be taken into account. Many people including a chemical maker and persons in our painting process involved in this project.

With such cooperation, I was filled with confidence for adopting this multi-metal paint coating treatment system in KMSI although the specifications cannot be change once it is determined.

I would like to take this opportunity to express my deepest gratitude to everyone involved and provided support.

## Author

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KYB Motorcycle Suspension Co.,Ltd.
Production Engineering Dept.
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Technology Introduction

# Installation of KMEX CVT Shaft Manufacturing Line

ITO Yoshiyuki, KOJIMA Ryota

## 1 Introduction

The vane pump for CVT is produced by KYB (hereinafter referred to as "pump") has been expanding its deployment overseas in response to the increased global demand, and we have been promoting internal production of major components in order to ensure our competitiveness. We had postponed overseas deployment of the shaft, which is introduced this review, and supplied it from Japan because we considered that it would be difficult to launch its production overseas within a short period of time, due to the facts that it requires sophisticated technologies for cold forging and that there are special processes involved, such as heat processing. In addition, The number of shaft was more than the production capacity on a global scale in FY2014, requiring us to increase the number of manufacturing lines.

The following 3 reasons convinced us to decide local procurement.

(1) KYB Mexico S.A. de C.V. (hereinafter referred to as "KMEX") expects the demand of 100,000 units per month.
(2) The Shaft manufacturing line's quality has become stable as it was completed a consistent line.
(3) There is a possibility of raw materials being locally procured.

In addition, we needed to improve the productivity while maintaining the quality when deploying overseas, in order to achieve the following aspects.

(1) Secure the production capabilities that meet the demands.
(2) Aim to reduce cost even if the materials are locally procured.
(3) Aim to synchronize with assembly lines.

Due to the above, we established the line by reduce the cycle time (hereinafter referred to as "C.T.") in KMEX compared to the current domestic line. In this review, I would like to introduce measures that we implemented in each process with the aim of reducing the C.T. The Fig.1 shows the target part for reference.

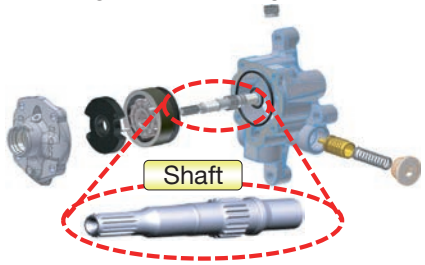


**Fig. 1** Shaft for CVT vane pump

## 2 Implementation Contents

The Shaft manufacturing line is an automated and integrated production line, which consists in lathe process, hardening, shot blast, grinding, polishing, and cleaning process. Before we promoted overseas deployment, we needed to review the production capabilities in order to synchronize with the assembly line. The entire amount of shaft is manufactured by multiple lines and supplied to other bases from Japan, the C.T. is set so that we can maintain the quality and efficiently produce the products.

If a facility with the same production capabilities as Japan was established in KMEX, it would create unnecessary intermediate stocks. In order to avoid this happen, we needed to reduce the C.T. and achieve the production capabilities, which were equal to the integral multiple of the assembly line (Table 1). In order to reduce the C.T., we needed to maintain the quality while limiting the capital investment. We aimed to reduce the machine time of each process (hereinafter referred to as "M.T.") based on the domestic line process method and process conditions, with which we have experience. We implemented horizontal deployment measures in processes, which had already achieved the target M.T. in Japan, and aimed to reduce the M.T. of processes that had not achieved the target M.T.

In addition, we needed to improve the setup change time in order to produce 2 models in the same line. I will also explain about this initiative.

### 2.1 Reducing the setup change time

With the line that produces multiple models, we needed to

**Table 1** Production capabilities of the assembly line and shaft line

| KYB Kanayama | | | | |
|---|---|---|---|---|
| Line name | Production capabilities (Per line) | Number of lines | Production capabilities (Total) | Remarks |
| Assembly line | 100 | 3 | 300 | |
| Shaft line | 130 | 4 | 520 | Including production for overseas supply |

| KMEX | | | | |
|---|---|---|---|---|
| Line name | Production capabilities (Per line) | Number of lines | Production capabilities (Total) | Remarks |
| Assembly line | 100 | 2 | 200 | |
| Shaft line | 200 | 1 | 200 | |

*KYB Kanayama: Production capabilities of the assembly lines as 100

reduce the setup change time to reduce the non-operating time. I would like to introduce the example of this initiative.

The grinding wheels for the centerless unit requires approximately 180 minutes per change. By standardizing the grinding part for both models, we removed the grinding wheels replacement work (Fig. 2). This was something we had already been implementing in Japan, and we deployed the same initiative in KMEX.

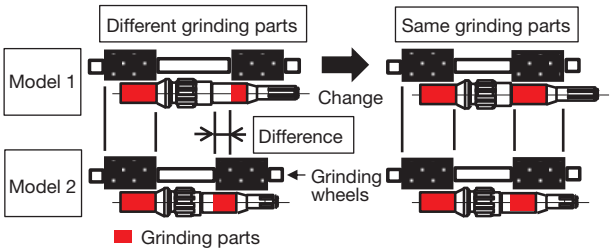


**Fig. 2** Standardizing the grinding parts

## 2.2 Implemented measures to reduce the C.T.

In order to synchronize with the assembly line and improve the productivity, KMEX needed to reduce the C.T. Processes that exceed the C.T. needed to reduce the M.T. (Table 2) I'd like to explain how we reduced the M.T. in each process below.

**Table 2** M.T. of each process

| Process name | M.T. | Implementation Contents |
|---|---|---|
| (1) Lathe process 1 | | Process division |
| (2) Lathe process 2 | | Chuck change, process sequence change |
| (3) Heat process | | Revised the cooling/transportation methods |
| (4) Shot process | | Secured the spray amount per cycle |
| (5) Grinding process | | Reduced the rough grinding allowance |
| (6) Polishing process | | Secured the polishing amount |
| (7) Cleaning process | | Increased the cleaning liquid flow |

C.T. Reduction

### 2.2.1 Lathe process 1

This is the process in which the outer diameter, edge face, and center hole are made with lathes.

In order to complete the process with the target M.T., we divided one process which was made by one lathe into 2 processes. We divided the processed parts according to the process sequence, due to the facts that the finished product would be the same and that the object flow would be simple.

The parts with strict dimension accuracy were processed in the one process with the same tool. All of the units were measured within the line to confirm the processed length in order to check for fitting failures. With this step, we prevented quality deterioration caused by dividing the process (Fig. 3).

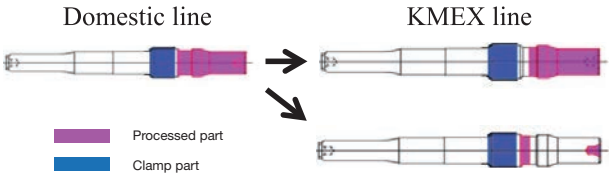


**Fig. 3** Lathe process 1

### 2.2.2 Lathe process 2

This is the process in which the outer diameter, edge face, and center hole are made with lathes.

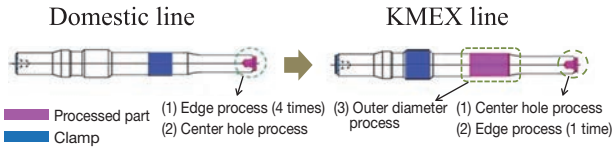


**Fig. 4** Lathe process 2

By switching the work chuck mechanism and changing the process order, we reduced the M.T. As a result, we were able to incorporate part of the grinding allowance into this process.

We changed the chuck mechanism from the cam type (jump type) to the collet type, which works faster. By changing the process sequence for the edge process and the center hole process, the number of processes for the edge was reduced (Fig. 4).

Because of the incorporated grinding allowance, we changed the clamp position.

### 2.2.3 Induction hardening and tempering process

In this process, the surface is heated and rapidly cooled down to harden the surface.

We reduced the M.T. by changing the cooling process to ambient temperature, which is performed after the hardening process. In order to prevent burns on operators, we need to cool down the heated shaft to ambient temperature. We used to use the cooling water, which was sprayed from the hardening coil, but we changed the process so that it is cooled down on the receiving jig during transportation (Fig. 5). By changing the cooling location, we can simultaneously perform the heat process and cooling operation, reducing the M.T.

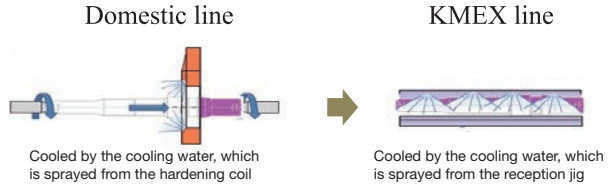


**Fig. 5** Explanation of the cooling method after the heat process

### 2.2.4 Shot blast process

In this process, beads (polishing material) are sprayed on the shaft surface at a high speed, removing the oxide on the surface, which had adhered on the surface during the hardening process.

In order to reduce the M.T., we needed to reduce the time, during which the beads are sprayed. We increased the amount of sprayed beads per period in order to complete the process within the target M.T.

We enlarged the air nozzle diameter on the inside in order to increase the air spray amount. Due to this, the amount of beads sprayed per period also increased (Fig. 6).

This was something we had already been implementing in Japan, and we deployed the same initiative in KMEX.

### 2.2.5 Grinding process

In this process, the sliding part is ground in order to secure the outer diameter, circularity, straightness, and coaxiality.

We reduced the M.T. by reducing the rough grinding allowance (Fig. 7). The grinding condition, which affects the quality, is the same as the condition in Japan, in which we have already had the experience.

We incorporated part of the grinding allowance into lathe process 2 in order to reduce the grinding allowance.

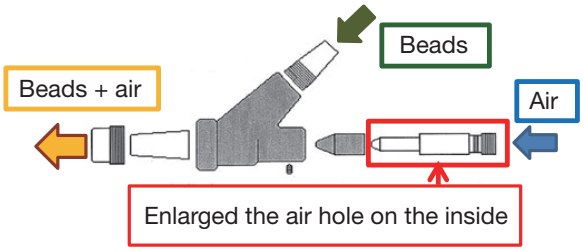


**Fig. 6** Improvement method for the shot nozzle

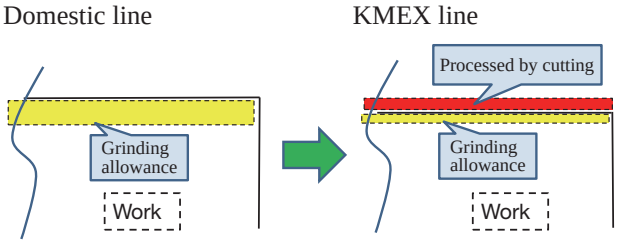


**Fig. 7** Changing the grinding allowance

### 2.2.6 Polishing process

In this process, the outer diameter of the sliding part, which was ground, is polished in order to achieve the surface roughness.

We needed to reduce the polishing time in order to reduce the M.T. In order to complete the process within the target M.T., we increased the RPM to achieve the same polishing amount.

If the RPM is the same, the reduced process time causes deteriorated surface roughness (Fig. 8). If the polishing amount (work RPM x polishing time) is the same, the surface roughness will be the same (Fig. 9).

This was something we had already been implementing in Japan, and we deployed the same initiative in KMEX.

### 2.2.7 Cleaning and boxing process

In this process, the shaft surface is shower-cleaned with cleaner in order to remove the adhered contaminant.

We needed to reduce the cleaning time in order to reduce the M.T. In order to complete the cleaning within the target M.T., we increased the surface that can be cleaned per period.

The nozzle used to move to clean the entire shaft range. We increased the number of discharge ports and flow volume in order to change the method so that the entire shaft range can be cleaned simultaneously (Fig. 10).

### 2.3 Result

We were able to achieve the target C.T. by reducing the M.T. of each process. We completed the launch of the line in KMEX in May of 2014 as per the schedule and have had zero market claims and zero line frames.

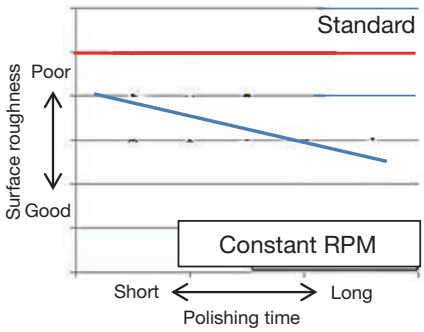


**Fig. 8** Relationship between the polishing time and surface roughness

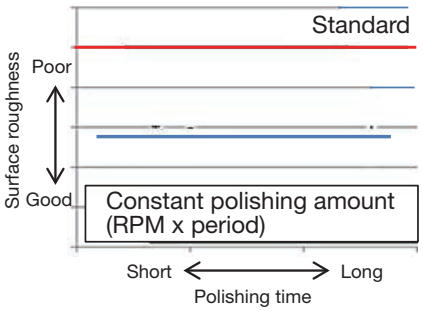


**Fig. 9** Relationship between the polishing amount and surface roughness

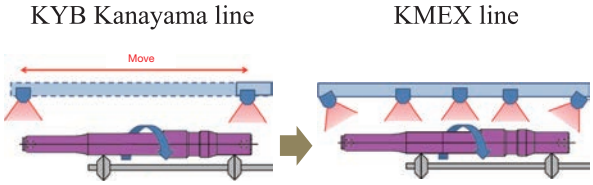


**Fig. 10** Comparison of cleaning methods

## 3 In Closing

After KMEX, we established another shaft line with the same specifications in KYB Industrial Machinery (Zhenjiang) Ltd. (hereinafter referred to as "KIMZ") in April of 2015. With the line establishment in KMEX and KIMZ, we were able to secure the global production capabilities that we had planned. In the future, we will promote cost reduction activities, including local procurement of raw materials.

Finally, I would like to express my the deepest gratitude for everyone involved in this project who provide great support.

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## Editors Script

Recently, I participated in a seminar about "technical tradition.' This is an issue in all companies under the environmental changes such as a low birth rate and aging population and the relaxed education policy. I was particularly impressed by the remark: "people never learn whatever you teach unless the subject is related to their philosophy and purpose of life." Basically, 80% of whether technical tradition is successfully handed down depends on those who are educated. Companies therefore needs to employ excellent human resources who are interested in their technology. I hope many young people become interested in our technology after reading the articles of KYB TECHNICAL REVIEW. (Matsuzaki, Editorial member)

This is the second time I wrote the Editors Script. I have been an editorial member for 5 years and I became part of the furniture. KYB TECHNICAL REVIEW introduces a wide range of contents from new technologies, products and production line, to articles and reports from overseas branches that have been increasing in recent years. These articles transmits passion for products, and sometimes difficulties and pleasure. I myself gain great inspiration while editing this review. It will be a real pleasure for me to be able to help publish articles through the TECHNICAL REVIEW, which can be shared in the KYB Group. I will encourage all departments in the company so that the KYB TECHNICAL REVIEW is read by as many people as possible. (Kamijo, Editorial member)

This is the first time I am in charge of the Editors Script. I'm not sure what I can write here. In this TECHNICAL REVIEW, I was in charge of the editorial by Prof. Fukuwa, who gives us various advice on "quake-resistant damper unit for furniture fall prevention" which we aim to commercialize. As contents of this editorial complies with the current theme, it is very helpful in developing the theme. I would like to receive continuous advice in the future. When I requested him to write an article, he was very helpful in completing it early and sending it to me without being urged.
(Sekine, Editorial member)




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