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Foreword

Artificial Intelligence Will Change Industries

TAMURA Satoshi*

Deep learning is a kind of artificial intelligence (AI) that has rapidly become popular in recent years. By learning enormous amounts of data sets using a multi-layered neural network that imitates the human brain, the technology can execute natural language processing, image recognition and other various tasks with high accuracy. In the history of AI, deep learning has particularly gained the spotlight with its high performance in achieving different tasks including image recognition and natural language processing. This technology is also expected to be further improved and applied to a variety of fields.

Now, what do you feel about the above text after having read through it? The above paragraph is actually that automatically created by AI after I told it to "explain what deep learning is." You probably see the text as if it had naturally been written by a human being, grammatically correct, and properly describing the subject. Next, look at the image in Fig. 1. This is also a piece of graphic that I asked AI to create just with the keywords "automobile", "future", "night", and "Milky Way". Like this, images with a quality that can be compared favorably with those drawn by human beings can be swiftly completed by AI in just several seconds.

Fig. 1 Image drawn by AI

Deep learning has been used not only in research and development (R&D) on natural language processing and image recognition, but also in R&D on speech processing. Familiar examples include voice commands to smartphones and voice interfaces of smart speakers. Furthermore, some have tried to apply deep learning to signal processing or data analysis. These applications have started to be introduced in chemical, medical, and mechanical industries.

Now let me expand on the meaning of the words "Artificial Intelligence", "deep learning", and "Machine Learning" as shown in Fig. 2. First, artificial intelligence (AI) means to artificially implement intelligence at a level equivalent to or even higher than human intelligence. AI covers various fields ranging from fundamental research to application engineering, including the development of humanoids and computer based Igo and Shogi. “Machine learning” is one AI approach. For implementing human learning mechanisms and functions on a computer system, machine learning pursues appropriate

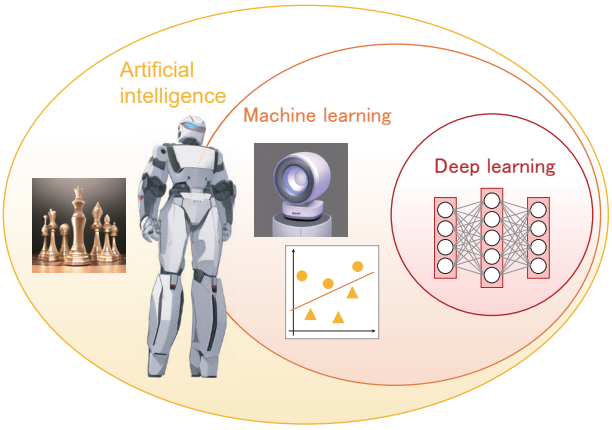

Fig. 2 Artificial intelligence, machine learning, and deep learning

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mathematical models and their algorithms as well as their application. Machine learning is also related to the above mentioned natural language processing, image processing, and speech processing as well as statistics. “Deep Learning” is a type of machine learning that uses a “deep neural network (DNN)” as a mathematical model.

It is in just the last decade that deep learning has rapidly advanced. This was achieved with the proliferation of the Internet and the higher performance of computers, which allowed collection of large amounts of data and high-speed processing of the collected data, although deep learning models themselves had been proposed since olden times. With a focus on industrial applications of deep learning, the following introduces several examples.

Efforts have arisen to implement “Anomaly Detection” to automate and optimize inspection of industrial products or status monitoring of manufacturing machinery.[1)] With this technology, computers can judge products OK or not OK just by scanning their images, thereby enabling systemization of inspection tasks by humans that are quite individual skills. This may eventually alleviate the lack of labor caused by the low birthrate and aging society. Manufacturing machinery can be installed with microphones and vibration sensors for continuous monitoring of operating status, which allows the detection of signs of failures or the performance of machinery maintenance at optimal timings. Plant owners can expect higher availability of production equipment and lower maintenance cost.

Detecting human errors or potentially dangerous tasks in the assembly process will improve product quality and help create a safer work environment. In addition, collecting and analyzing information about employees’ tasks and the traffic line of moving machines and then conducting a PDCA (Plan, Do, Check, Action) cycle to develop and execute an improvement plan will probably improve operations and their efficiency. These efforts are called "Service Engineering". R&D related to such service engineering is underway by leveraging AI technology.[2)] Concrete examples of R&D include an analysis of images captured by monitoring cameras to notify any misoperation or dangerous tasks and an analysis of information obtained from employees' wearable sensors to identify any issues.

Deep learning has the problem that its mathematic models are likely to be a black box and people cannot exactly know the information or logic used by computers in making decisions. Then, to inform people of the behavior of AI, an effort called “Explainable AI (XAI)” has gained attention from the viewpoint of application to industry and medicine.[3)] In a deep learning model for image analysis for instance, the parts of the image focused by the computer in making decisions can be disclosed. Another example is a system to analyze information obtained from many different sensors that is designed to be able to calculate the importance of each piece of information. Furthermore, an attempt is widely underway that will effectively use the findings obtained for developing new industrial products or projecting the effectiveness of drugs.

Promoting these effective uses of AI described above in industry should enhance the possibility of technical innovation and new business development. To do so, “Digital Transformation (DX)” is a must to digitize all information at the site, connect the digital information with AI technology, and establish a new information utilization means in the whole business flow. During the COVID-19 pandemic, we were physically separated from our workplace and became acutely aware of the necessity of DX for online meetings and teleworking as well as for information exchange with sites or among employees. Beyond DX lies AI. Toward the age of living under or even after the pandemic as well as to be able to respond to the world's dramatically changing circumstances, I believe that we need to use AI as much as possible.

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Editorial

Thoughts on the Degradation of Oil

DEGUCHI Mikio*

1. Introduction

The author has been involved in a joint research project with KYB Corporation for several years. The project is intended to develop a sensor that can detect changes in the properties of oil caused by its degradation by using a low-cost simple device. Oil is used in mechanical equipment for various purposes including lubrication, cooling, electrical insulation, and rust prevention. It is also widely used as a working fluid in hydraulic systems virtually everywhere in the world. However, oil gradually changes in property with time as the systems are operated as seen in the familiar example where the engine oil used in automobiles gets black little by little as the mileage increases. Such changes generally progress unfavorably. Therefore, this is called "degradation".

Oil degradation is mainly caused by oxidation and contamination. The degradation appears as changes in various physical parameters.[1)-6)] The degree of oxidation can be evaluated by total acid value but we are focused on "permittivity", which is an electrical parameter that may be relatively highly correlated with total oxidation.

The permittivity of a material can be determined as the capacitance (a parameter indicating how easily the material can charge electricity) between two electrodes filled with the material. Capacitance measurement itself is one of the basic electrical measurement techniques and may be carried out using various methods. In fact, there is sufficient space for exploring an appropriate method for detecting changes in oil properties from various angles. This paper briefly introduces our related efforts and describes my various thoughts about the word "degradation" of oil.

2. What is Permittivity?

The “permittivity” of a material can be plainly described as how easily the material can be electrically drawn. Electricity borne by an object is called "electric charge". Electric charge can be positive (+) or negative (-). It is well known that like charges (positive charges or negative charges) repel each other and unlike charges (positive and negative charges) attract each other. All matter consists of elements that are combinations of atoms as a basic unit. Each atom includes a positively charged nucleus surrounded by negatively charged electrons. In other words, matter contains countless positive and negative charges. Normally, matter has the same amount of positive and negative charges. The center of gravity of positive charges is aligned with that of negative charges. These two types of charges are evenly distributed in the matter as a whole.

When matter is filled between two electrodes and applied with a voltage, the positive charges in the matter are repelled by the positive electrode and attracted by the negative electrode. The negative charges are applied with a force in the opposite direction. As a result, the center of gravity of the positive charges in the matter is misaligned with that of the negative charges. This is called "polarization". Thus, permittivity is a parameter indicating how easily this polarization takes place.

There are several possible causes of polarization. One is that the electron cloud surrounding the nucleus of each atom is attracted by the positive side to cause displacement. This is called electron polarization, which is a phenomenon that always takes place in all matter as long as matter consists of atoms. Some kinds of matter consist of atoms that are divided into positive and negative ions and are bound together by attractive forces between the positive and negative ions. In this case, if a force is applied to the positive and negative ions in opposite directions to each other, the ions each move from a position of equilibrium in the opposite direction, resulting in a positional difference in the center of gravity between the positive and negative charges. This is called ionic or atomic polarization.

Some other kinds of matter originally consist of molecules in which the center of gravity of their positive charges is dislocated from that of their negative charges. Molecules that have originally been polarized are called "permanent dipoles". Matter consisting of permanent dipoles, when viewed as a whole, are not particularly biased in terms of polarity, because the dipoles are usually oriented at random. However, when the positive/negative poles are applied with a force in the opposite direction,

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the dipoles are aligned in a direction parallel with the force. As a result, the matter as a whole is polarized. This is called orientation polarization.

It can be said that the majority of molecules constituting matter consist of permanent dipoles. One typical and familiar example is water molecules. A water molecule consists of two hydrogen (H) atoms and one oxygen (O) atom. Hydrogen is assigned the atomic number 1, which means that it has only one electron. This electron is used to bond to the oxygen atom. This uncovers the positive charge of the nucleus (proton) of the hydrogen atoms to make them positive and the oxygen atom negative. The two hydrogen atoms and the oxygen atom are not aligned in a line but bonded together at an angle of 104.5°. This means that the center of gravity of the positive charge is dislocated from that of the negative one. Therefore, water shows a notably high permittivity among liquids.

3. Detecting Minute Changes in Permittivity

The capacitance between two electrodes is proportional to the permittivity of the insulation between the electrodes. Any change (increase) in permittivity due to oil degradation is as small as several percent at most, although it depends on the extent of the degradation. Furthermore, the electrodes of the sensor only show a small capacitance themselves because the sensor cannot be so large. So, it is necessary to detect tiny changes in such a small value. These minute changes in permittivity may be detected in several ways.

In general, when you try to measure a physical quantity using an electronic technique, you always end up measuring the magnitude of the target quantity in units of voltage or time. A challenge you must eventually overcome is how you can practically convert the magnitude of capacitance into a voltage or time.

For example, it is useful to remember that the voltage between two electrodes can be determined by dividing the amount of charges accumulated between the electrodes by the capacitance between the electrodes. Measuring the voltage between the electrodes when a certain amount of charges is present there will give the capacitance. To accumulate a certain amount of charges between the electrodes, you can just supply a certain amount of current for a certain time. If the current has a known fixed value, you may either supply the current for a certain time to measure the voltage of the charged electrodes or measure the time you need to complete the charging. Anyway, the rate of change in capacitance is very small and is similar to the rate of change of the measurement indicator. When trying to detect any minute change, the measurement performance directly depends on how you can suppress unavoidable noise to ensure an appropriate signal-to-noise (S/N) ratio.

To resolve this challenge, a device should be prepared that can convert minute changes in capacitance into much larger changes in another physical quantity. One of the means to implement this is to make use of “resonance”. Resonance refers to a phenomenon in which a system with a natural frequency (a resonance frequency) is excited at a frequency close to its natural frequency to vibrate with a large amplitude even with weak excitation. In an electric circuit, resonance may occur with a combination of capacitance and “inductance”, which constitute the two major parameters of electromagnetism. Inductance is normally implemented by a coil. A coil is a spiral conductor wrapped around any core. Since capacitance is represented by the letter C and inductance by the letter L, resonance with capacitance and inductance is generally called "LC resonance".

When resonance occurs, the phase relationship between the signal exciting the resonance and the vibration caused by the excitation substantially changes around the resonance frequency. The phase is a quantity indicating the timing at which the vibration swings in whichever direction. Therefore, when phase differences are plotted with the horizontal-axis showing frequency and the vertical-axis showing the phase difference between the exciting signal and the vibration caused by the signal, the curves (representing the phase characteristics) show a steep slope around the resonance frequency. On the other hand, the resonance frequency changes as the capacitance changes. With the frequency of the exciting signal kept at a fixed value close to the resonance frequency, any minute change in resonance frequency can be expanded and

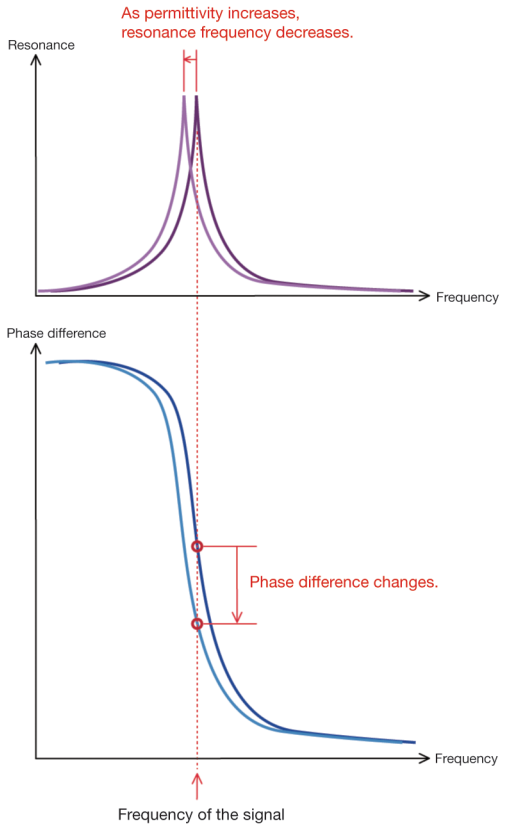

Fig. 1 Principle that a capacitance change is expanded to a change in phase difference and how it is observed

captured as a phase difference because of the steep slope of the curves (Fig. 1).

To enable sensitive detection of changes in capacitance using this method, it is desirable that the phase characteristics curve has a slope as steep as possible at the resonance frequency. When inductance is usually implemented by a coil, however, the coil does not necessarily have components only for inductance, but also those for winding resistance or capacitance between the windings, which can reduce the sharpness of the resonance. Another challenge is that the magnetic field generated by a current flowing through the coil is always expanded to the surroundings because of its inherent nature, leading to an unavoidable problem of interference with the surroundings.

To resolve these problems, we use an electronic circuit to implement the characteristics equivalent to those of the inductance usually implemented by the coil.[7] This does not mean using special electronic devices but only a combination of generally available devices. This circuit is called a General Impedance Converter (GIC) and can virtually convert capacitance into inductance. In the sensor we are developing, we can cause LC resonance to take place between the capacitance of the sensor electrodes and the equivalent inductance with GIC, thereby enabling sensitive detection of very minute changes in permittivity caused by changes in oil property. The GIC thus features the excellent benefit that the whole device can be set up only with general materials at low cost without using special components.

4. Consideration of Oil Degradation

Then, why does the permittivity of oil change (increase) when the oil degrades? One major factor of oil degradation or change in material properties is the oxidation of oil molecules. In other words, the question is why the permittivity of oil changes when the oil molecules are oxidized.

An oil basically consists of a number of combinations of carbon (C) atoms and hydrogen (H) atoms. Unlike water molecules, oil molecules are not permanent dipoles themselves and do not have polarity. This is one of the reasons why water and oil cannot be mixed.

When oil molecules are bonded with oxygen atoms due to oxidation, however, the parts of the oil molecules that are bonded with oxygen atoms will be charged negative. This is because oxygen is located around the top right corner of the periodic table, which means that its atoms have relatively high electronegativity. As a result, the oil molecules will be polarized. With this acting as an additional factor of orientation polarization, the oil molecules will increase in permittivity as a whole.

There are literally many kinds of oil. I find it somewhat strange that countless types of oil are basically made from only two elements: C and H. Incidentally, a computer program is similar to oil in that it also consists of numerous combinations of two types of elements: zero (0) and one (1). Moreover, it is well known that the DNA information of living organisms consists of a sequence of four kinds of bases: adenine (A), guanine (G), thymine (T), and cytosine (C). In fact, these bases can only generate two types of pairs: A-T and G-C. So, the DNA information also consists of only these two patterns of base sequence. In short, all things existing in the world consist of a few or limited number of types of elements. Their characteristics or differences are implemented by numerous combinations of these elements.

In a computer program, 0 and 1 when alone only give the information that they are present there. Then, combining 0s and 1s in a series can represent a meaning as a number or a command. The relationship between the combination and the meaning is not fixed or certain. In language for instance, Japanese is expressed by a combination of 50 notes and English by combinations from a 26-letter alphabet. Even the sound of an identical combination of "a" and "i" may indicate "love" in Japanese or "I" in English.

As human genome analysis has progressed and gene diagnosis technology has advanced, it has become possible to learn which specific diseases you are likely to suffer from in future by examining your DNA. This means that you are now able to understand the meaning of a base sequence of A-T and G-C just by reading it. But I wonder what links the base sequence with its meaning to begin with.

The mechanism by which oil permittivity increases with oxidation is as described above. However, what gave oxygen atoms the property of being likely to be negatively charged in the first place? Of course, this is because oxygen is located around the top right corner of the periodic table, but why do elements located in the top right corner of the periodic table have higher electronegativity? This can be explained through calculation of the electron orbit of atoms based on quantum mechanics as you know, but why are electrons negatively charged to begin with? When you pursue the answer to these questions in this way, you may finally reach a point where nobody can explain what it is all about.

A discipline that pursues the source of matter is particle physics. According to theory, an atom can be divided into quarks, leptons and other elemental particles that have different characteristics. However, nobody can explain why those elemental particles have such characteristics. Different combinations of these elemental particles can constitute various types of atoms or matter, but nobody can explain why a specific combination of the elemental particles forms a specific material or generates the unique property of the material. A familiar example may be metallic elements. The metal with the atomic number 26 is iron and that with the atomic number 29 copper. Iron and copper have obviously different properties. How can you explain the difference in property between the

two metals with different atomic numbers? How could you describe the reason why the element with the atomic number 26 has the property of "iron", not that of "copper"?

I teach my students computer programming. I insistently tell them to always put comments on programs they are writing. The term comment here means words to be added to the relevant parts of a program to explain what is processed in the parts. Comments are made with words describing, for example, what a specific variable here expresses or the meaning of a specific calculation written there. By putting comments on your program, you can re-organize ideas in your mind, being more aware of errors. During writing, you may certainly feel OK with your program while you are thinking in various ways for the program. With no comments, however, you may often forget what made you write this part of the program in this way after a while. In some cases, you might even forget the fact that you wrote the program yourself.

In a computer program in which each line comes with adequate comments, you can ideally read the comments like a series of text describing what the program is processing. In other words, making a program is comparable to writing a paper, as I always tell my students. A program written with alphanumeric characters and mathematical expressions is practically the same as language. Processes of programs can be expressed in words. Machine-level instructions of computer programs consist of combinations of 0s and 1s. Various patterns of a series of 0s and 1s are connected to meaning indicated by their corresponding words.

A specific sequence of 0s and 1s could be reproduced by randomly putting 0s and 1s together. However, such a sequence is made by chance and does not have any specific meaning. For computers, programmers intentionally create a pattern of 0s and 1s to represent the meaning of the program. By using the means of different combinations of elements, programmers can express their intention.

As mentioned above, is it known that base sequences of DNA have their own meaning and the combination including 26 protons, and 26 electrons indicates an element having the properties of a metal called "iron". These are the facts in the real world. Any combinations made by chance should not have any meaning. If such a combination has a meaning, this is contradictory to the assumption that the combination was made by chance. Given that the words "by chance" or "randomly" denote that a thing takes place with no reason or no cause-and-effect relation, evolutionism is an incoherent theory in this sense.

Anything with meaning should involve an entity who has given the meaning as in computer programs that always involve their programmer. The entity who has given the meaning must be a being with intelligence as in the programmer who exercised their wits to create the program. The "meaning" of things is usually expressed by "words". Let me here collectively call "meaning" that can not necessarily be expressed by voice or text (so-called language) "words". Without these "words", all matter in this world is just random assemblies of atoms and molecules.

The Bible says, "In the beginning was the Word". The beginning of the Bible also includes the phrase: "In the beginning God created the heavens and the earth". In Japan where Bible-based philosophy has seldom been proliferated in the local culture, the term "God" (Kami in Japanese) may remind people of somewhat "cheap" words such as Kamiwaza (literally meaning acts of God) or Kamitaiou (super-excellent response). God in the Bible in turn refers to the Creator. The famous phrase "In the beginning was the Word" is followed by "and the Word was with God, and the Word was God". Namely, what created heaven and earth (the Creator) is the Word itself. The Bible declares that the meaning of everything can be sourced to the Word, that is, God.

Even if the base sequence of DNA accidentally represents the DNA pattern of human beings, no living human being could have been created without the “Word” of "life". I heard that 23 types of amino acids were found in asteroid samples brought back by the Japanese space probe Hayabusa. Amino acids are just a small part of the components of the human body. Without activation of a program (i.e., words) to select and combine the necessary parts (levorotatory amino acids), no human body can be created. Even if a human body could be created by this method, it would just be a physical object called a human body without "life" breathed in.

People, particularly Japanese who have grown up with education heavily centered in Evolutionism, usually have no idea about the Creator. This is noted as "original sin" by the Bible. However, the Bible says, "God saw everything that he had made, and behold, it was very good". What was very good when God created heaven and earth changed, which means that everything tended to get worse. When oil changes in property due to oxidation, the phrase of the Bible is elicited as the "degradation" of oil.

The Bible also says, God created man in “his own image". In other words, man was created to concretely express how wonderful the wisdom of God is and how glorious the nature of God is. This can explain the decisive differences between human beings and other animals that can obviously be recognized in the real world. Some species of plant have beautiful flowers. They may come into flower for the purpose of attracting insects for easier pollination. But, if that is the only purpose, do they have to be decorated with those petals that all differ in color, pattern and shape? We feel a sense of beauty when we see flowers. This is because we are what God created in his own image. Is there any other reason?

There is one thing that I have long doubted. Music, especially Western music, may be played in a major scale or in a minor scale. Music played in a major scale generally sounds bright and cheerful while that played in a minor key sounds depressing or sorrowful. The only difference in main chords between the major and minor scales is the third note, i.e., half-tone higher or not. I wonder why these notes sound cheerful or sorrowful just by slightly changing the note pattern. We, as human beings, have been connected to a program (words) that can make us have such specific feelings in response to particular patterns of notes. I cannot understand this in any other way. We can be moved by or feel beauty from a piece of music because we were created by God in his own image. Is there any other reason?

We, who used to be "very good" in the beginning, became unaware of the Creator because of our own "sin". However, the Creator had known very well from the beginning that we would become so. We do not have the capability of making amends for our own "sin". The Bible says, "the wages of sin is death". We were separated from the Creator because of “sin”. As a result, our body "deteriorates" with time and eventually dies. We cannot do anything about this fate ourselves. Then, the Creator prepared an astonishing plan to resolve our fate. That is, behold, he planned to come to the earth as a human being, and to die as a scapegoat for us. This was implemented by Jesus Christ about two thousand years ago. Furthermore, he died by Crucifixion on a cross, which was probably one of the most barbaric ways of dying. Still, the death was beyond his death as he was the Creator. He still exists with the phrase, "I am who I am".

Apostle John, who directly saw Jesus Christ and lived together with him for a while, wrote in the gospel-book, **"For God so loved the world that he gave his one and only Son, that whoever believes in him shall not perish but have eternal life".**

Of course, the only Son here means Jesus Christ himself.

John also wrote in the letter: **"Whoever does not love does not know God, because God is love.**

This is how God showed his love among us: He sent his one and only Son into the world that we might live through him.

This is love: not that we loved God, but that he loved us and sent his Son as an atoning sacrifice for our sins".

In other words, man was created by God "in his own image" to concretely express "God is love" as a visible form to all.

If you believe in Evolutionism assuming that God is nowhere, the oil should change in property with time as you use it, and amino acids should be generated at some point in time, leading in the end to the birth of life. You may believe that oil "evolves", not "deteriorates". All materials necessary to make up amino acids are available: C and H contained in oil and O and N available in the air. Then, assuming that life was created by chance from these materials, does that life-form have “love” on earth?

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Technology Introduction

Technology for Detecting the Orientation of Oil Seal

TURUMI Takuya

1 Introduction

Recent production sites are required to automate their inspection process due to higher product quality requirements and reduced work force. In KYB, the Production Technology R&D Center and Production Engineering Department are jointly promoting the development of inspection technologies to automate the inspection process. Among those is the development of an automatic inspection technology to replace human inspectors allocated to the manufacturing process of oil seals (hereinafter "seals") that are one of the components of shock absorbers (hereinafter "SA"). The technology has been introduced in mass production. This paper describes the overview.

2 Purpose of Development

The purpose of the technical development is to automate the inspection process for inspector labor saving. A technology for detecting the orientation of the insertmetal (hereinafter the "metal"), which is one of the seal components, has been developed.

Human inspectors are allocated to the process of checking finished seals. The inspection technology we have developed is introduced into the process that may be the source of reversed metals, not the process of checking finished seals, with the aim of reducing the loss caused by non-conformities.

3 Target Parameters of Development

The target parameters for inspection capability and time were set as shown in Table 1. Evaluation error means recognizing a non-conforming item as a conforming one by mistake. In case of an evaluation error, non-conforming items will be released to the subsequent process, which may lead to claims in the market. Contrary to evaluation error, over-inspection refers to recognizing a conforming item as a non-conforming one. Over-inspection prevents work from being released to the subsequent process, resulting in a halt in the production. This eventually leads to lower productivity. The target inspection time was set based on the current visual inspection time of human inspectors to prevent worsening of the cycle time.

Table1 Target parameters of development

	Evaluation error [%]	Over-inspection [%]	Inspection time [sec.]
Target	0.000	Not more than 0.3	Not more than 2.1

4 Outline of Target Part

Photo 1 shows an enlarged view of the SA and seal assembly, the seal to be inspected, and the front and reverse sides of the metal.

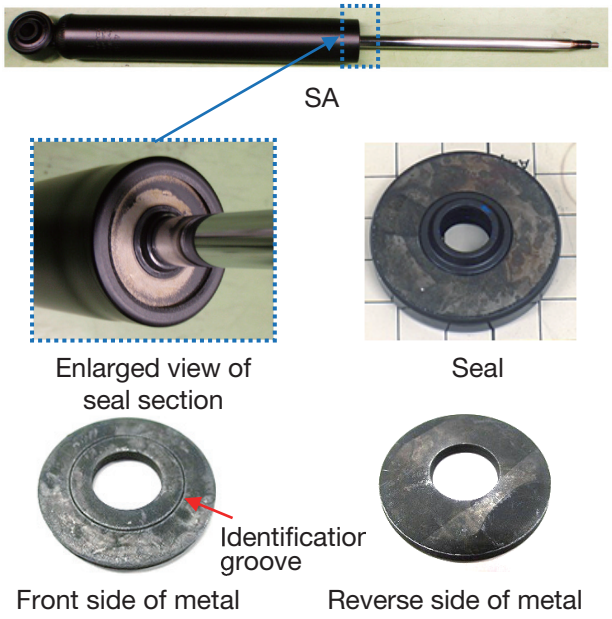


Photo 1 SA, seal, and metal

The seal is a part for preventing oil leakage through the sliding part of the piston rod of SA. The metal, which is one of the seal components, is molded integrally with rubber material to form the seal. The metal has front and reverse sides that can be differentiated from each other. Molding the metal into the seal with its wrong side up will result in a higher risk of oil leakage. To prevent this, the metal has an identification groove on one side. In this

document, the side of the metal with the identification groove is called the front side.

5 Overview of Process with Inspection Technology Introduced

The inspection technology was introduced into the process in which human operators manually set metals and rubber pieces on the jig [Note 1)] before molding. Photo 2 shows the work bench and jig in the target process. The work bench had to be replaced by a device for automated inspection.

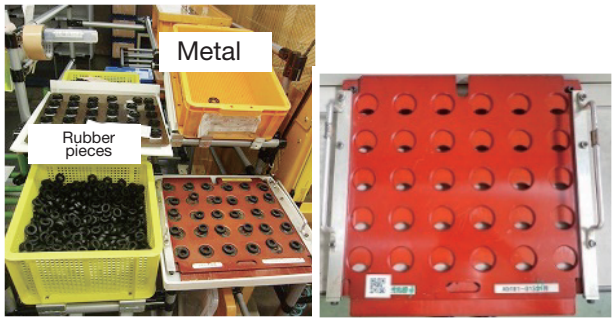


Photo 2 Work bench and jig

The operator puts the jig on the work bench and sets metals with the side with the identification groove facing up in the circular pockets one by one. Then, the operator places rubber pieces on each metal and sets the jig in the molding machine.

Note 1) The jig is used to set metals and rubber pieces in the molding machine.

6 Details of development

6. 1 Inspection Method

The inspection used an image processing system that can not only capture images from a position where the system cannot obstruct the operator but also examines all metals on the jig at a time. It was decided to determine whether the metals are front or reverse facing through image processing, superficially by detecting the presence of the identification groove, which is the most distinctive feature among the differences between the front and reverse sides.

6. 2 Inspection System

Fig. 1 shows an example of the configuration of the inspection system. Internally built communication software was used to transmit signals from the image processing and inspection software to the digital I/O board within the inspection PC. The digital I/O board and PLC [Note 2)] were interlocked so that metals could not be released to the subsequent process unless they passed the inspection.

The image processing and inspection software has inspection, calibration, and set-up modes as described later. The software was designed so that the calibration and set-up modes can be switched over with a push-button switch.

This loop-running inspection is automatically started when the operator's hand leaves the imaging area.

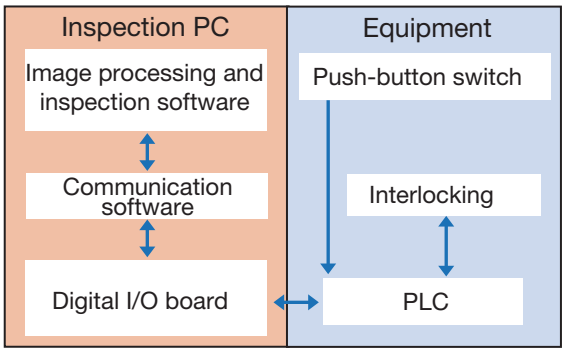


Fig. 1 Configuration of inspection system

Fig. 2 shows the flow chart of operation of the inspection software that was introduced in mass production:

Note 2) Acronym for Programmable Logic Controller.

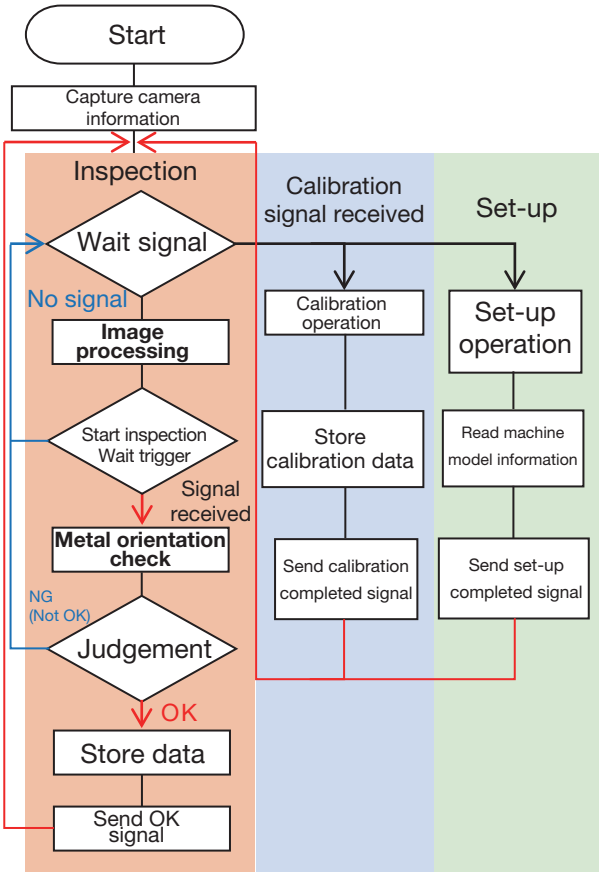


Fig. 2 Flow chart of software operation

In mass production, the push-button switch can be used to switch the operation mode from inspection to calibration or set-up. Inspection mode is run in loop and does not need to be started up with the switch. The system is configured to trigger the inspection when the operator's hand leaves the imaging area, and the molding machine has work in position. The image processing

technology is used to locate the operator's hand and determine whether work is set in the machine or not.

This paper focuses on introducing the metal check (front/reverse side) in the flow chart.

6. 3 Optical Equipment

Photo 3 shows the actual inspection machine. Fig. 3 shows the general layout of the optical system. This optical system consisted of a camera and two lighting units. The camera was installed directly above the jig at a height where the camera could not interfere with the operators. The resolution of the camera and its lens were selected to enable the detection and imaging of the identification groove of the metals set in the jig. The lighting units were located in such a manner that allowed irradiation of the whole area of the jig from the right and left sides.

Photo 3 Actual inspection machine

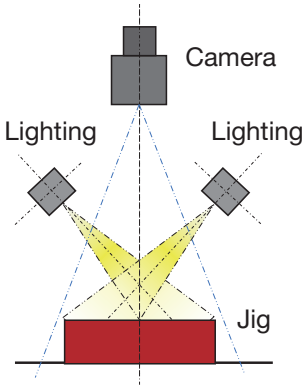
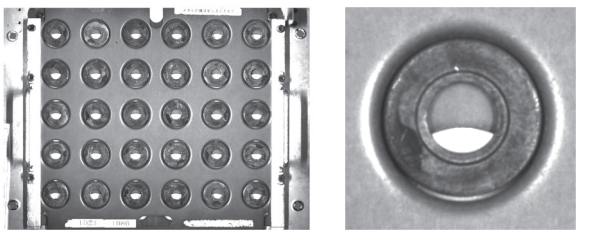


Fig. 3 General layout of optical system

Photo 4 shows images captured by the system on the actual inspection machine. Conditions for the inspection were set under the constraint that the layout of the lighting and camera system was limited by the equipment layout of the production line.

The inspection machine is likely to be affected by disturbance light because the machine cannot be covered with blackout curtain as this may lead to workability deterioration and the ingress of contaminants during molding. Then, an inspection algorithm has been developed that is unlikely to be affected by these factors.



Entire image　　Enlarged view of image

Photo 4 Images

6. 4 Inspection Algorithm

6. 4. 1 Flow of Image Processing and Inspection

Fig. 4 shows the general flow of the processes from image capturing to inspection.

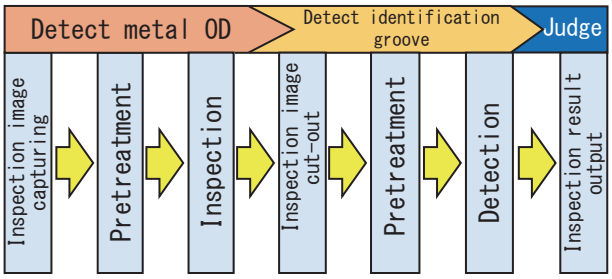


Fig. 4 General inspection flow

After an inspection image is captured, the outside diameter of the metals is detected to determine the position and number of metals. Then, only the area around the circular identification groove of each metal is cut out to allow detection of the groove. The number of grooves is compared with the number of metals to make a judgement. When these numbers match, "OK" is displayed. When they do not match, "NG" (Not OK) is displayed along with the location of the NG metal(s). For NG, the operator flips the reversed metal(s), automatically turning NG into OK.

6. 4. 2 Pretreatment

In practice it is difficult to directly detect the identification groove on the captured image. So, the image must be processed to highlight the features to be detected. In this project, a band-pass filter was introduced. The band-pass filter passes frequencies within a certain range and is used to extract the outside diameter and identification groove. As shown in Photo 4, the contour of the metals on the jig and their identification groove appears darker than the surroundings. The contour (outside diameter) and identification groove of metals can be extracted using the band-pass filter.

There is a difference in gray value [Note 3)] between the contour of the metals on the jig and their identification groove and the surroundings. This difference is considered unlikely to greatly diminish even if the metals are affected by disturbance light. So, the use of the band-pass filter allows the detection of elements of the outside diameter and identification groove of metals without being substantially affected by disturbance light.

The band-pass filter was applied with commands that had been prepared in the image processing software.

Note 3) The level of brightness. The white-to-black level is given by a number between 0 and 255.

Photo 5 shows an example of an image captured before treatment and another subjected to processing with the filter and automatic binary processing that allocates black or white to individual pixels according to their brightness. In the image after treatment, the areas in white indicate the parts that were extracted by the pro-

cessing. Hereinafter the band-pass filter processing and the automatic binary processing are collectively called the pretreatment.

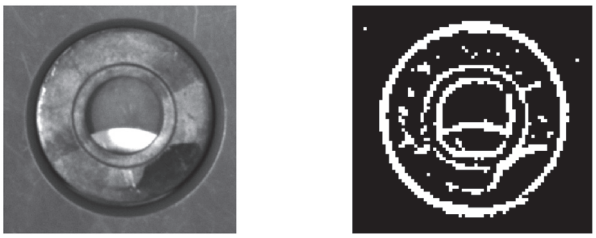


Photo 5 Images before and after image processing

6. 4. 3 Detection Method

Feature extraction from images subjected to pretreatment was done with the Hough transform technique. The Hough transform is a feature extraction technique used in image processing and can be used to detect lines and circles in the image. Circle detection finds any circles within the target image that match the diameter information that has been given in advance. If an applicable circle is found, the coordinate of the center of the circle is detected. In this project, the outside diameter of the metal and the diameter of the identification groove indicated in the drawing are used as the diameter information to be given to the system.

6. 4. 4 Detection of the Outside Diameter of Metals

The outside diameter of the metals is detected in the captured images that have been subjected to pretreatment and the Hough transform in terms of the outside diameter. Photo 6 shows an image after the band-pass filter processing and another image after the Hough transform in terms of the outside diameter. The dots in red appearing in the image subjected to the Hough transform are the dilated center points of the metals. The automatic inspection system determines the number of metals by counting the number of these red dots.

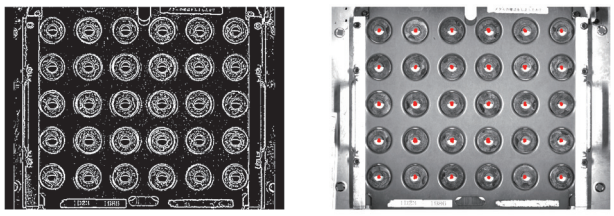


Photo 6 Metal outside diameter detection process

6. 4. 5 Detection of Identification Grooves

Photo 7 shows inspection images of the identification groove. This inspection uses the center of the circle detected by the Hough transform of the metal outside diameter. From the image, a rectangular section is cut out in dimensions larger than the diameter of the circular identification groove indicated in each drawing. Then, the images shown in right of Photo 7 are obtained as many as metals are captured in Photo 4. Each of the cut-out images is subjected to pretreatment and then the Hough transform in terms of the diameter of the circular identification groove. This will detect the identification grooves. Photo 8 shows an image after the pretreatment and another image after the Hough transform in which the center of the circle has been detected and dilated. The number of identification grooves can be determined by counting these center points.

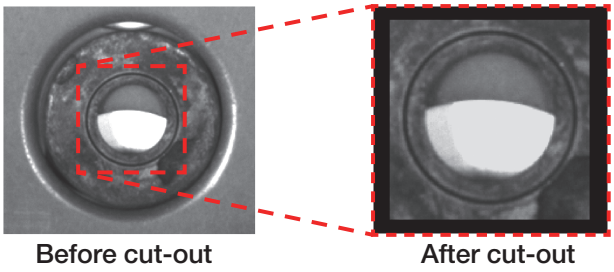


Photo 7 Cut-out inspection images

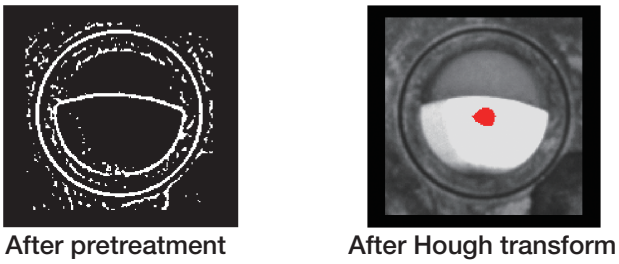


Photo 8 Detected identification groove

6. 4. 6 Evaluation

After detection of the identification grooves has been completed, the inspection results should be evaluated. Evaluation criteria have been established so that the jig passes the inspection (OK) when the number of metal outside diameters detected matches the number of identification grooves while the jig fails the inspection (NG) when it does not. For mass production machines, the jig is locked and cannot be taken out of the work bench as long as the result is NG. The jig cannot be released from the work bench until the result is turned to be OK.

7 Results of Development

The results of the evaluation of the inspection capability are shown in Table 2. 62,000 parts currently in production were used in the evaluation of the inspection capability during the period between January 8 and February 1, 2022.

Table 2 Results of evaluation

	Evaluation error [%]	Over-inspection [%]	Inspection time [sec.]
Target	0.000	Not more than 0.3	Not more than 2.1
Result	0.000	0.005	2.0
Evaluation	○	○	○

The targets for all the items were achieved.

The automatic inspection system was introduced in April 2022. Inspection labor saving, which was established as the purpose of this development project, was achieved.

8 In Closing

This project successfully developed technology for detecting the orientation of oil seal metals. The following summarizes the project:

(1) The inspection was made during the process for setting metals in the jig.
(2) The presence/absence of the identification groove was identified by image processing for inspection.
(3) The inspection algorithm included edge detection with the band-pass filter and circle detection with the Hough transform.
(4) The inspection capability was proven for mass production with an evaluation error rate of 0% and an over-inspection rate of 0.005%.
(5) he inspection time was maximum 2.0 seconds, which is equivalent to the visual inspection time for human operators.
(6) The technology was introduced in mass production and inspector labor saving was achieved.

The inspection technology described in this paper can be applied not only to the detection of the identification groove of the metals but also to other inspection processes with circle detection such as for assembly error of circular parts.

Finally, I would like to take this opportunity to sincerely thank all those concerned who extended cooperation to this development project.

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Engaged in development of appearance inspection technology.

Technology Introduction

Incorporation of Processing of Base Plates for Piston Motors into FMS Lines

HANAEDA Ken

1 Introduction

As excavators in the Chinese construction equipment market have become larger, there has been a demand for boosting production of large excavators. Under this situation, KYB Corporation has received more orders for piston motors (Fig. 1) manufactured in its Sagami Plant (Fig. 2). It was decided to establish a plant-wide production system in Sagami Plant, requiring enhanced production capacity for the base plate (the part in red shown in Fig. 1). Another demand was to reduce the selling price while needing to develop competitive products. To increase the profit margin, it is essential to carry out activity to reduce the cost of the base plate that accounts for a substantial proportion of the product cost.

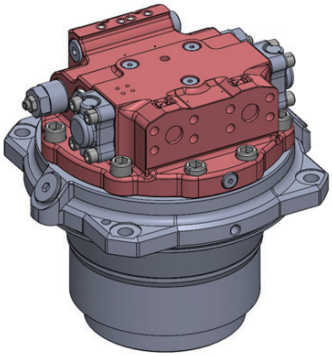

Fig. 1 Piston motor

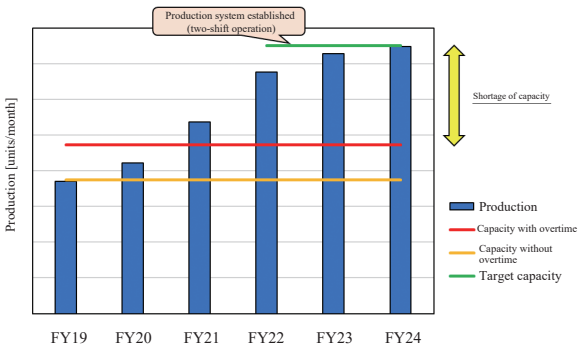

Fig.2 Projected production of base plates and production capacity

2 Purpose

To achieve the target manufacturing cost of the cost reduction activity and to establish a new production system for base plates.

3 Targets

- Manufacturing cost	Down 22%
- Base plate production capacity	Up 66%

4 Requirements

[1] To cut back capital investment by optimizing production lines.
[2] To implement preventive maintenance using sensing technology and internal automatic evaluation of machining centers.
[3] To ensure the process capability for precision deep hole drilling.

5 Overview of Lines

The base plate processing line consists of a machining process with machining centers (hereinafter the "MC") and a finishing process including deburring, inspection, honing, surface grinding, and jet cleaning. Among these, the MC machining process may use the serial (Fig. 3) or parallel (Fig. 4) processing line configuration depending on the number of types of work. These lines have the following features:

[1] Serial line

Fast processing line with less set-ups for limited types of work.

[2] Parallel line

FMS-based Note1) line with less set-ups for a variety of work. The use of FMS allows the production of many different parts and unattended operation. Fig. 5 shows the FMS operation screen.

Note 1) Acronym for Flexible Manufacturing System.

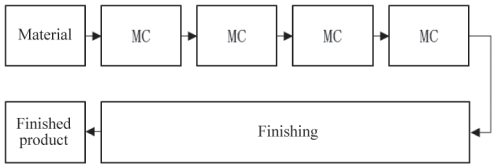

Fig. 3 Overview of serial processing line for base plates

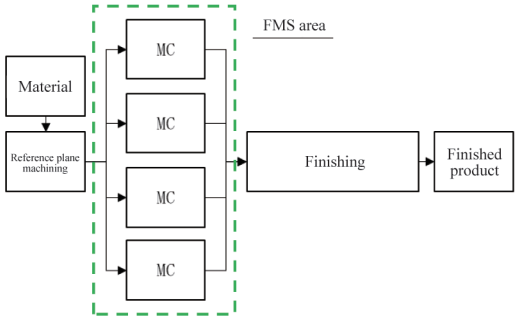

Fig. 4 Overview of parallel processing line for base plates

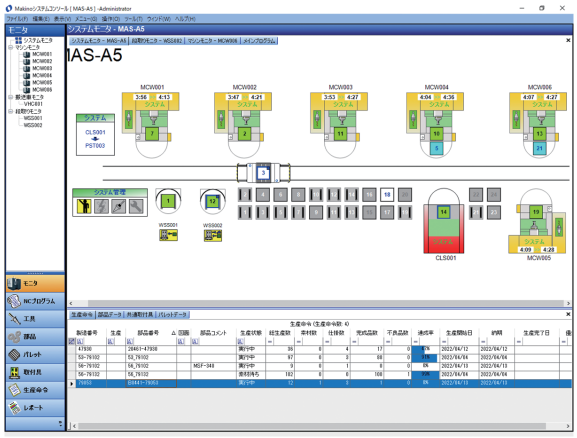

Fig. 5 FMS operation screen

6 Implementation

6. 1 Optimization of Production Lines

6. 1. 1 Overview of Improvement

To establish a base plate production system, an approach was introduced that added two more MCs to the existing parallel line to achieve the target cost and the target production capability. Before deciding on the approach, two proposed approaches were compared with each other: one was to add equipment to the existing serial line and the other to add equipment to the existing parallel line, because building a brand new line required huge capital investment.

6. 1. 2 Results of Comparison of Proposed Approaches

Table 1 shows the results of the comparison. The serial and parallel line approaches had their own advantages and disadvantages and both approaches could satisfy the target production capability. In this project, the parallel line approach was selected because it was judged to be able to satisfy the target cost with a minimum number of equipment units with no time loss for dividing the processing time.

Table 1 Comparison of proposed approaches

Item		Mark	Proposal [1] Serial line	Mark	Proposal [2] Parallel line
Characteristics		—	Fast line with less set-ups	—	FMS-based line with less set-ups for a variety of work
Machine model		—	MSF-340 *One model	—	MAG-14 to MSF-340 *11 models
Quality	Quality	×	Positioning is required in each process. Some processes cannot be divided to ensure the precision requirements.	○	Single-chuck machining. Not so affected by the positioning accuracy.
Cost	Additional equipment	×	3 units	○	2 units
	Extra personnel	—	+1 person/shift	—	+1 person/shift
	Manufacturing cost	×		○	
Productivity	Processing time	×	Division of processing time causes time loss	○	No division of processing time, no time loss Minimum tool changes
	Set-up	○	A single product requires no extra set-up	×	Extra small set-ups in finishing process
	Initial and final pieces check	○	Only parts machined in the relevant process to be measured	×	All machined parts to be measured in each equipment unit
	Piecework	○		×	
Others	Advantages	—	Less vulnerable to process trouble	—	Relatively easy to increase capacity with additional equipment
		—	Simple physical and information flows	—	Easy to implement unattended operation due to long processing time
Total evaluation		×		○	

6. 2 Automation of Jig Inclination Measurement and Automatic Internal Evaluation

6. 2. 1 Current Problems

The base plate is subject to a stringent tolerance for the squareness between the reference plane and the bearing bore. To maintain the accuracy, it is essential to always achieve the squareness of work to the MC spindle (Fig. 6). Conventionally, operators have tried to ensure the accuracy by manually measuring the accuracy of the MC spindle and jig. However, such manual measurement involves destabilizing factors including misadjustment, mismeasurement and forgetting to measure.

6. 2. 2 Automatic Measurement Using Touch Sensor

Higher capital investment leads to higher cost. Then, we built a software program to automatically measure displacement and evaluate equipment accuracy by using the touch sensor installed in the MC process. The following describes the measurement flow and Fig. 7 shows the flow chart of the measurement program.

[1] If the last accuracy measurement was in the previous month or earlier, proceed to the measurement sequence (monthly measurement)

[2] Using the touch sensor, measure the reference plane of the jig that is clamping work (Fig. 8).

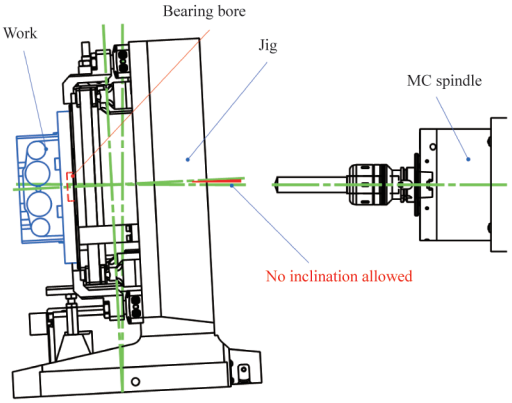

Fig. 6 Positional relation between work and MC spindle

[3] If the measurement result is within the specification limits, proceed to the machining sequence. If the result is out of the limits, issue an alarm to urge operators to take remedies.

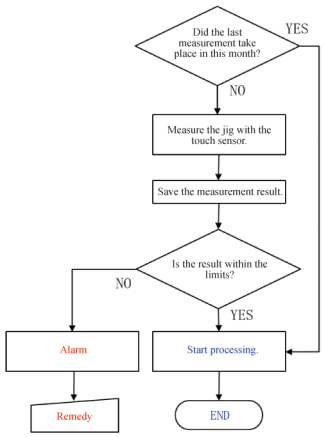

Fig. 7 Flow of measurement program

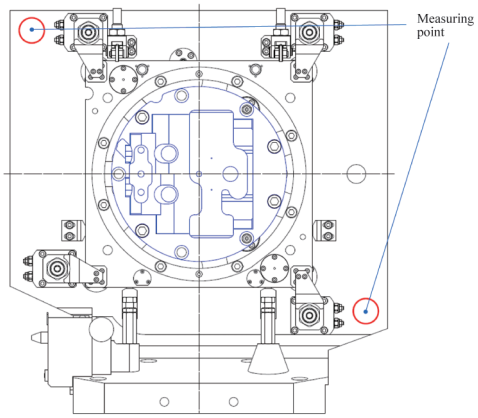

Fig. 8 Measuring point of touch sensor

6. 2. 3 Verification of Proposed Approaches

We compared the measurements of actual work with the jig specifications because we could not directly measure actual work. We determined that the measurements satisfied the work specifications when they met the jig specifications (Fig. 9).

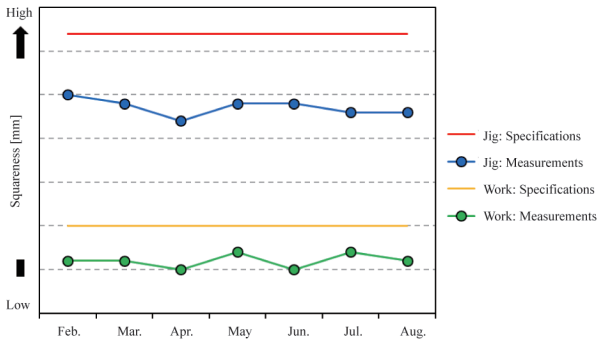

Fig. 9 Relation of measurements between jig and actual work

6. 3 Ensuring Process Capability by Improving the Honing Stone

6. 3. 1 Current Problems

The spool bore, which is an important part of the base plate, is roughly machined in the MC process and then finished by the honing machine. In the initial quality check, however, the process failed to meet the spool bore cylindricity requirements. A comparison of cylindricity before and after honing revealed that the cylindricity actually worsened after honing (Figs. 10 and 11).

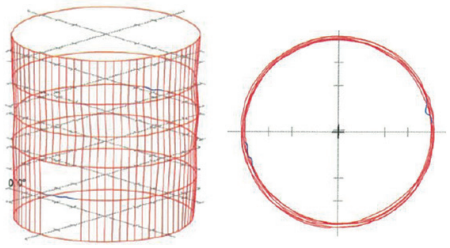

Fig. 10 Before honing

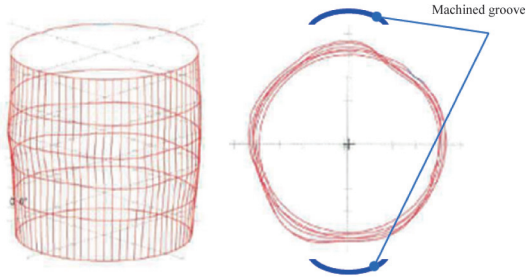

Fig. 11 After honing (before improvement)

6. 3. 2 Causes of Lower Honing Accuracy

A cause investigation identified two possible causes of lower honing cylindricity:

[1] Bore profile specific to the base plate

Fig. 12 shows the cylindrical section of the spool bore. Problems occurred in the parts c and d in Fig. 12. In the relevant parts, the circumference of the circle is partially grooved. The presence of the machined grooves affects the processing area, resulting in substantial variations in cutting load.

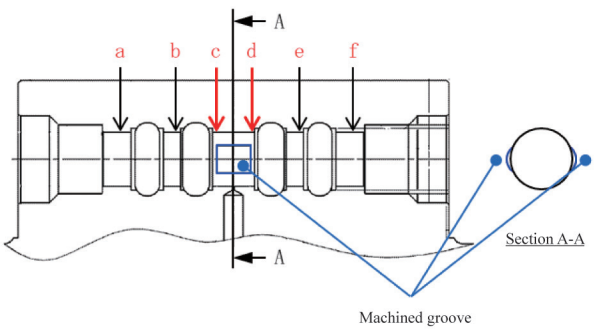

Fig. 12 Section view of spool bore

[2] Hardness of the bond of honing stones

Adjustment work must be carried out every time the honing stone is replaced. So, a relatively hard bond has

been conventionally used to extend the stone change cycle. While the service life of the stone has certainly been longer, the self-sharpening effect has been reduced, worsening the honing performance.

6. 3. 3 Improvement of Working Accuracy by Changing the Stone Bond

As mentioned above, there has been a conventional tendency that relatively hard bond is used to extend the stone life. To address the problem that dull stones are used to hone the parts with substantially variable cutting load, it was decided to use a softer bond. The use of softer stone bond improved the self-sharpening to ensure that new abrasives are always exposed. This has improved the honing performance, achieving stable processing not depending on the work profile.

6. 3. 4 Verification of the Proposed Approaches

A verification of the accuracy after improvement has determined that the cylindricity has been substantially improved (Fig. 13). Furthermore, a quality check after continuous processing (N = 20) has determined that the cylindricity, which had been around the upper limit of the specifications, was substantially improved, satisfying the process capability requirements (Fig. 14). Despite the concern with the softer bond, the stone adjustment time per replacement has been shorter. The total tool change time has remained the same because the frequency of stone replacement has increased.

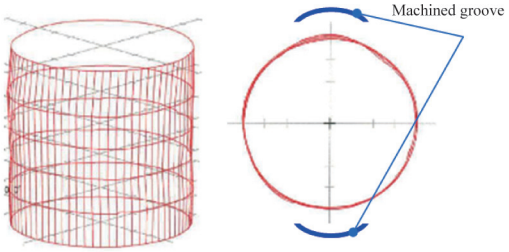

Fig. 13 After honing (after improvement)

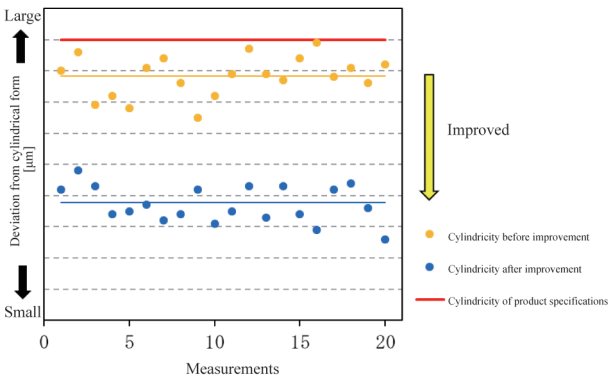

Fig. 14 Cylindricity before and after improvement

7 Results

Table 2 shows the results of the improvement.

Table 2 Results of improvement

Item	Target	Result	Evaluation
Manufacturing cost	Down 22%	Down 19%	×
Production volume	Up 66%	Up 64%	△

Possible causes of failing to achieve the targets are:

[1] Higher manufacturing cost due to lower availability

A major cause of lower availability was that work waiting for finishing had to be temporarily placed at the point where several types of work join after the FMS area. To improve the situation, we plan to install shelves for work waiting for finishing. This improvement is expected to help achieve the target.

[2] Deviation from the initial production plan

The reason for failing to achieve the target production volume was that the initial production plan for the target month for evaluation was not achieved. Still, the target production capacity was achieved.

8 Conclusions

We have successfully implemented stable preventive maintenance using a new measurement method, thereby establishing a product satisfying the process capability which was conventionally difficult to achieve. From now on, we will carry out activities that can develop preventive maintenance into predictive maintenance based on accumulated data and will also continuously improve the availability whose target has not yet been achieved.

9 In Closing

Finally, I would like to take this opportunity to express my appreciation to the related functions that extended cooperation in building the production line as well as those who extended guidance and support to us.

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Technology Explanation

Use of AI Technology in Development of SA Elements

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Abstract

Although there has been a third AI (artificial intelligence) boom in recent years, few organizations in the world have been able to gain competitive advantage through the use of AI.

In addition, KYB is focusing on the development of sliding parts for shock absorbers (SA) to achieve both ride comfort and maneuverability at a high level. In order to carry out this development efficiently, we have been providing data-driven support for the development of SA fluid.

This paper introduces the SA Element Development x AI initiative led by Digital Transformation Improvement Dept for these reasons.

When utilizing digital technologies such as AI, it is important to carry out data quality control and provide user-friendly applications. Therefore, we have constructed a platform to safely manage and operate the driving test data collected during the evaluation of developed SA products in auto vehicles, and developed an application to easily search and analyze the data managed by the platform.

With this platform at our disposal, we can now focus on driving tests and data analysis, freeing us from the laborious data management tasks that used to be necessary.

We are already using this platform in some auto vehicle evaluations. Data useful for future SA development is being accumulated in the platform, and we feel that we can realize a sustainable data-driven system to improve development capability.

This paper describes AI-based frequency analysis technology that is the result of joint research with universities, along with the technology and philosophy behind the AI services that utilize such frequency analysis technology for further development, and data analysis platform thus constructed.

1 Introduction

We have been experiencing the third AI boom in recent years. Companies and research institutes throughout the world have addressed social implementation [Note 1)] of AI technology to resolve challenges in all fields.

Of the companies who have introduced AI, not less than 60% are still at the stage of Proof of Concept (PoC). An investigation[1)] has revealed that only 12% of organizations in the world have been able to gain competitive advantage through the use of AI.

Major reasons why they have not been able to actively promote the use of AI are:

[1] they have no proper knowledge and technology of AI, and

[2] they have not constructed a platform for AI operation.

Item [1] implies that they cannot step ahead out of the PoC as they are not able to determine whether their challenges should be resolved by AI or not. In KYB, that is why Digital Transformation Improvement Dept is addressing an AI human capital development activity [Note 2)] for employees to learn not only AI technology but also how to set challenges (for more information, refer to "Initiatives to Develop Digital Human Capital" included in this issue of KAYABA Technical Review).

Item [2] above leads to cases where they cannot proceed to the operation phase because the development of AI technology has advanced without establishing a system to collect and manage the necessary data for AI learning. In addition, there may be another case of failing to utilize AI. AI technology can originally prove its worth when combined with other digital technology, which finally resolves issues. However, optimal solutions or services may not be proposed for lack of knowhow on other necessary technologies.

This paper explains the SA Element Development x AI Initiative, rather than describing the human capital development.

Recently, KYB has been focusing on the development of sliding parts for SAs to achieve both ride comfort and maneuverability at a high level [2),3),4)]. Digital Transformation Improvement Dept has provided data-driven support to the development of hydraulic fluids since its foundation in 2019. Specifically, the Department has analyzed the driving test data collected for fluid evaluation using a variety of analysis approaches to compare the developed fluid with conventional ones for verification. Based on the results of the data analyses, the Department has supported the creation of ideas about evaluation techniques and product development.

The analysis approaches that the Department has adopted for trial include frequency analysis using deep learning, which is one of the latest AI technologies. Several analysis approaches including this AI-based analysis method have turned out to be useful for the future development of SA elements. To establish a sustainable data-driven system to improve the development capability, we have developed a “platform”, “application software”, and “AI services”, which will be described in the following chapters.

Note 1) To apply and develop results of research to resolve social issues.

Note 2) KYB prefers to use the term "human capital " instead of "human resources".

2 Requirements

In this development activity, we have constructed a platform for implementing centralized management of driving test data including data retrieval and analysis.

The construction of the data analysis platform focusing on “data quality control” and the development of user-friendly data analysis applications were applied with the following requirements.

2. 1 Data Analysis Platform

The requirements to ensure data quality control are:

[1] Collected driving test data shall be standardized and able to be saved in the platform.

[2] Records of test conditions and other descriptions on the data in item [1] above shall be standardized and able to be saved in the platform.

[3] Driving test data shall be linked to the test conditions and able to be managed on the platform.

[4] Data pretreatment including the linkage above shall be able to be automated.

[5] No tampering or loss of data under management of the platform shall occur.

The driving test data has been standardized in such a manner that sensor measurements are saved in the same format irrespective of who carried out the measurement by using a dedicated logger that was developed for standardization of vehicle measurement and that automated data processing and permanent data management on the platform have been implemented by effectively using Amazon Web Services (hereinafter "AWS"). We have also developed a test condition recording application with which anyone can record test conditions in the same format using the same wording. Details of the application will be explained in the following chapters.

2. 2 Data Analysis Application

Data can deliver its value only after it is analyzed and utilized for decision making. The following describes the requirements for the “automatic analysis reporting application” that has been developed to be generally used for any kind of driving test.

The application shall:

[1] allow for retrieval of data to be analyzed,

[2] allow data analysts to automatically create graphs that may be frequently referred to,

[3] be able to promote the use of AI and Business Intelligence (BI) and to support idea creation,

[4] be able to be intuitively operated, and,

[5] be stably operated.

The easy-to-operate application we have developed can provide several functions including “data retrieval”, “analysis reporting”, and “support to idea creation”. With consideration given to the micro service[Note 3)], the application was redesigned not to affect other functions during modification of some functions. This application uses AWS to ensure stable operation. The following chapters provide details of the application.

Note 3) An engineering method that divides a single application into small services to enhance the development efficiency and minimize the affected range.

3 Overview of Data Analysis Platform

3. 1 System Configuration

Fig. 1 shows an overview of the system we developed. The. system constructed on the AWS cloud is designed to implement data collection, saving, visualization, and analysis.

3. 2 Data Collection

For proper analysis of the driving test results, it is necessary to appropriately link and manage measurements of the driving test data to the spreadsheet meta data recording the test conditions. Thus, this system has a data collection line for the driving test data and another line for the meta data.

The driving test data is measured using a dedicated logger developed with KYB's smart road monitoring system[5)]. Unprocessed driving data measured with this dedicated logger is uploaded to AWS by an Edge PC. With consideration given to the expandability of the dedicated logger, Amazon S3 [Note 4)] has been selected as the data upload destination because S3 can save data in various formats including image and audio data sets that are not

currently collected.

The meta data can easily be recorded by test personnel just by connecting to a dedicated website from their own tablet or other similar data terminal and then inputting the necessary information there. Information items to be collected as meta data have been standardized through preliminary discussion among those concerned. The dedicated website, particularly the information input screen, has been designed to be user-friendly based on opinions collected through interviews with those who are working on the site. With the aim of reducing the burden of website operation and management as well as the operation cost, the static website hosting function [Note 5)] of Amazon S3 was introduced. The website is only allowed to be accessed by authorized users who have passed a user authentication through the in-house network, ensuring security as well.

Note 4) A data storage service that can save and protect data with no limit on data type and capacity.

Note 5) A static website can be constructed by uploading web contents to Amazon S3.

3. 3 Data Processing

Data measurement by the dedicated logger is automatically started at the time when the logger switch is turned on. This means that even driving data of a vehicle running out of the testing section is measured too. Then, a program to only extract driving data of a vehicle running from the testing section was built as a workflow of AWS Step Functions. [Note 6)]

With input of the meta data and unprocessed driving data, this workflow refers to the meta data and extracts the driving data collected in the testing section. The extracted data is processed into an easy-to-handle format and then saved in Amazon S3. The meta data can be stored in a relational database (hereinafter the "RDB") linked to the date and time of measurement of the driving test data. This data management allows users to retrieve the driving test data they want to analyze whenever necessary (Fig. 2).

The use of the cloud service has not only enabled the fast processing of the workflow but has also improved fault tolerance and has established a backup environment at low cost. The cloud service can also be used to relatively easily build and operate a workflow in which cost only arises for using the necessary resources. For conventional data processing, the meta data has been prepared in a spreadsheet software application, from which the driving test data has been manually extracted in several days. It has needed a number of man-hours to complete the data processing for organizing the driving test data just for one day. From now on, the established workflow will automatically carry out a series of data process-

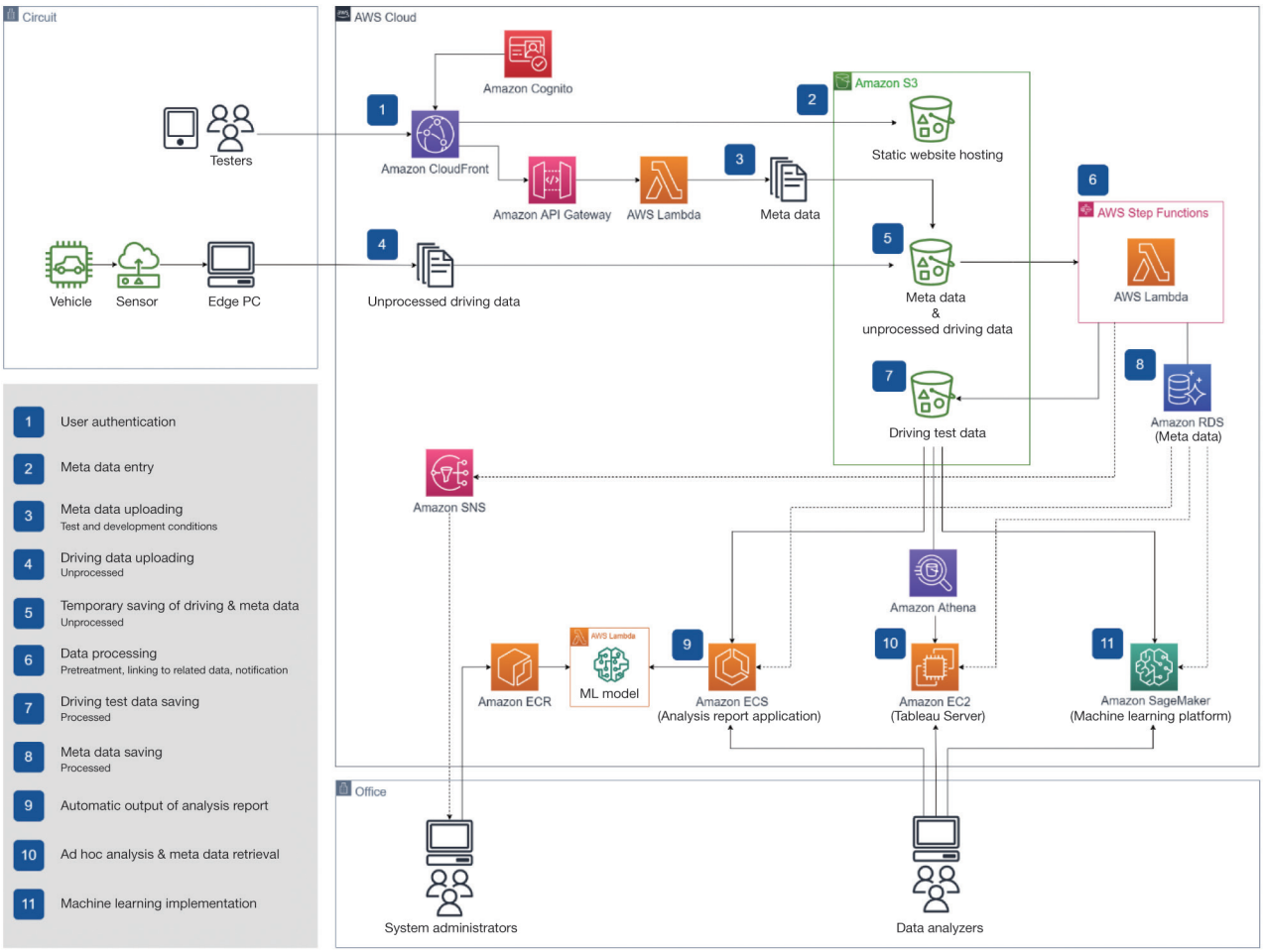


Fig. 1 Overview of data analysis platform

ing tasks just with manual data entry of test conditions by test personnel, substantially reducing the man-hours for data processing.

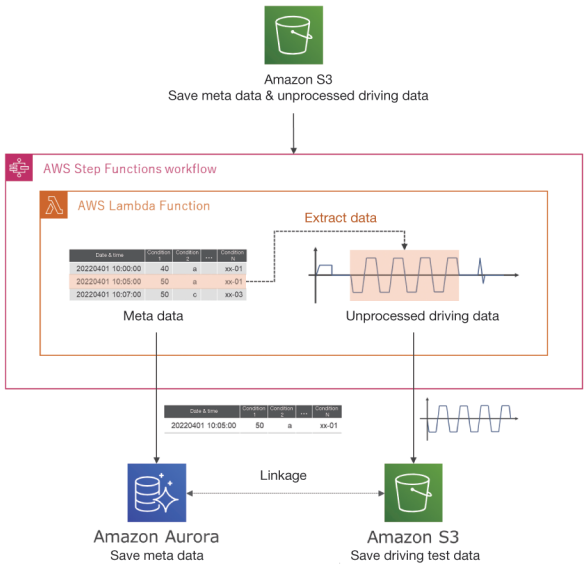


Fig. 2 Overview of workflow

Note 6) A service with which users can create a series of workflows by allocating two or more AWS services.

3. 4 Data Analysis

The data analysis platform provides the following analysis approaches applicable to the managed driving test data, so that analyzers can proceed with the analysis step by step:

[1] Simplified analysis using standard reports
[2] Ad hoc analysis Note 7) using BI tools
[3] Advanced analysis using AI

Note 7) One-off data analysis that is conducted as necessary with no analysis items or details predetermined.

3. 4. 1 Simplified Analysis Using Standard Reports

Once the driving test data is managed on the platform, data analyzers can first view the analysis report automatically output by an internally built web-based application. This web-based application was developed by consulting KYB's analysis techniques. Just by selecting any given driving test data, anyone can easily create a standard report on the test results with the analysis knowhow accumulated in the past. Details of the functions provided by this web-based application will be explained in Chapter 5.

With the web-based application, the creation of standard reports, which was difficult without dedicated tools or well-informed people, has now been standardized. In addition, the safe data management by the platform releases analyzers from management work on data and dedicated tools and allows them to concentrate on analysis, research, and development tasks.

3. 4. 2 Ad Hoc Analysis Using BI Tools

While the analysis reports certainly characterize the driving test data, an ad hoc analysis environment using BI tools is available to enable even deeper analyses. KYB provides a data analysis environment using Tableau not only for this development activity but also across the company.

We have also developed and provided a function whereby anyone can easily retrieve any given driving test data by connecting the RDB managing the meta data to Tableau (Fig. 3). With this search function, analyzers can now efficiently conduct statistical analysis of driving test data sets collected under similar test conditions or comparison and verification of similar driving test data sets that are only different in specific conditions. Another function available is the downloading of search results. This may be useful for sharing the search results or data pretreatment for “advanced analysis using AI”, which will be described later.

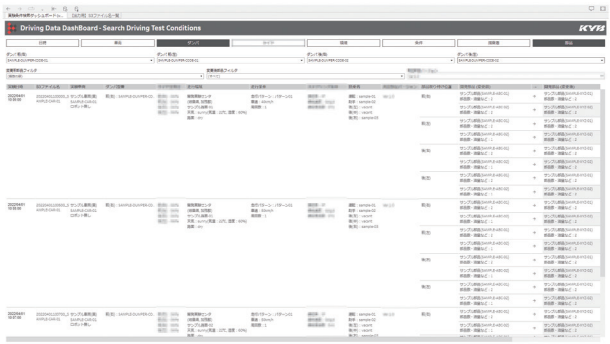


Fig. 3 Driving test data search screen

3. 4. 3 Advanced Analysis Using AI

An environment to implement machine learning Note 8) is available to support more advanced analysis approaches for the driving test data. Digital Transformation Improvement Dept is promoting an activity to develop AI human capital capable of effectively utilizing Amazon SageMaker. Note 9) In liaison with the promotion work, the Department has also advanced the development of this system.

Currently, the Department provides SageMaker Notebook Note 10) as a data analysis environment in the test phase. In the development phase with the aim of proceeding to the product phase including machine learning implementation, the Department recommends carrying out development from local PCs using a dedicated Software Development Kit (SDK) for AWS. Not only by simply providing an environment for machine learning implementation but also by distributing sample codes already organized and actively disclosing the know-how for Amazon SageMaker use accumulated in the company, the Department supports the promotion of AI utilization. The environment provided by the Department allows human capital who have already utilized Amazon SageMaker to quickly obtain any given driving test data man-

aged by the platform and conduct advanced analysis by leveraging various analysis technologies including AI.

Finally, the AI that was developed in this activity has been incorporated into an AI service, which is now available. The AI service includes a function with which anyone with no knowledge about AI can freely obtain analysis results given by AI so long as data is available. Details of the AI that was developed as well as the AI service will be described in Chapter 6 onward.

Note 8) A technology with which a computer can learn rules and patterns from a variety of data including numeric values and text to determine the current condition and prospect the future.

Note 9) A service that provides an environment to quickly develop, learn, and distribute machine learning models.

Note 10) A service that can interactively implement a series of tasks including data visualization and machine learning model building.

4 Effort for Establishing an Appropriate Development and Operation System

4. 1 Development Taking Expandability Into Account

We carry out system development using Infrastructure as Code (hereinafter "IaC") taking subsequent expandability and maintainability into account. IaC provides a way of managing the configuration of infrastructure using source codes. It uses source codes to define server environments and application settings. When building a system, IaC can be used to reduce the man-hours, increase efficiency in reutilization, and reduce human errors in manual operation. This system uses Serverless Framework for AWS Step Functions and other applications (including the workflow described above) and HashiCorp Terraform for network- or security-related infrastructure.

4. 2 Scheme for Team Development

Besides IaC, we use another scheme for team development in various applications. That is the source code version management tool GitLab with which we can promote daily development jobs safely and quickly. Source codes created by development personnel are reviewed by well-informed people before being merged into the production environment. Once a service is formally released under a CI/CD Note 11) environment, the latest version of source codes is tagged, which is one of the GitLab functions. The use of this rule ensures that, should a service release fail in future, the service can be swiftly rolled back to the last version that has proven to provide normal operation (Fig. 4).

Note 11) Refers to a system that automates the build, test, and development processes. CI and CD are acronyms for Continuous Integration and Continuous Delivery respectively.

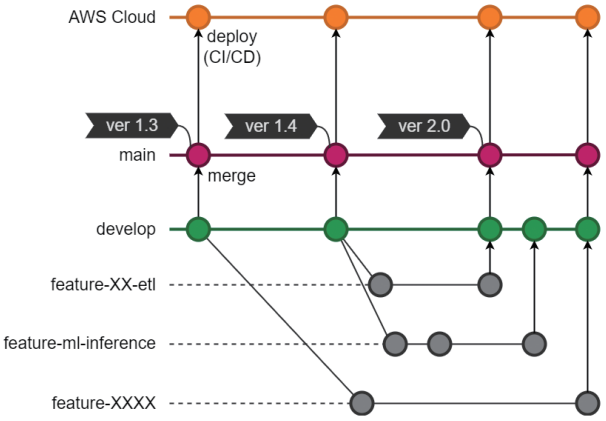


Fig. 4 System development using tagging

4. 3 Multi-account Cloud Operation

As the number of systems running in the company increases in future, it will be necessary to establish an appropriate operation rule for AWS accounts. KYB is promoting a multi-account operation that uses the single sign-on method to switch over multiple AWS accounts depending on the type and environment of the system (Fig. 5). Developers and maintainer are only allowed to access specific operations according to their own set of authorizations invested to individual service accounts.

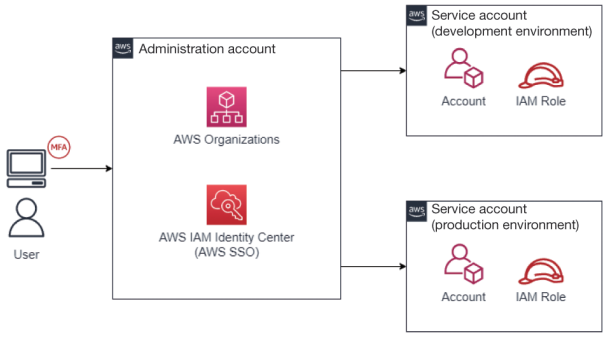


Fig. 5 Overview of multi-account operation

Distribution of authorizations for services and functions to different accounts can help control cloud security and eliminate the need of setting maximum usage of each account. This can be expected to reduce the burden of AWS administrators and users. This operation rule is also applied to the construction of this system.

5 Development of Automatic Analysis Reporting Application

As amounts of data increase, data visualization requires more time and more man-hours. Then, we have developed a web-based data analysis application that can quickly visualize the results of the analysis of driving test data and then automatically output a report (hereinafter the "web-based analysis application") without the laborious tasks that used to be necessary.

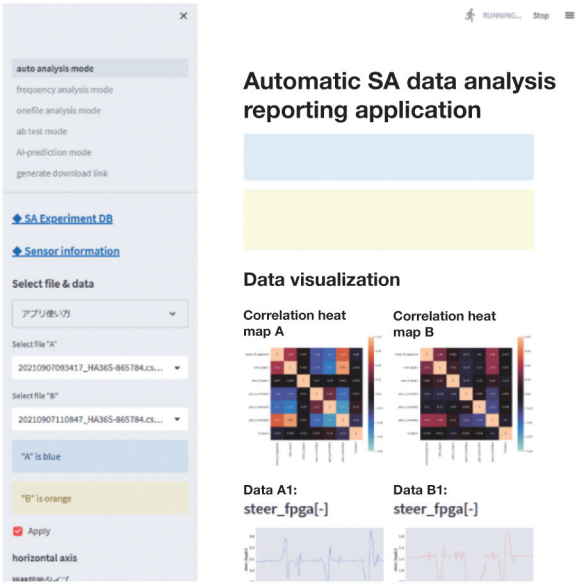


Fig. 6 Screens of the web-based analysis application

Using the web-based analysis application, you can easily access the driving test data uploaded in the cloud (Fig. 6). Just by selecting a set of driving test data you want to analyze, the web-based analysis application automatically visualizes the data set, eliminating the need for complicated setting or operation. You may also extract data you want to analyze in detail (for example, a data set collected for a certain period immediately after the start of a test) as necessary, and then view the data in different scales. The driving test data may also be filtered by test conditions, which also serve as a description of the data to be analyzed, on the Tableau screen shown in Fig. 3, Chapter 3. Data retrieved in this way will also be automatically visualized on the application. We assume that the web-based analysis application will be used in these ways.

There are three modes in the web-based analysis application as described later. You can select the desired mode depending on the application.

5. 1 General Analysis Mode

General analysis mode is available for the typical visualization formats, which data analyzers frequently use to create drawings. Through hearing from those concerned who were involved in data analysis, data visualization formats that were popular among them were selected. Specifically, these formats include line graphs, scatter diagrams, and histograms. In addition to these views, the application is designed to be able to output sensor measurement statistics, correlation maps, and other relational data just with a simple mouse operation on the web-based application.

Fig. 7 shows an example of the visualization of the driving test data collected for the evaluation of SA fluids using actual auto vehicles. The use of the web-based analysis application made it possible to quickly identify the characteristics of the data obtained from more than one sensor, substantially reducing the time needed to complete the process from data collection to visualization.

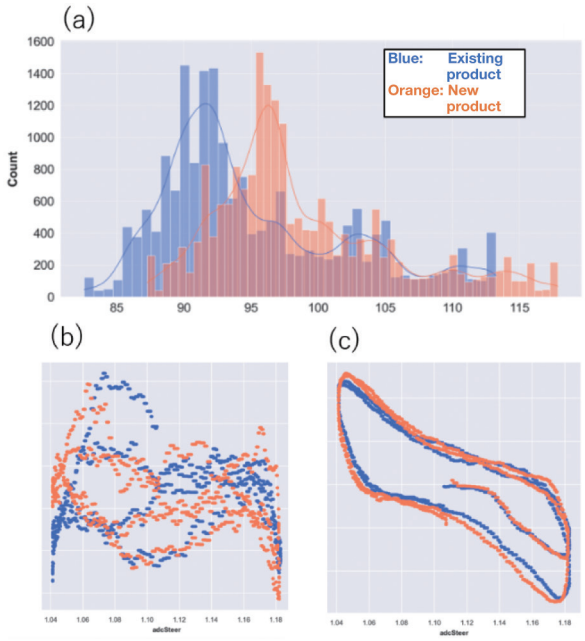


Fig. 7 Case example of using the web-based analysis application (general analysis mode): (a) Histogram of Sensor A, (b) Scatter diagram with X-axis for Sensor A and Y-axis for Sensor B, (c) Scatter diagram with X-axis for Sensor A and Y-axis for Sensor C

5. 2 Frequency Analysis Mode

Frequency analysis mode allows users to view spectrograms of power spectra and time-frequency analysis. Detailed parameters for creating frequency analysis graphs can be individually set. Basically, the web-based analysis application automatically sets parameters in response to the data input, allowing users to easily visualize the data without paying attention to detailed settings.

5. 3 AI Analysis Mode

AI analysis mode is where all users can easily carry out frequency analysis with AI. Detailed information about the AI-based approach we developed will be described in the next chapter.

5. 4 Downloading of Driving Test Data

A function that allows users to separately download the driving test data selected on the web-based analysis application as CSV files is also available. A signed URL with an expiration date is issued to target users so that they can download the data just through a simple mouse operation.

This function can meet the needs of users who want to visualize data in their own way, using familiar analysis tools.

6 Use of AI and Setting-up of Challenges

Deep learning is one of the latest AI technologies and a general-purpose method to be utilized to resolve any challenge. On the other hand, in comparison with conventional proven technologies, deep learning delivers just equivalent or possibly inferior performance depending on the challenge. Therefore, it is important to discuss the following questions before starting to develop an AI-based technology:

[1] Is the use of AI is the best way of resolving the challenge?

[2] Can the challenge be adjusted so that the use of AI is the best solution?

You can easily answer question [1] if you have proper knowledge about AI. You may hardly be able to answer question [2] unless you have general knowledge and experience in interpreting challenges in addition to knowledge about AI. The following describes specific examples of setting up challenges:

6. 1 Background and Challenges

KYB has promoted the development of SA sliding parts to achieve both ride comfort and maneuverability at a high level. It was known that sensory factors including ride comfort would be substantially affected by a change of SA fluids only. However, the relationship between the fluid and the vehicle behavior had not been fully clarified.

At first, we had the existing product and a new product that was identical to the existing one except for an improved fluid. These products were tested on actual auto vehicles for evaluation and frequency analysis (Fig. 8). A comparison of the results of fluid analysis between the existing and new products only identified a minor difference between the two. Was this minor difference attributable to the fluids or to any environmental factors such as road noise? Or might it be caused by differences in driving manner? [Note 13] There arose the problem that the cause of the minor difference was difficult to determine.

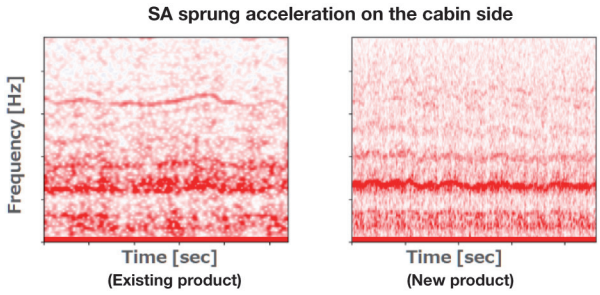


Fig. 8 Results of analysis of SA sprung frequency for different fluids [Note 12]

Note 12) The spectrograms were generated with Fourier transform to visualize vibration. Part of the information is confidential and has been intentionally deleted or blurred.

Note 13) Even under the same test conditions, the operation of the accelerator and/or steering wheel of auto vehicles may slightly vary.

6. 2 Setting up Challenges for AI

KYB has addressed the development of advanced anomaly detection technologies[6),7)] utilizing deep learning, which is one of the latest AI technologies, including "appearance inspection through image processing" and "poor weld detection". By effectively using insights from this experience, we decided to treat the acceleration information, among the driving test data items related to the SA fluid, as follows:

[1] Acceleration of existing product: Reference data

[2] Acceleration of new product: Comparative data

The AI-based anomaly detection technologies were applied to develop a technology to only learn the acceleration information (reference data) of the existing product and detect what is new in the new product. [Note 14]

In short, the challenge of "detecting what is new in the new product" was interpreted as "comparing the results of frequency analysis between the existing and new products and only detecting the differences attributable to the fluids". The latter was further replaced by the challenge of "anomaly detection for which the use of AI is effective". These considerations were made in the initial stage of the development phase before the full-scale development was launched.

Note 14) An AI-based technology that compares acceleration between the existing and new products and identifies frequency bands with substantial differences.

7 General AI-based and Proposed Approaches for Anomaly Detection

The newly developed approach is an application of AI-based encoder and decoder. The approach is generally used to input image or other data that is dense with information to an encoder where the information is compressed and then further input the compressed information to a decoder where given data can be reconfigured. This approach has the following two major advantages:

[1] Difficult-to-handle high dimensional data can be converted into low dimensional data, which can be used as a feature value for machine learning.

[2] The data compression/reconfiguration process is expected to deliver a noise removal effect. (In other words, only distinctive data can be reconfigured).

If the encoder and decoder learn to reconfigure input data [Note 15], determining the difference between the reconfigured data (output data) and the input data can locate noise. This noise corresponds to flaws or stains that are found in appearance inspections. Thus, this approach is often used at sites requiring anomaly detection (Fig. 9).

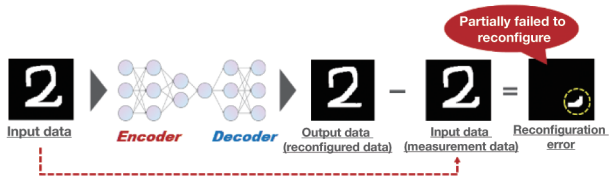


Fig. 9 AI-based approach for fault detection of hand-written text

Note 15) An approach for an encoder and a decoder to learn to ensure that the input data is identical to the output data is called an autoencoder.

7. 1 Proposed Approach

In the proposed approach, the encoder learns to receive input of spectrograms of the unsprung acceleration of the existing product and the decoder learns to output (or reconfigure) spectrograms of the sprung acceleration (Fig. 10).

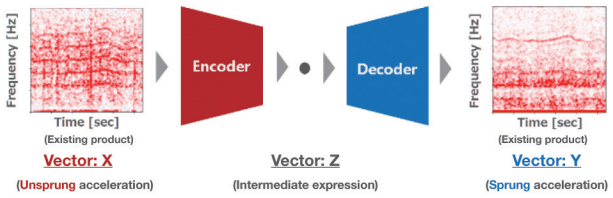


Fig. 10 Overview of proposed approach

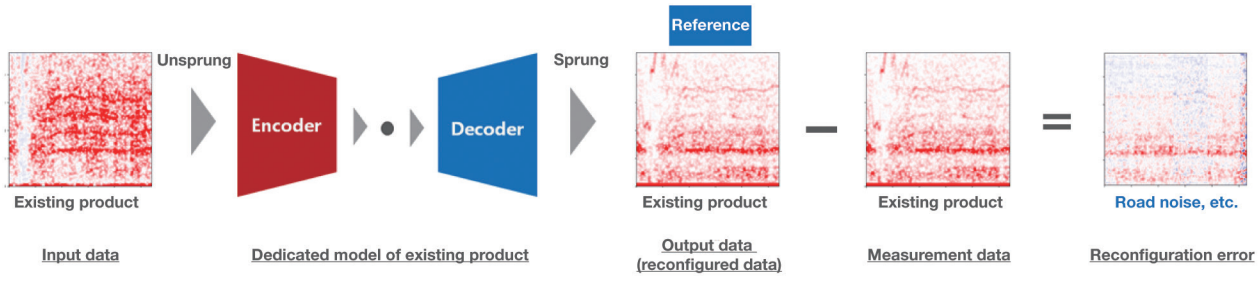
Learning huge amounts of data from the existing product alone can generate a dedicated model for the existing product. The model here means a computing unit that outputs the sprung spectrogram of the existing product after being input with its unsprung spectrogram.

If part of the existing product data that was not used for learning is input to this model, the sprung acceleration with noise removed can be output. Identifying the difference between this output data and the actual measurement data allows visualization of the noise (Fig. 11(a)). This visualized noise is expected to be able to be interpreted as "test errors including road noise".

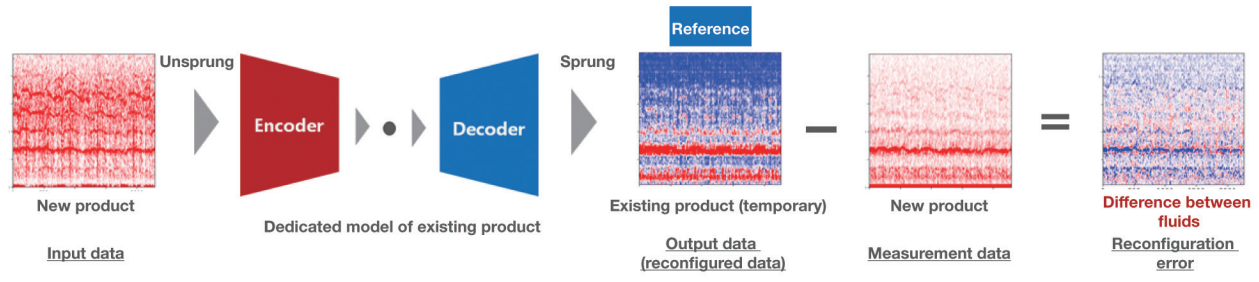
If data from the new product is input to this model in turn, only the frequency bands that correspond to those of the existing product data can be output. Identifying the differences between this output data and the actual measurement data allows observation of the frequency bands that failed to be reconfigured well as noise (Fig. 11(b)). This visualized noise is expected to be able to be interpreted as "differences in frequency bands attributable to the fluids".

When visually checking the spectrograms for reconfiguration errors, however, users may discover minor variations in color by unavoidably relying on their subjective determination. Then, we have proposed another plotting method that averages spectrograms out in the direction of the axis for frequency and visualizes shifts in frequency bands using a line graph (Fig. 12). We believe that this plotting method allows users to determine the differences between fluids regardless of users' expertise.

Another advantage of this proposed approach is that only a relatively small amount of data from the new product is needed while large amounts of learned data (the existing product data in this case) need to be available. This means that, as long as large amounts of driving test data to be benchmarked are collected in the initial stage of the development phase, AI-based frequency analysis can be made even with small amounts of data from the



(a) Learned model with existing product data as input



(b) Learned model with new product data as input

Fig. 11 Overview of proposed approach

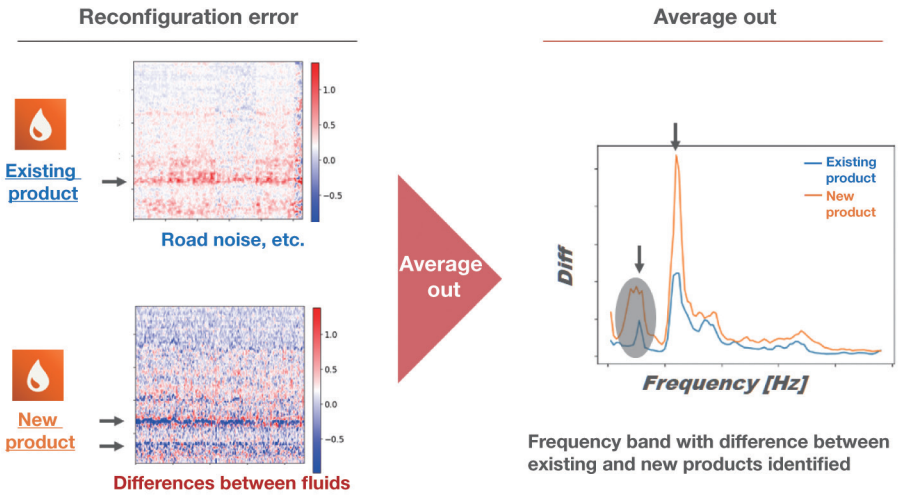


Fig. 12 AI-based visualization of differences in sprung frequency bands between existing and new products

new product. Note that the model generated in this proposed approach is a black box. The grounds on which the data was reconfigured is unknown. It must be remembered that analysis results should be used for reference purpose only.

8 AI Support for Development of SA Elements

Digital Transformation Improvement Dept uses Python [Note 16)] for development of AI-based technologies including the proposed approach described in Chapter 7. Therefore, expertise on AI and Python as well as a dedicated operating environment are needed for effective use of the proposed approach. We thought that, in fact, many people faced a hurdle to obtain expertise and prepare the operating environment. We then developed an application embedded with AI (the proposed approach) to establish an environment where anyone can try the AI-based frequency analysis.

Note 16) One of the general-purpose programming languages. Python is the de facto standard language for AI development.

8. 1 Case Example of Utilizing Internally Built AI Services

The AI service we developed is available as one of the functions of the "automatic analysis reporting application" described in Chapter 5. One thing that is different from the other functions is that the AI service also supports data that is not managed by the platform [Note 17)] Any users can temporarily upload their own data via the web-based application to analyze the data using the AI service.

This AI service has the following objectives:

[1] To allow users to use the AI service only with the test data available even if they are unable to easily carry out a driving test, lowering the hurdle for AI technology.

[2] To implement AI-based analysis of virtual driving test data generated by simulation, based on the assumption that a high-precision physical SA model including fluid will be created in future.

[3] To allow expanded usage of the AI service to take place by not limiting users or data types.

Finally, Fig. 13 shows an example of using the AI service for any given driving test data. The accuracy of detecting what is new in the new product is expected to rise through comparison of analysis results between the conventional and proposed approaches.

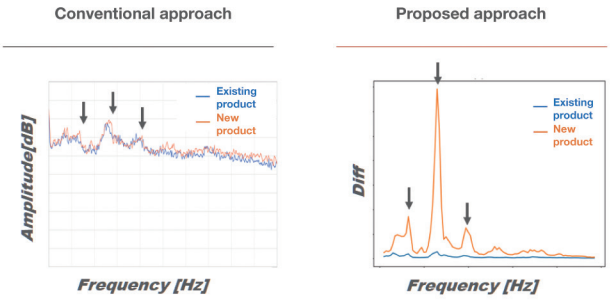


Fig. 13 Comparison of results of frequency analysis between conventional and proposed approaches

Note 17) Must be in a specified data format.

8. 2 Technologies Supporting the AI Service

The development of this AI service has used Container, which is a virtualization technology. Container technology specifically refers to the method of collectively managing and operating AI applications and its operating environment in a single package. A Container containing applications and operating environment can be started up either locally or in the cloud, minimizing environment-dependent problems. [Note 18)]

AWS provides many different Container-related services. Users can freely select these services according to their needs.

We do not actually use the AI service (the proposed approach) so often in our daily development activity. So, we selected the AWS Lambda service for which we only pay for what we use. Although it takes several minutes to

complete the start-up process with AWS Lambda, containers can be started and used at minimum cost, implementing the operation and management of an environment where anyone can use AI services safely whenever needed (around No.9 in Fig. 1).

Note 18) In some cases, modification is needed depending on the container start-up environment.

9 Outlook

Under this development project, the construction of a data analysis platform for improved capability for SA development has been completed. In fact, it is difficult to determine whether the platform has contributed to improved development capability or not at this moment because the platform has little track record of operation yet. Still, the platform did provide users with the following value:

[1] Users have been released from data management work.

[2] An environment where users can focus on driving tests and data analysis has become available.

The platform has been constructed to be able to manage and operate a variety of driving test data. If a driving test that cannot be assumed at this moment is carried out in future, however, the platform may fail to cope with the analysis. So, we would like to develop a maintenance system ensuring that the platform can be operated over a long time and can handle even unexpected problems.

The “AI service” described in this paper was developed by applying the results of the joint research of Gifu University and Digital Transformation Improvement Dept of KYB. The service is available in a user-friendly manner even to users who are not AI experts. From now on, we would like to introduce AI-based technologies and algorithms developed not only by Digital Transformation Improvement Dept but also by other functions into the service. To achieve this as well, we plan to establish a scheme to respond to inquiries on how to use the platform or the development environment from AI human capital or advanced IT human capital in various functions.

10 Concluding Remarks

This development project has constructed a system to effectively use driving test data. We understand that some employees may have inhibitions on the Work Style Reform using digital technology. Still, we will promote digital transformation (DX) by adequately explaining the full value of accepting DX.

The know-how accumulated in this development project can be also applied to building platforms for types of data other than driving test data. Any functions facing difficulties with data utilization can collaborate with us for resolving their challenges.

Finally, I would like to take this opportunity to sincerely thank all those concerned in the related functions who extended great support and cooperation to this development project.

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Product Introduction

Development of Anti-cavitation Vane for Travel Motor of 7-ton Hydraulic Excavator

SUZUKI Jun

1 Introduction

The existing hydraulic travel motor for 7-ton hydraulic excavators is equipped with an add-on shockless relief valve as standard. The shockless relief valve (hereinafter the "relief valve") has the same structure as that of the hydraulic travel motor for mid-size excavators. This means that the relief valve consists of many parts and is expensive.

Then, we have developed another valve for 7-ton hydraulic excavators that can replace the existing relief valve. This paper introduces this new, simple anti-cavitation valve (hereinafter the "anti-cavitation valve").

2 Overview of the Product

2. 1 Background

MAG Series hydraulic travel motors are available in a product lineup of 11 models for 1-ton to 35-ton hydraulic excavators (Table 1). While motors for mini excavators of 6-ton or smaller are equipped with an anti-cavitation valve as standard, those for 7-ton or larger excavators are equipped with a relief valve as standard. We tried to mount the anti-cavitation valve that is used in the smaller class motors on the hydraulic travel motor MAG-50VP-1100F for 7-ton class excavators but it could not prevent the occurrence of cavitation because a large inertia force is applied to the motor during the braking of large vehicles. It has thus been difficult to use the anti-cavitation valve in this motor. Still, in response to the recent market demand for cost reduction, we have developed a simple anti-cavitation valve for the travel motor for 7-ton hydraulic excavators that can replace the relief valve. Fig. 1 shows the appearance of the product.

Table 1 MAG Series product lineup

Excavator class (tons)				Product model	Output torque	Valve type (anti-cavitation/ relief)
~5	~15	~25	~35		kN-m	
~1. 7t				MAG-12VP-120E	1. 18	None
~2. 5t				MAG-18VP-230F	2. 16	Anti-cavitation
~3. 5t				MAG-18VP-350F	3. 14	
~4. 5t				MAG-26VP-400F	3. 92	
~6. 5t				MAG-33VP-650G	6. 37	
~8. 0t				MAG-50VP-1100F	10. 8	Relief
	~12t			MAG-85VP-1800	17. 7	
	~15t			MAG-85VP-2400E	23. 5	
		~25t		MAG-170VP-3800G	35. 3	
		~25t		MAG-170VP-4000H	39. 1	
			~35t	MAG-180VP-6000G	56. 0	

Fig. 1 Appearance of the product
(MAG-50VP-1100F with anti-cavitation valve)

2. 2 Functions and Features of Relief Valve

The existing relief valve plays the role of relieving the pressure surge during the vehicle's braking, suppressing the cavitation, and adjusting the braking feeling. When the brake is applied, the counterbalance valve mounted on the travel motor closes its opening on the outlet side earlier. The relief valve is then operated to generate a braking torque and absorb the inertia force during braking. It also adjusts the shockless operation pressure and time to obtain the desirable pressure rise characteristics during braking, achieving the braking feeling demanded by customers.

[During traveling]

Fig. 2 shows the hydraulic circuit diagram of the relief valve during traveling. When the pressure oil flows into the Pin port, the counterbalance valve is in the travel position. The oil is guided into the hydraulic circuit, starting the motor.

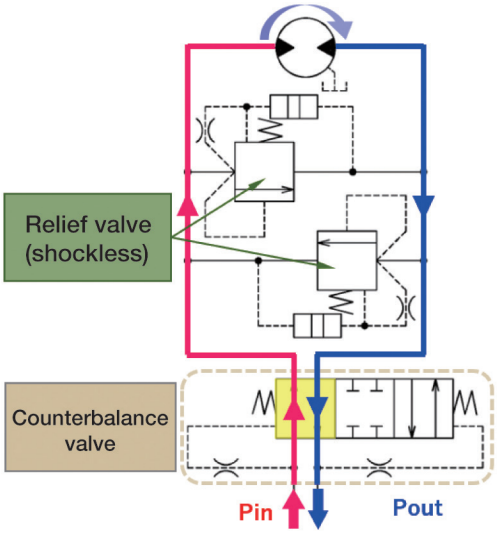

Fig. 2 Hydraulic circuit diagram of relief valve (during traveling)

[During braking]

Fig. 3 shows the hydraulic circuit diagram of the relief valve during braking. While the supply of the oil to the Pin port is interrupted, the motor is kept running due to the inertia force of the vehicle. This raises the braking pressure to generate a braking torque, absorbing the inertia force. When the braking pressure is equal to or higher than the relief valve settings, the pressure escapes to the other side as indicated by the arrow (green), suppressing cavitation. The shockless relief valve shows a two-step increase in braking pressure as shown in Fig. 4. The pressure waveform shown in Fig. 4 represents measurements obtained with a flywheel testing machine.

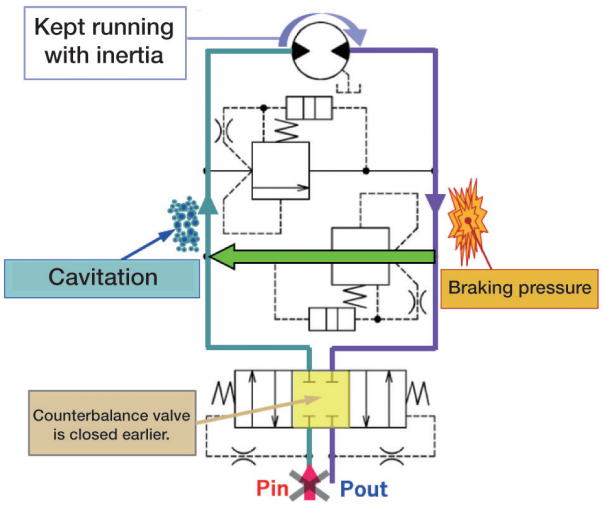

Fig. 3 Hydraulic circuit diagram of relief valve (during braking)

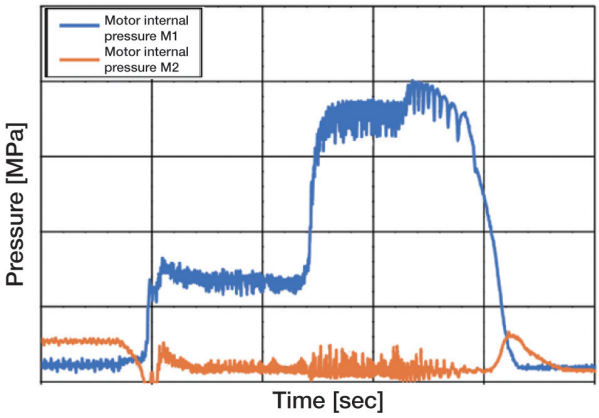

Fig. 4 Braking pressure characteristics of motor with relief valve

2. 3 Functions and Features of Anti-cavitation Valve

Unlike the relief valve, the anti-cavitation valve does not have a surge relief function supposed to work during braking. That is why it is necessary to tune the opening characteristics of the counterbalance valve to generate a braking torque, absorb the inertia force during braking, and keep the braking pressure within the allowable limits. Cavitation is suppressed by bypassing the high-pressure fluid to the low-pressure side using the anti-cavitation and counterbalance valves.

Figs. 5 and 6 show the hydraulic circuit diagram of the anti-cavitation valve during traveling and braking respectively. Adjusting the opening characteristics of the counterbalance valve enables various pressure rise characteristics to be obtained during braking, achieving the braking feeling demanded by customers. Table 2 shows a comparison in functions between the relief and anti-cavitation valves.

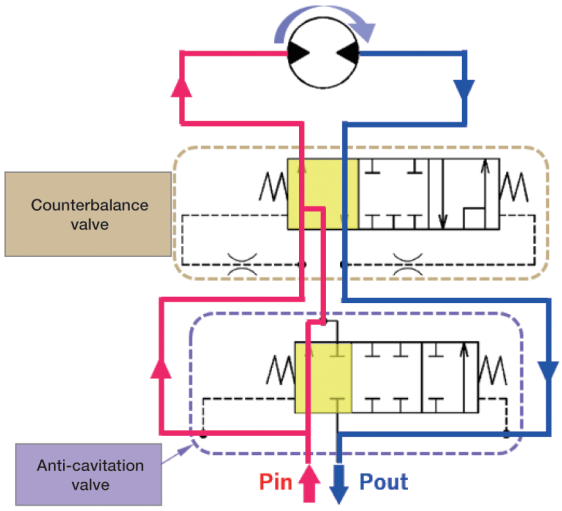

Fig. 5 Hydraulic circuit diagram of anti-cavitation valve (during travelling)

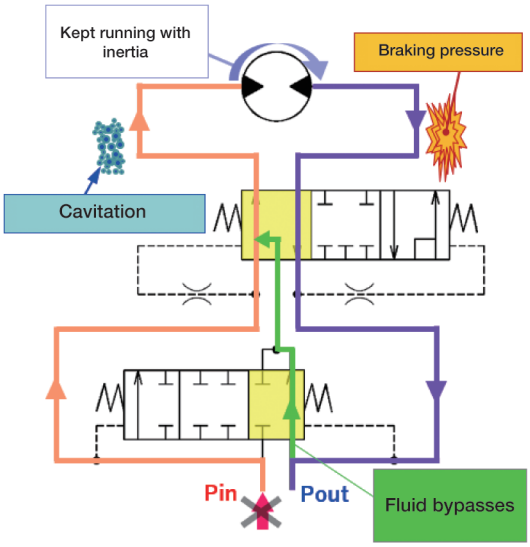

Fig. 6 Hydraulic circuit diagram of anti-cavitation valve (during braking)

Table 2 Comparison of functions between relief and anti-cavitation valves

Function	Relief valve type		Anti-cavitation valve type	
	Relief valve	Counterbalance valve	Anti-cavitation valve	Counterbalance valve
[1] Relief of braking pressure surge	●	×	×	●
[2] Cavitation suppression	●	×	●	
[3] Fulfillment of braking feeling	●	×	×	●

2. 4 Comparison of Valve Structure

Figs. 7 and 8 show the structure of the relief and anti-cavitation valves respectively. While the relief valve consists of 33 parts and is expensive, the anti-cavitation valve is simple and consists of only 10 parts.

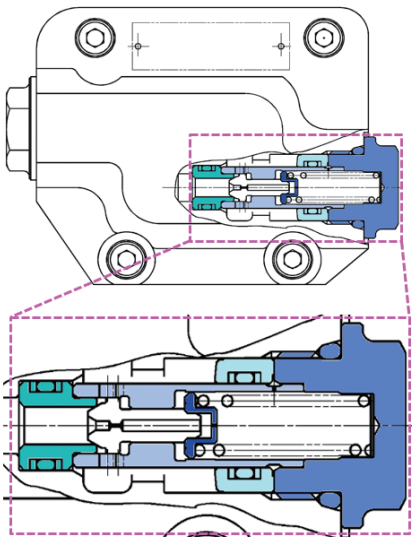

Fig. 7 Section view of relief valve

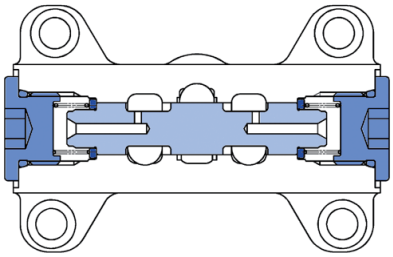

Fig. 8 Section view of anti-cavitation valve

3 Technical Challenges in Introducing Anti-cavitation Valves

The challenges in introducing the anti-cavitation valve to the motor for 7-ton excavators are to ensure that the valve can keep the braking pressure from rising up to the upper limit, absorb the inertia force, and attain the braking feeling demanded by customers by tuning the opening characteristics of the counterbalance valve as well as by suppressing cavitation during braking of the 7-ton vehicle.

4 Features of Anti-cavitation Valve for 7-ton Hydraulic Excavators

As mentioned above, unlike the relief valve, the anti-cavitation valve can adjust its opening characteristics and closing time to achieve various pressure rise characteristics during braking. With the anti-cavitation valve, it is possible to achieve a moderate increase in braking pressure as shown in Fig. 9, thereby enabling the vehicle's driver to feel good braking and keeping the pressure surge within the allowable limits. Besides this, it has been confirmed that other pressure rise characteristics as shown in Figs. 10 and 11 can be obtained. Note that this newly developed valve offers motor performance and durability that are equivalent to those of the existing relief valve since this new product is an alternative to the existing counterpart.

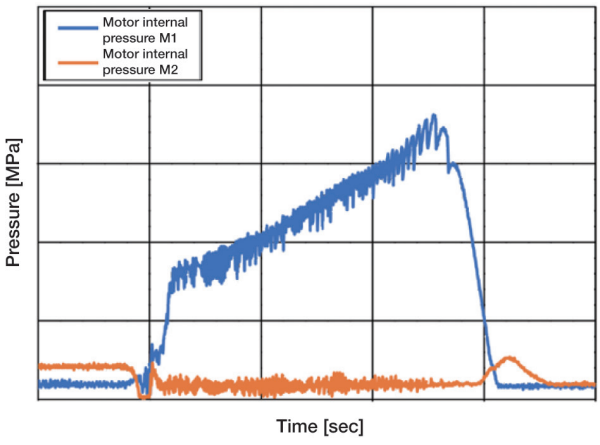

Fig. 9 Braking pressure characteristics of motor with anti-cavitation valve [1]

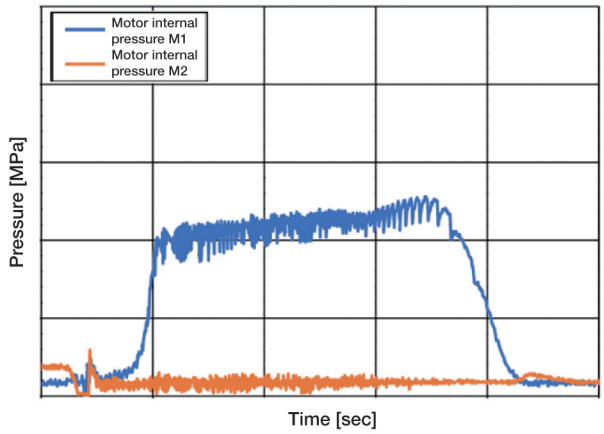

Fig. 10 Braking pressure characteristics of motor with anti-cavitation valve [2]

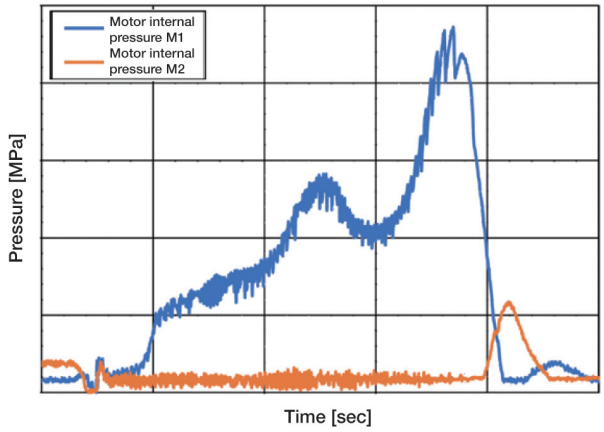

Fig. 11 Braking pressure characteristics of motor with anti-cavitation valve [3]

5 In Closing

To introduce the anti-cavitation valve to the travel motor, it is necessary to match the motor with the vehicle by adjusting the opening characteristics of the counterbalance valve. In reality, drivers may encounter various types of excavator crawler (steel, rubber) and various types of road surface (sheet steel, soil, concrete) depending on the vehicle class and model, so it is difficult to exactly estimate the braking feeling only through verification with flywheel testing.

The test data obtained in this development project will be applied to analysis modeling, reducing the time needed to match motors with vehicles. This will certainly improve the estimation technique. In the future, we would like to determine, through simulation, the motor behavior in operation modes that are difficult to reproduce in a bench test, contributing to the clarification of failure phenomena occurring in commercially available excavators.

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Product Introduction

Development of Vane Pump for AT

GOMI Hiroki

1 Introduction

The vane pump for AT [Note 1)] introduced in this paper is to be used as a hydraulic source of the new AT mounted on the new SUV [Note 2)] that has been developed by Mazda Motor Corporation. Manufacturing of this product was launched in December 2021.

Note 1) Automatic Transmission.

Note 2) Sport Utility Vehicle.

2 About AT Unit

The AT unit (Photo 1) on which the newly developed vane pump will be mounted is a step-type automatic transmission (hereinafter “the AT"). The AT uses a power transmission system that is different from that used in CVT [Note 3)] for which KYB has developed and produced vane pumps so far. The pump used for the AT is required to deliver a discharge pressure different from that of the pump used for CVT. KYB is preparing its first vane pump product lineup for the AT. Table 1 compares the specifications of these two types of transmission.

Note 3) Continuously Variable Transmission.

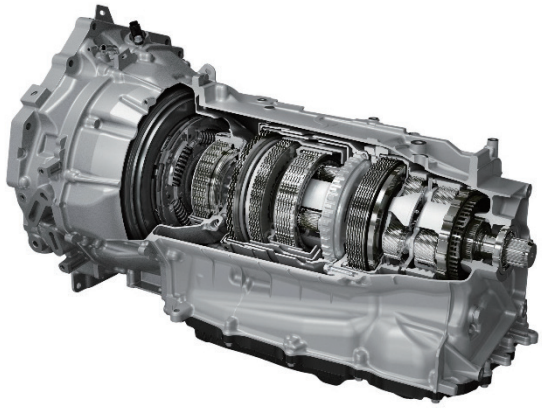

Photo 1 Appearance of transmission unit *

* The use of the photo has been approved by Mazda Motor Corporation. All rights reserved.

Table 1 Comparison of specifications of AT and CVT

Type	AT	CVT
Speed change by	Gearset	Belt
Hydraulic pressure requirement	Up to 2.1 MPa	Up to 6.0 MPa

3 Newly Developed Vane Pump

The newly developed vane pump is based on the existing product for CVT. Since the pump specifications for the AT are different from those for CVT as described above, we reviewed all the specifications of the existing vane pump for CVT to set up optimal specifications for the AT during the development stage.

The first point to be considered in the development stage was that the vane pump for the AT is only required to deliver a low discharge pressure. Then, we reduced the friction of the existing product as far as possible while maintaining the required durability, contributing to improved fuel efficiency of the vehicle.

We also improved NVH [Note 4)] which is essential for the pump start-up characteristics and the vehicle ride comfort, achieving an optimal design to satisfy the required specifications.

Photo 2 and Table 2 show the appearance and detailed specifications of the new vane pump respectively.

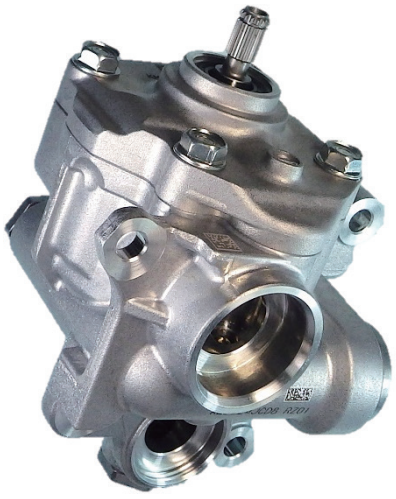

Photo 2 Appearance of new vane pump

Table 2 Specifications of new vane pump

Type	Balanced vane pump
Basic discharge	15.9cm^3/rev
Pump revolutions	Max. 7,420 rpm
Discharge pressure	Max. 2.1 MPa
Oil temperature range	-40˚C to 165˚C
Production site	Japan

Note 4) Noise, Vibration, and Harshness.

4 Performance Improvements

4. 1 Improvement of Volume Efficiency

In the newly developed vane pump, the clearances of the sliding parts have been optimized, specifically reduced, to match the discharge pressure. The smaller clearances lead to less leakage or lower flow loss in the pump, resulting in higher volume efficiency but lower durability, such as seizure of the sliding parts, is unavoidable. Still, a deformation study through FEM analysis (Fig. 1) and a critical durability test helped us set an optimal clearance. As a result, the volume efficiency has been improved while the required durability is maintained.

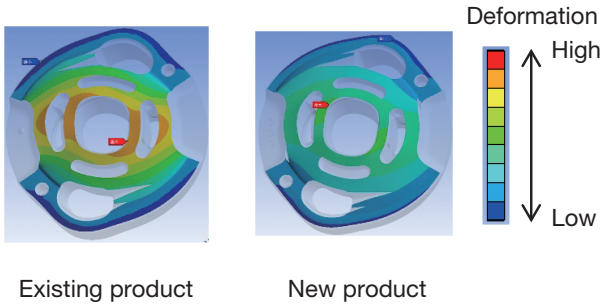

Fig. 1 Example of FEM analysis

4. 2 Improvement of Mechanical Efficiency

The driving torque of a vane pump is the sum of the theoretical torque and the loss torque (friction). To improve the mechanical efficiency, it is primarily necessary to reduce the loss torque. Major components of the loss torque include the torque consumed for pressure loss in operating the flow control valve [Note 5)] and the sliding torque for the vanes to maintain contact with the walls of the cam ring. To reduce these two kinds of loss torque, the following improvements were made.

Note 5) When the pump has an integrated flow control valve.

[1] Lowering the working pressure of the flow control valve
[2] Using a thinner cam ring
[3] Using thinner vanes

For item [1], lowering the working pressure of the flow control valve can reduce the loss torque due to pressure loss. This causes the flow control valve to internally circulate excess flow, thereby enabling the pump to leverage the flow to improve the suction capability (Fig. 2). However, the reduced working pressure naturally lowers the hydraulic pressure in the internal circuit, resulting in the disadvantage of lower resistance to cavitation. Cavitation is a phenomenon in which the air dissolved in the hydraulic fluid is released as air bubbles. Repeated release and dissipation of such air bubbles causes wear or damage to the pump components.

To resolve the problem, the suction part of the cam ring was machined to have notches, expanding the suction oil path. This reduced the pressure loss to improve the suction capability (Fig. 3).

For item [2], the cam ring bore, which decides the basic discharge, has been enlarged in some parts from that of the existing product. With this design change, the width of the cam ring has been reduced by 24% (Fig. 4). This reduced the area of vanes to which pressure is applied, resulting in a lower sliding torque.

For item [3], KYB introduced its thinnest vanes (29% thinner than the existing vanes) for the first time to further reduce the area to which pressure is applied and the sliding area (Fig. 5).

These improvements reduced the loss torque by about 20% from the existing product that performs equivalent work, successfully improving the mechanical efficiency.

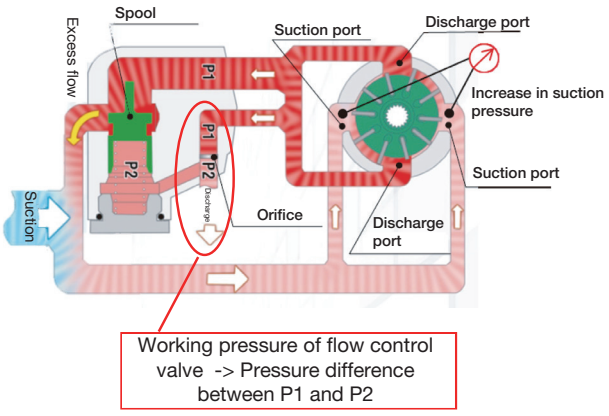

Fig. 2 Oil circuit in vane pump

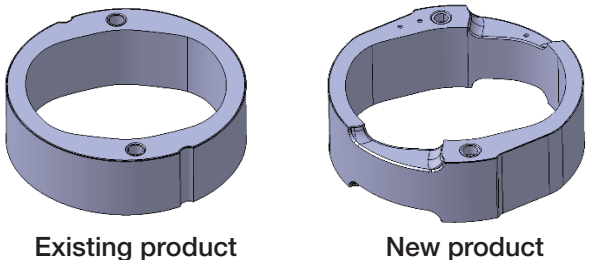

Fig. 3 Comparison of cam ring specifications

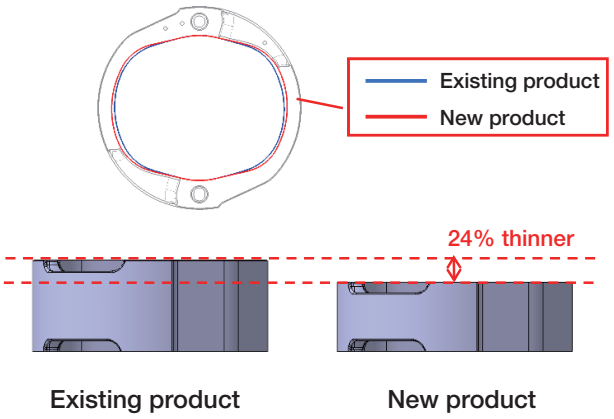

Fig. 4 Illustration of thinning of cam ring

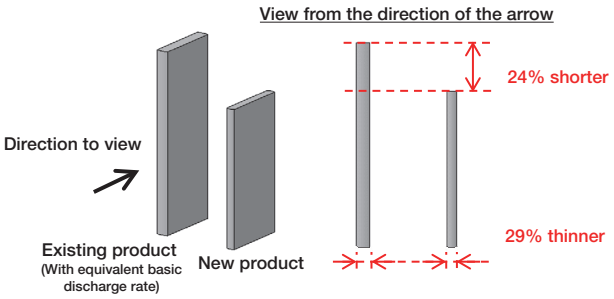

Fig. 5 Thinning of vanes

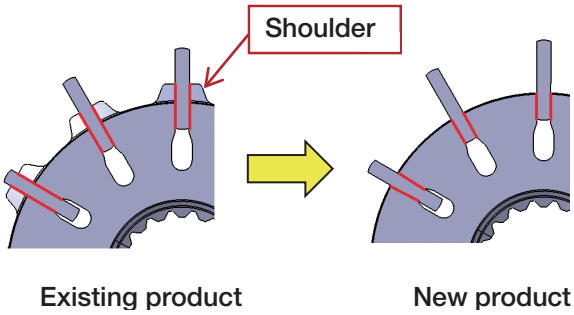

Fig. 6 Rotor geometry

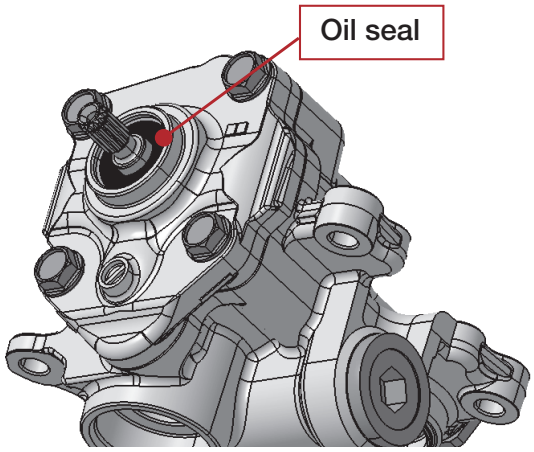

Fig. 7 Oil seal

4. 3 Improvement of Start-up Characteristics

As described above, reduction of the loss torque was achieved by thinning the vanes to deliver a lower contact pressure against the walls. The trade-off was lower start-up capability. As the transmission pump has recently been required to deliver rapid start-up from the viewpoint of improvement of automobile functionality, the start-up characteristics needed to be improved.

Then, we changed the rotor design to eliminate the "shoulders", reducing the sliding resistance of the sticking-out vanes (Fig. 6). We also optimized the back pressure for pushing the vanes out and the clearance of the sliding parts of the vanes to improve the start-up capability at low temperatures, successfully achieving start-up characteristics that were superior to those of the existing product. Furthermore, the pump cover has been fitted with an oil seal to attain improved airtightness, preventing oil release from the pump during halts and reducing the time needed to suck the fluid again during restart. These measures contribute to further improved start-up characteristics (Fig. 7).

4. 4 Improvement of NVH

As automobiles have recently become quieter year after year, the demand for quieter transmissions has been rising. It is also a must for pumps to have improved NVH characteristics.

In the newly developed vane pump, the port profile in the side plate was optimized to suit the environment where the transmission unit is used (Fig. 8). The optimized port helped reduce the discharge pulsation, suppressing vibration. The notches in the side plate, which connect the vane chamber with the port and help build a pressure in the vane chamber, were tuned through simulation (Fig. 9). This improved the quietness of the pump during both normal and high-speed rotations.

While the existing product had these notches only in side plate A, the new product has the notches in both side plates A and B. This design change increased the supply of high-pressure fluid to the vane chambers to alleviate the delay in pressure rise during high-speed rotation or during the use of fluid with much entrained air, serving as measures for cavitation (Fig. 10).

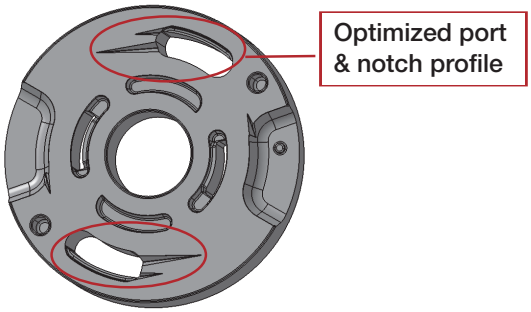

Fig. 8 Ports and notches of side plate

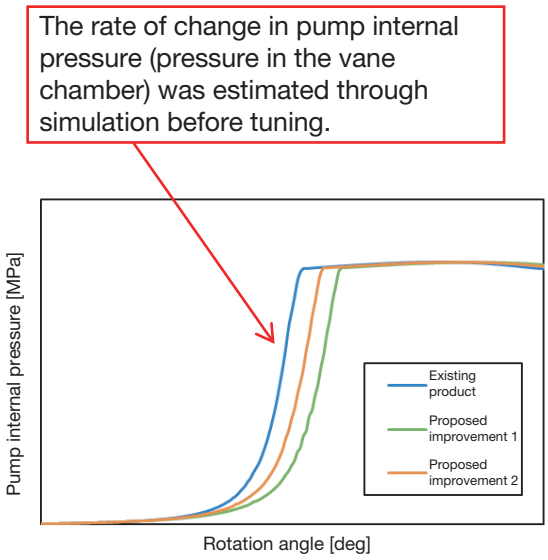

Fig. 9 Example of simulation of pressure in vane chambers

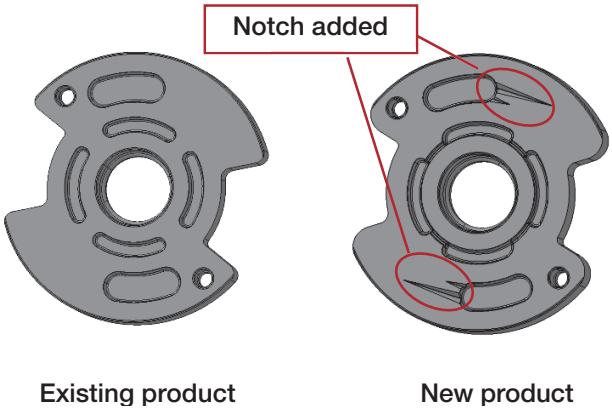

Fig. 10 Notches added

5 Conclusions

We have developed KYB's first vane pump for the AT and achieved the following:

[1] Development of a vane pump optimized for the AT
[2] About 20% lower loss torque than existing product
[3] Achievement of both durability and low driving torque
[4] Improved start-up characteristics
[5] Lower noise

The improvements discussed in this development project are shown in the inclined development views of the existing and new products (Fig. 11).

6 In Closing

The vane pump for the AT was developed according to specifications that KYB has never experienced in its product development history. Mass production of the vane pump has been achieved through great cooperation of all those who were involved in the development project.

I would like to take this opportunity to deeply thank all partners including those involved in the program from Mazda Motor Corporation as well as all personnel in the related functions of KYB.

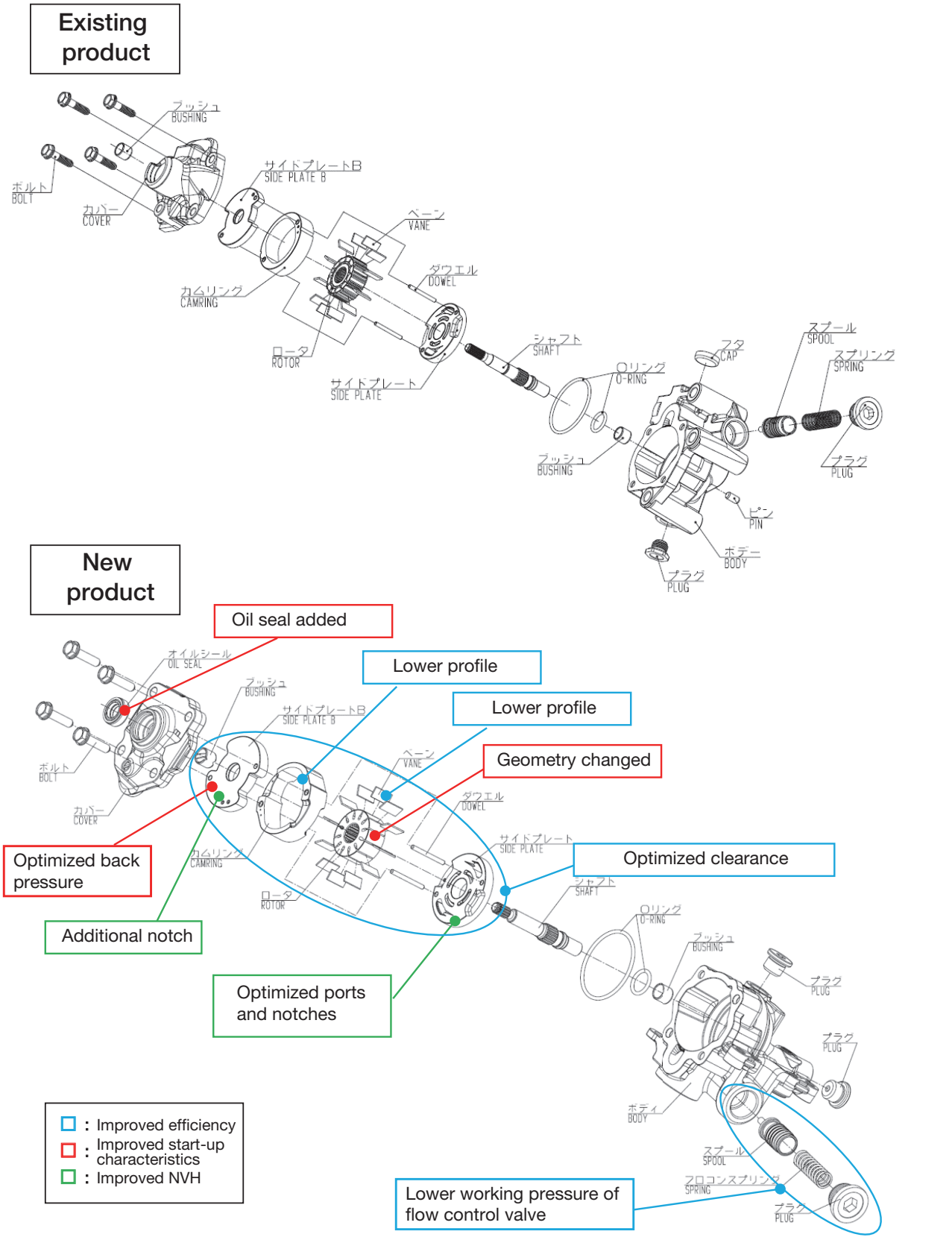

Fig. 11 Inclined development views of existing and new products

Author

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Joined the company in 2012.Pump Engineering Dept., Steering Business Dept., Automotive Components Operations Engaged in design of vane pumps.

Explanation

Initiatives to Develop Digital Human Capital

MIYAUCHI Yuuki　ISASHI Ryosuke　TAKINO Shinsuke

1 Introduction

These days, all industries need to obtain or develop digital human capital[Note 1)]. KYB has also systemized internal education and training to develop its own digital human capital. This report introduces KYB's initiatives to develop digital human capital.

Note 1) KYB prefers to use the term "human capital" instead of "human resources". This report uses "human capital" accordingly.

1.1 The Outset of Development of Digital Human Capital

The outset of the development of digital human capital was a cross-company activity project in 2016 that applied data mining[Note 2)] to analysis of casting failures in the group companies. The activities included learning statistics and promoting the use of data mining tools. The project eventually helped employees understand the necessity of data analysis in the company. Then, another activity was launched in 2018 to develop artificial intelligence (AI) human capital.[1)] The participants learned the knowledge and technologies necessary for more advanced analysis using machine learning[Note 3)] or deep learning[Note 4)].

In this activity, KYB gathered participants who were interested in AI throughout the company and asked engineers who had AI knowledge and technology to give lectures. A regular meeting was held every month to provide programming courses using e-learning and to carry out original small tests for participants along with their explanation. Based on the results of their daily learning, participants used various approaches to try to resolve challenges related to AI implementation given by Administration. The final part of the activity was group work to resolve actual administration challenges left unsolved in the company by means of AI. For a challenge related to vibration data of active suspensions for railroad applications, many participants built machine learning models taking into account cost and even processing speed on the assumption that the models would be introduced to the actual system. Thus, the activity yielded marvelous human capital development. The first term of the activity in FY2018 was followed by the second term in FY2019.

Note 2) The process of analyzing large amounts of data using statistics and other analysis techniques to obtain useful insights such as hidden patterns of data.

Note 3) A technology to learn regularity and patterns of data from a variety of data including alphanumeric characters so that computers can determine the current condition and predict the future.

Note 4) A technology to automatically extract features to be focused on from data and use them for determination of the current condition and future prediction.

1.2 DX Promotion and KYB-IoT Platform

During these activities, the world has been focused on digital transformation (DX). In Japan, the government and industry insisted on the necessity of using data and digital technology. KYB established the Digital Transformation Improvement Dept. in 2019 to accelerate the use of digital technology. Fig. 1 shows KYB's original data utilization steps[Note 5)]. The first step is digitization that turns analog information into data. This is followed by data collection and data saving in databases. The process thus advances toward digitization. It is further assumed that the process evolves into digital transformation based on the premise that all business communications and transactions will be done digitally .

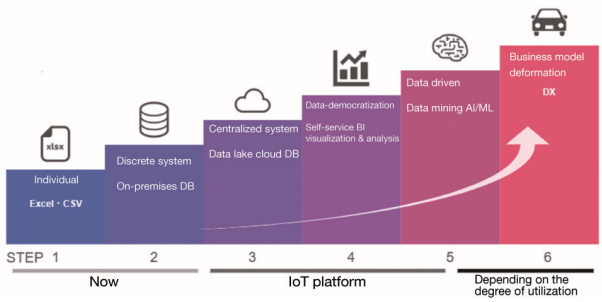


Fig. 1 Data utilization steps

To accelerate the data utilization, KYB constructed itself a KYB-IoT platform on the cloud. The platform supports Steps 3 and 4 of the data utilization process. At the outset, KYB promoted "defensive DX" mainly in the production domain.[2)] Now it has just begun with preparation for "offensive DX" in the product development domain and new business development.[3)]

Note 5) In 2021, some functions had already promoted the use of clouds and AI, but the whole company was still in Step 2.

1. 3 Implementation of Digital Human Capital Development

Along with the construction of the KYB-IoT platform where employees can flexibly use data with no constraints on time or location, the company is addressing the development of human capital who can effectively use the platform. These human capital should be familiar with business intelligence (BI) toward data-democratization, which is indispensable for the data utilization steps, and AI that enables more advanced analysis. Besides these technologies, employees are required to understand the significance of DX and foster proper IT literacy. They are given an explanation as to possible business losses that may arise without the use of data and digital technology and educated to raise their awareness of the necessity of preventing such losses.

In this way, we have established the digital human capital development program from a broader perspective covering not only AI but also BI, IT, and clouds. We are also trying to systemize these activities into a cross-company project through collaboration with Engineering Planning and the Human Capital Development Center.

2 Overview of Digital Human Capital Development

2. 1 Definition of Digital Human Capital

Before the start of the digital human capital development, the Digital Transformation Improvement Dept. preliminarily discussed which digital human capital we should try to develop with the related functions. As a result, the digital human capital KYB should develop were defined as "human capital who have both the technical skill to use digital technology and business transformation skill". This is because, to implement DX, KYB needs human capital who not only have acquired technical skills by participating in internal and external training courses but also have business transformation skills with which they can continue addressing challenges to achieve their purpose.

2. 2 Roadmap of Digital Human Capital Development

Fig. 2 shows a roadmap of digital human capital development established in 2020. In addition to IT Education for improving AI, BI and IT literacy, KYB has started DX Education to teach the basics of all necessary subjects for DX implementation.

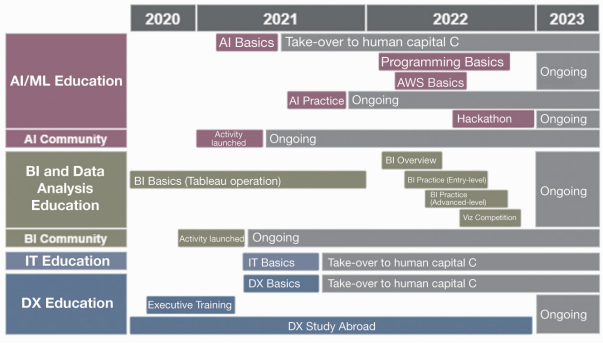


Fig. 2 Roadmap of digital human capital development

DX Basics is a lecture course aimed at ensuring that the concept and understanding of DX take root properly throughout the company. Trainees learn why the company needs digital technology and why they need to be aware of digital transformation. They also take a lecture on how to reform the organization to implement DX. Executive Training is conducted with support from Amazon Web Services, Inc. (AWS)

2. 3 Systemization of Digital Human Capital Development

Fig. 3 shows the relationship of scale and specialty among the courses. Centering on the AI and BI human capital development, the figure indicates DX Basics and other training courses to be provided to employees who are temporarily sent to the Digital Transformation Improvement Dept. for "studying abroad". As the digital human capital development is expanded, the map in Fig. 3 will be updated accordingly.

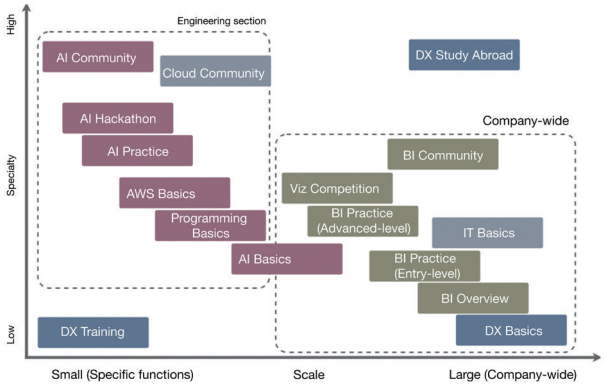


Fig. 3 Scale and specialty of digital human capital development

To establish a scheme or system of digital human capital development, the Digital Transformation Improvement Dept. has worked with the Engineering Planning Department and Human Capital Development Center since 2022 to create a skill level chart as shown in Fig. 4. Its creation is based on our idea that such a chart will help employees figure out a specific skill level they should try to reach next and will appropriately support their growth as individuals. Besides this chart focusing on AI and BI, we plan to develop additional skill level charts for other digital technologies.

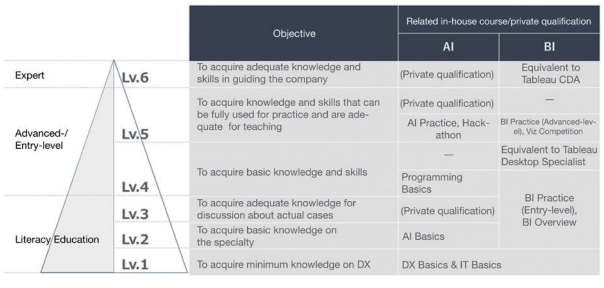


Fig. 4 Digital human capital skill level chart (under discussion)

2. 4 Year-round Digital Human Capital Development Curriculum

Fig. 5 shows the current year-round education curriculum in 2022. The first course of the curriculum is DX Basics that lectures the necessity of DX and an outline of digital technology. Trainees will broadly understand the purpose of learning about these issues. The curriculum is designed to connect this DX Basics to AI and BI human capital development and further to IT Education as a means of implementing DX. We will describe AI human capital development in Chapter 3 and BI human capital development in Chapter 4.

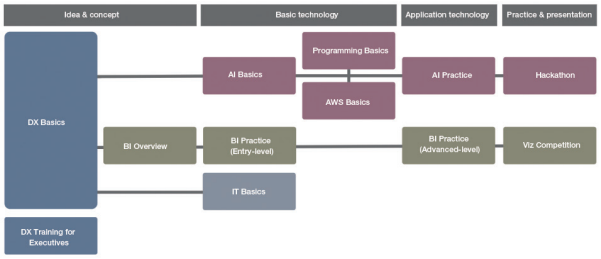


Fig. 5 FY2022 digital human capital development education program

3 AI Human Capital Development

3. 1 AI Human Capital Development Initiative

Currently, KYB has two pillars of AI human capital development: AI Education Curriculum and AI Community. The AI Education Curriculum covers a wide range of education from basic courses designed to learn knowledge and skills to ensure that no employee is ignorant of AI/ML[Note 6] to practical courses to learn the knowledge and skills necessary for appropriately operating the machine learning models that have been implemented. These education courses will be described in detail in section 3.2. AI Community provides places for employees to openly communicate with each other or to actively use the knowledge and skills they have obtained through education courses for resolving challenges facing the company. This will be described in detail in section 3.3.

Note 6) AI services that only need data are differentiated from ML (machine learning) that can build machine learning models itself.

3. 2 AI Education Curriculum

3. 2. 1 Background

The AI human capital development initiative launched in 2018 has yielded certain results so far. To further expand the AI human capital and further increase the practical cases contributing to the company's business, KYB decided to introduce MLOps[Note 7], which had gained recent attention, to the education system and provide opportunities for employees to learn the operation of machine learning models. This decision was made with the background that, although a constructed machine learning model increases in value only if it yields results to end users as expected, the building and operation of an IT system with such a machine learning model is recognized as a function involving many issues to be considered. It is impossible for a single role, such as data scientists, to cover all domains. To resolve the issue, data scientists, data engineers, and machine learning engineers should technically cooperate with each other through smooth mutual communication toward a final common goal, rather than independently promote their own development work. Then, an education curriculum with MLOps taken into account was started for all trainees. This allows them to imagine during their education what will specifically take place after the introduction of AI/ML and to build the knowledge and skills necessary for establishing a sustainable machine learning system.

The lecture materials used in the AI Education Curriculum, except for programming courses, have been prepared by in-house engineers. With these internally prepared materials, the lectures can provide familiar topics including in-house failure cases.

Note 7) A paradigm that aims to connect the development process of machine learning with the operation process of the same to achieve continual improvement after the supply of services.

3. 2. 2 Track Record

The AI Education Curriculum in 2022 has four courses including those launched in 2021:

(1)AI Basics

AI Basics is an entry-level course of the AI Education Curriculum and intended to make AI widely popular among employees. This course has been provided to ensure that no employee is ignorant of AI/ML.

The course consists of lectures by chapter that begin with data collection, followed by data preprocessing/visualization, feature extraction learning, hyperparameter[Note 8] tuning, and inference, according to the proper machine learning workflow. In the introduction of the lectures, the difference in definition between AI and machine learning is explained. In addition, the lectures widely cover different specific approaches of machine learning and the basic theory of deep learning. Materials used in the lectures include not only simple explanations of individual technologies but also actual cases in KYB, for example, what employees doubted in the past AI hu-

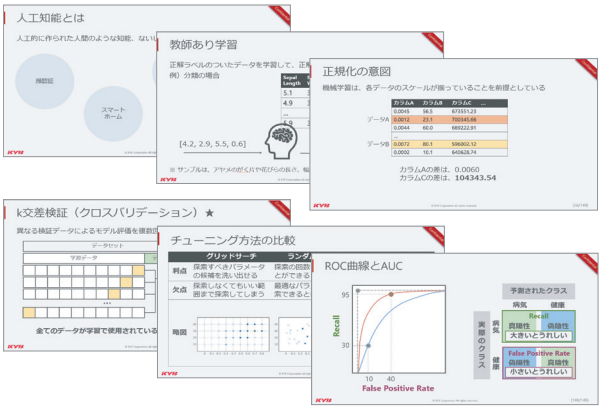


Fig. 6 Education materials for AI Basics

man capital development and what they were confused about during implementation. Thus, these materials have been designed to be suitable for the current skill level of the company's employees. Some of the textbooks provided in the lectures are shown in Fig. 6.

Note 8) Parameters that are not automatically learned by machine learning algorithms. Hyperparameters are generally decided based on the developers' experience and/or optimization methods used.

(2)Programming Basics

The Programming Basics course provides a place for trainees to output the knowledge they obtained in the AI Basic course. Trainees who finished the AI Basic course can implement machine learning through programming. Based on what they learned in AI Basics, they try to do programming to build a machine learning model. This course does not involve a dedicated lecturer teaching in a room like hands-on training, although it does start at a specified date and time. Instead, individual trainees access webinars that have been prepared in advance and learn online. Instructors will only respond to trainees who have a question. Trainees can look into what they are not sure about at their own pace and receive support from instructors whenever they like to resolve the problem right away. The use of this online learning is intended to improve the practical skill of trainees.

(3) AWS Basics

KYB widely uses AWSs as a base to implement machine learning, including the KYB-IoT platform. Trainees who have finished the education curriculum are thus required to smoothly get ready for the development environment provided for AWSs. In addition to this background, the AWS Basics course is intended to explain the basic knowledge and techniques about AWS to trainees before they attend the following AI Practice and AI Hackathon courses.

It is very important to learn the necessity of using the cloud environment to implement machine learning and MLOps. If a machine learning system is built in an existing on-premises environment, some technical liabilities would be generated in future. This course presents such liabilities and explains the advantages of the cloud environment where data scientists and machine learning engineers can concentrate on essential tasks including development. Like the Programming Basics course, this course has been designed to allow trainees to freely access webinars within a specified course period and to allow instructors to only respond to trainees who have a question. Fig. 7 shows some of the materials provided in the course.

(4) AI Practice

AI Practice is a hands-on training course where trainees can build machine learning models in a cloud environment based on the knowledge obtained in the AWS Basic course and then implement the operation of these models. This course was internally developed in 2022.

At the beginning of this hands-on course, trainees are supposed to carry out implementation of machine learning models in an assumed existing on-premises environment. They not only simply implement machine learning models but also learn effective visualization methods during preprocessing as well as precautions for dividing data sets. The course presents case examples of implementation that can be applied by trainees to development work immediately after they finish the course. Next, they are supposed to use Amazon SageMaker [Note 9)] to implement machine learning models in an assumed cloud environment. We have tried to prepare materials for this course to present an overview of the implementation range as needed, with which trainees can clearly identify the functions they have implemented at the moment.

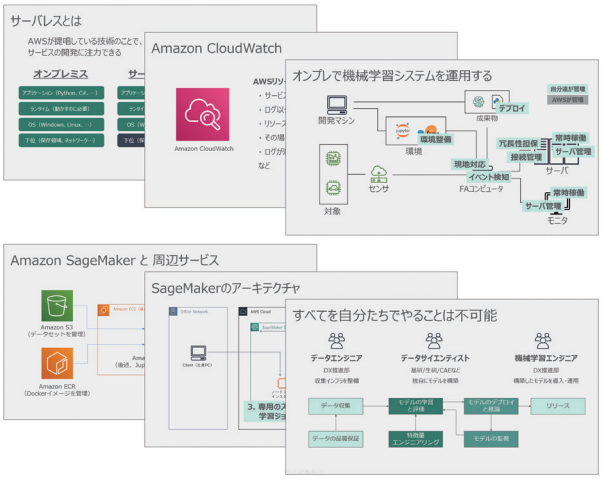


Fig. 7 Education materials for AWS Basics

Note 9) A cloud service that provides an implementation environment for rapid development and deployment of machine learning models.

(5) AI Hackathon

AI Hackathon is an event for trainees to output in teams the knowledge and skills they have obtained through the year-round education curriculum. Trainee teams try to solve hypothetical challenges presented by Administration by using machine learning. This activity involves not only implementation of machine learning models but also the design of peripheral machine learning systems by taking into account the operation system of machine learning models and the Well-Architected Framework[Note 10)] proposed by AWS.

During the activity period, an "office hour" for each team is available once a week so that the team can consult with AWS Solution Architects[Note 11)] about any questions about implementation of the design or machine learning under discussion in the team . Individual members of each team are given a specific role and required to show check items they should achieve. This check-out system is used to quantitatively evaluate how close the team members are to the goal set by Administration after the completion of the Hackathon. In the Hackathon presentation attended by management and AWS, individual teams report the results of implementation of machine learning models and the unique thoughts they put in when designing the machine learning system. Photo 1 shows how the AI Hackathon presentation was held. Fig.

8 shows some of the materials available in the presentation.

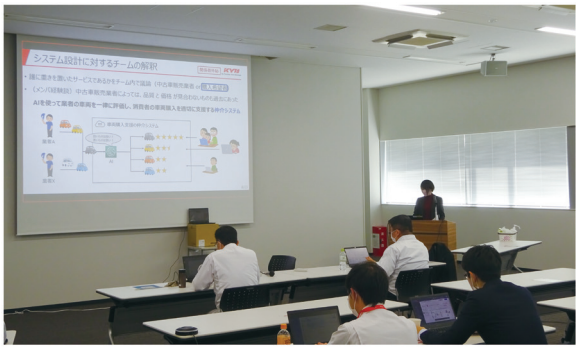


Photo 1 AI Hackathon presentation

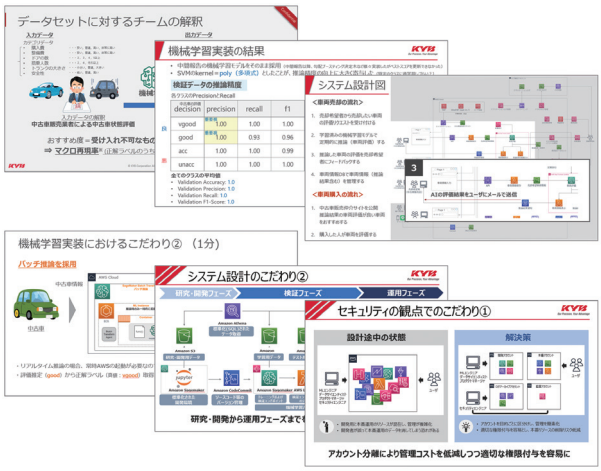


Fig. 8 Hackathon presentation materials

Note 10) Major concepts and design principles for designing and executing solutions on the cloud proposed by AWS.

Note 11) A professional who provides appropriate solutions for customer needs including cloud services.

3. 3 AI Community

3. 3. 1 Background and Purpose

Independent AI development by AI human capital within their own department would be inefficient from the viewpoints of proliferation of technology and formation of culture. This might generate barriers to immediate contribution to business. the Digital Transformation Improvement Dept. thought that a medium or a continual hub for all employees to communicate with each other beyond their functions or titles was needed. Then, we decided to plan and operate a place for employees with a common passion to openly share technologies by discussing what they were concerned about and introducing the latest technical information and newly published books to each other. This is AI Community. An initiative to use your own knowledge and skills to resolve concrete challenges that was launched in 2022. We thought that AI Community would become a group contributing to business, thereby enabling the members to continue challenging new things all the time. We will disseminate the success stories of AI Community both inside and outside the company, with the aim of further expanding our AI human capital.

3. 3. 2 Track Record

Since its establishment in 2021, human capital with advanced AI/ML knowledge and skills have gathered from various domains including product development and production engineering to be members of AI Community.

(1) Information sharing and promotion support

Discussions among AI Community members using chatting tools are opened within the company. Examples in the past include introduction of AI/ML development themes addressed by Community members, troubleshooting support for other members based on member's own experience in development, and deployment of manuals for building a Python[Note 12)] environment for easier implementation of machine learning. AI Community also plays the role of supporting the promotion of latest technologies, including verification of pilot versions.

Note 12) A general-purpose programming language that is the de facto standard for AI development.

(2) Group work

The group work program, which was launched in 2022, is intended to contribute to the company by utilizing the AI/ML knowledge and skills owned by the Community members. The program solicits concrete challenges faced by individual members during their daily development work. Other members then participate to resolve selected challenges through mutual cooperation. The following introduces some of these activities:

[1] Research on a new analysis approach where structural analysis with FEM has been reduced for machine learning

CAE Improvement Dept. has been discussing integrating a detailed FEM (finite element method) based model of laminated leaf valves into the SA analysis system to achieve high-accuracy prediction of the performance characteristics of shock absorbers (hereinafter "SA"). FEM can take into account detailed physical phenomena that cannot be covered by conventional theoretical calculations, such as the fastening axial force and the partial contact of leaf valves. However, it takes a long time to complete the FEM calculation. Then, the department has improved the prediction accuracy without increasing the calculation time by reducing the order of the FEM-based laminated leaf valve model to a machine learning model and integrating it into the SA analysis system. This technology has been highly rated both inside and outside the company.

AI Community implemented and verified various machine learning models proposed by its members, trying to enhance the prediction accuracy. This activity eventually helped substantially improve the accuracy of predicting the SA performance characteristics.

[2] Improving the product stamp inspection performance through deep learning

The Production Technology R&D Center is promoting the automation of appearance inspection in the SA mass production system through deep learning. The current ac-

curacy of identifying stamped characters on products using deep learning is 99.92%. However, the current deep learning method has not been adequately verified through comparison with other similar methods.

To achieve an even higher accuracy of the stamping identification, AI Community has implemented and verified various methods other than the one that was already scheduled to be introduced into the mass production system. Unfortunately, none of them was found to be superior to the current candidate. However, many of them were the first ever methods implemented by the members who participated in the activity including YOLO[Note 13)]. Community members could distinctly feel their own technical growth through the group work.

Note 13) One of the physical object detection algorithms that can recognize the contour of an object at a high speed with high accuracy.

3. 4 AI Human Capital Development Challenges and Their Solutions

This section describes challenges related to the AI education curriculum and AI Community as well as solutions to these challenges.

3. 4. 1 AI Human Capital Development Challenges

(1) Follow-up support of the curriculum

Currently, continual follow-up support to employees who have finished the education curriculum is not available. These employees may fail to maintain the skills they learned if they are not involved in AI/ML in their development work.

(2) Group work activity period

The term of a single course of group work activity of AI Community is as short as three months. In many cases members failed to fundamentally resolve challenges.

(3) Evaluation with objective measures

No specific measures have been established to evaluate the education curriculum or AI Community. What results the total human capital development initiatives have brought about is unclear.

3. 4. 2 Solutions to Challenges

To resolve these challenges, we reviewed the total activities and discussed the following solutions:

(1) Encouraging trainees to take part in AI Community

Among trainees who have finished the education curriculum, some do not have an opportunity of getting involved in development work despite being interested in AL/ML. It is effective to encourage such employees to actively take part in AI Community. Once involved in the Community, they can receive continual follow-up support through group work after finishing the curriculum. It is also expected they will maintain the skills they have learned.

(2) Reviewing the group work period

The group work activity period of AI Community should be changed to one year so that members can try to fundamentally resolve challenges. Challenges to be selected should be quantitatively evaluated for business impact, necessary resources, and other factors using their own methods. Then, themes that are believed to be most effective should be selected.

(3) Strengthening the group work scheme

With an eye toward operation as a machine learning system, the group work scheme should use AWSs as its development environment. Group work should be promoted with technical support from AWS. The results of group work activities should be evaluated by determining whether AI/ML challenges have been resolved by Community members (trainees of AI Education).

4 BI Human Capital Development

4. 1 BI Human Capital Development Initiative

Like the AI human capital development initiative, KYB's BI human capital development initiative has two pillars: BI Education Curriculum and BI Community.

4. 1. 1 BI Education Curriculum

The BI Education Curriculum provides employees with training courses to build important skills for data utilization, including data preprocessing, visualization, and analysis while practically using Tableau[Note 14)], which has been introduced into the company as a standard BI tool.

Note 14) A BI tool provided by Salesforce Japan Co., Ltd.

4. 1. 2 BI Community

BI Community is an in-house community consisting of trainees who are taking or have finished the education curriculum as well as those who are interested in in-house data utilization. Community members share their knowhow, case examples both inside and outside the company, and BI-related information.

4. 2 BI Education Curriculum

4. 2. 1 Background

BI originally refers to the process of "collecting data, putting it together and accumulating it in a location, analyzing it according to a purpose, and visualizing it into a user-friendly format". However, the BI Basics course provided in 2020 mainly focused on how to use tools. The course might have misled its trainees to believe that BI is just data visualization using tools. Moreover, the course was rather focused on attracting new users, failing to provide an adequate approach for trainees to "self-propelling" the data utilization themselves.

After learning this lesson, we modified the curriculum for 2022 so that trainees can learn step-by-step according to their interest in BI.

4. 2. 2 Track Record

The BI education curriculum in 2022 has three courses: BI Overview, BI Practice (Entry-level), and BI Practice (Advanced-level). Firstly, the following describes the breakdown of trainees in different courses of the curriculum in 2022.

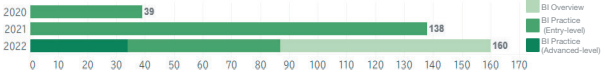


Fig. 9 Trainees of BI education by fiscal year

Fig. 9 shows the number of trainees of the BI education curriculum in these fiscal years. The accumulated total number of trainees is 337. In 2022, 160 employees took the courses. The majority were employees from the Engineering Division, AC Operations, or Production Division. These functions are those involved in data analysis in their research and development or improvement activity. Still, participation in the curriculum has been gradually expanded to include affiliated companies and management divisions. We have found more and more employees from different functions being interested in BI education.

Now let us explain the details of these BI courses:

(1) BI Overview

To provide an opportunity for employees to be interested in BI, it is essential to make them understand the current situation in which we are surrounded by a data-abundant environment and for them to have data literacy[Note 15)] for implementing BI to begin with. Then, this BI Overview course was set up for all employees to deepen their understanding of the preconditions for the use of BI, such as the definition of BI and data literacy with support from Salesforce Japan Co., Ltd. (hereinafter "Salesforce Japan").

Data literacy involves analyzing data, which can be implemented by Tableau. Lectures of this course cover data analysis. Lecturers present trainees with familiar data examples such as weather reports and sales data, so that they can learn, for example, why data visualization is effective for the analysis. The latter half of the lectures includes a recreation program for trainees to answer an entertainment quiz by operating screens created on Tableau. The program makes trainees easily understand what they can do with Tableau, helping them to proceed to the next step, namely, the BI Practice (Entry-level) course.

(2) BI Practice (Entry-level)

In the BI Practice (Entry-level) course, trainees can receive hands-on practice of basic operation and data classification of Tableau, including simple plotting such as drawing line and bar graphs, data filtering, and learning differences between continuous and non-continuous data.

Each section of the course has exercises. Two dedicated assistant instructors support a group of five or six trainees and respond to their questions. Assistant instructors consist of volunteers from BI Community so that these individual instructors can also improve their understanding of BI.

The course uses lecture materials that have been prepared by Salesforce Japan. These materials are brushed up reflecting feedback from trainees and lecturers.

Some of the results of trainees are shown in the following figures. Note that these results are in the preparation stage before being put in service. They were temporarily created to verify practicality in the case of using in-house actual data. Fig. 10 shows the dashboard of communication terminals for oil status, vibration, and temperature sensors along with their battery status. Fig. 11 shows the dashboard for changes in patent applications of different countries that has been developed by the Intellectual Property Department.

Fig. 10 Layout of sensor communication terminals and their battery status

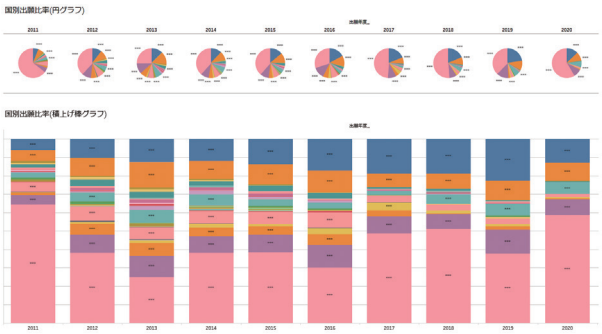


Fig. 11 Analysis of changes in patent applications of different countries[Note16)]

(3) BI Practice (Advanced-level)

The most likely difficulty for users in performing data collection, analysis, and visualization may be the development of a data environment. Particularly when users have just started using Tableau, they often handle existing data. That is' why the BI Practice (Advanced-level) course is focused on how to organize existing data. We designed the course to include data splitting and data coupling for linking two or more data sets using Tableau Desktop[Note 17)] and Tableau Prep[Note 18)] as well as data preprocessing such as name-based aggregation by correcting orthographic variants.

Using a data set consisting of several files, the lecturers explain in a storytelling style how to organize the data set by identifying any inconsistent parts of the data. All materials used in the lectures were internally prepared.

We believe that trainees can vividly experience the process of data processing, which is important for proper visualization and analysis of BI data. We have received feedback from trainees that they have successfully resolved remaining issues.

Note 15) The generic name for the capability to read, analyze, use, and describe data.

Note 16) Concrete numbers and names have been blurred.

Note 17) A specially designed tool for data analysis and visualization. One of the Tableau products.

Note 18) A specially designed tool for data pretreatment. One of the Tableau products.

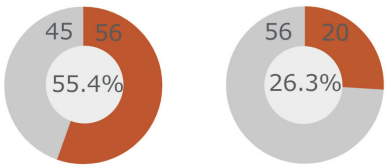
4. 3 BI Community

4. 3. 1 Background

It may be difficult for trainees alone to identify challenges or organize data of their own function. Then, a cross-function community was established to support them to achieve "self-propelling". This BI Community mainly consists of trainees of the BI Education curriculum. Community members can freely consult with each other about their concerns over how to use Tableau or data-related issues.

4. 3. 2 Current Challenge

BI Community has 177 members consisting of 101 Creators[Note 19)] and 76 Viewers[Note 20).] However, active users of Tableau in the last three weeks are not more than 50% of licensed users.



(a) Creator (b) Viewer

Fig. 12 Ratio of active users to licensed users

Thus, the Community activity has not been vitalized as planned. We recognize that a data-driven culture has not yet been successfully developed.

Note 19) A type of license that authorizes the use of Tableau products. Developer license.

Note 20) A type of license that authorizes the access to screens that have been created.

4. 3. 3 Cause Analysis

We analyzed the behavior of users to figure out the cause of the challenge. The analysis has revealed the following:

About Creators

[1] 16 Creators make their own results open to the community.

[2] Creators do access the results [1] (within the same function).

[3] Creators do use Tableau but have not yielded many results.

About Viewers

[4] Viewers access the screens that have been made open to the community by the Digital Transformation Improvement Dept.

- Equipment predictive maintenance support system
- Equipment data collection/analysis system (MES service) [4)]

[1] and [2] imply that Creators have started to proactively act in the functions. According to [3], however, they have not yet reached the stage of creating screens to be made open to the community. They may face some challenge. Otherwise, they may have completed analysis, but just produced results that are locally accessed by a limited number of users.

On the other hand, Viewers usually use Tableau to access screens they want to view. It can be estimated from [1] and [2] that Viewers are likely to use Tableau if data or screens that relate to themselves are available. In other words, the screens made open to the community may not be those wanted to view by the Viewers who do not use Tableau.

From the above, it can be concluded that a support system for the user group applicable to [3], which is a bottleneck, must be developed.

4. 3. 4 Solutions

To resolve the challenge, the operation of the education curriculum should be revised to focus on user support. We discussed the following solutions:

(1) Providing on-demand learning contents

The live lectures, which have been prepared and held by members from the Digital Transformation Improvement Dept. on an as-needed basis, will be changed to a video streaming service, ensuring the support man-hours. With this service, trainees can take on-line lectures whenever they like. It can be expected that the number of in-house users will increase.

(2) Creating a skill map

Along with the video streaming service described above in (1), a skill map will be created and made available. The skill map should be linked to the existing lectures so that trainees can obtain visualizations of their own skill set and maintain their motivation for self-learning.

5 Future Prospects

Since its launch of full-scale initiatives to develop digital human capital in 2021, KYB has promoted the development of an education curriculum and the operation of communities. Through these activities, the company has enjoyed an increase in AI and BI human capital and new cases of data utilization that have never been seen before.

We will continue considering measures to increase the in-house digital human capital. For AI human capital development, we will build a development platform where even more AI human capital, ranging from beginners to masters, can flexibly use AI. We would also like to generate more cases of establishing an MLOps environment for AI's contribution to business. To do so, it is necessary to establish a cloud environment operation rule for wider deployment throughout the company. Besides this, it will be even more important to carry out DX promotion to expand the KYB-IoT platform appropriately according to the scale of function or project. For BI human capital development, we would like to facilitate data linkage among the business functions centered on the improvement of data analysis skills of individuals. To achieve this, we should discuss the company's general data governance, including how data should be, how data should be available, where data should be compiled, and who is responsible for data management, to provide data to users in an easier-to-use way.

6 In Closing

This report has introduced KYB's initiatives to develop digital human capital. The true purpose of education is achieved only if employees apply the knowledge and skills they have learned to their daily development work contributing to business. Toward the implementation of DX, we would like to continue to generate more cases of in-house data utilization and expand the education curriculum needed by the company being aware of world trends.

Finally, we would like to take this opportunity to sincerely thank all those concerned in the related functions who extended great support and cooperation to the promotion of the initiatives.

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Essay

Account of Residence in Indonesia

SHIMENO Yoshirou

1. Introduction

I was sent to PT. KYB Hydraulics Manufacturing Indonesia (hereinafter "KHMI") located in Indonesia in October 2015 and worked for the company as an expatriate for about six years and eight months until my repatriation in June 2022. During the expatriation, I definitely experienced various things. In this essay, I've written several episodes I remember rather freely like a collection of short stories. I will be happy if you take time to read them.

2. Indonesian is the Second Easiest Language in the World

When I asked the then President of KHMI "is there anything I should prepare for expatriation?", I was told, "First of all, learn Indonesian to be able to have conversations in everyday life". Before expatriation, I took an Indonesian course for about 90 hours. The teacher was a Japanese who used to live in Indonesia for quite a long time and taught me not only the language but also local culture and customs. This information was very useful for me to live in Indonesia during my expatriation. One thing that particularly impressed me in the Indonesian course was the phrase "Indonesian is the second easiest language in the world" as seen in the title of this section. Probably when my learning came to a deadlock, the teacher abruptly told me, "Indonesian is the second easiest language in the world". This phrase was followed by the question "What do you think is the easiest language in the world?" I answered, "I think it's English", because it is widely used as an official language in the world. The teacher gave me an unexpected answer full of humor, "Unfortunately no, the correct answer is your mother language". Those were the teacher's words to encourage me to have confidence since Indonesian is the next easiest language to your mother language that you are familiar with.

3. No Orders

In October 2015 when I moved to Indonesia, the Southeast Asian Region including Indonesia saw a significant slowdown in demand for construction equipment. Only less than one year had passed since KHMI had started operation. During that time, the company had no product delivery at all in some months partially because it was able to produce only one model of construction equipment. I was told by the President as soon as I arrived at KHMI, "You do not need to report to duty on Friday since we've just decided to make Friday a no-work day to reduce production". I then recalled those days when I had joined KYB as a newcomer. When I reported to work at Gifu South Plant which was my temporary workplace in that July, the General Affairs Manager told me that, "Those who have been assigned to Hydraulic Engineering should take a paid leave on next Monday. Full-time employees belonging to Hydraulic Engineering will be off for lower production, but trial employees will not be covered". History was repeated. The words of the President made me feel insecure about the start of my work in Indonesia which would begin with a no-work day for lower production. I managed to switch my mind by recognizing the situation as "I will only rise up from the current worst of times" and then started to work.

On those days on which workers had nothing to directly produce, we provided group education. But we almost ran out of suitable topics for lectures. Workers were under accumulated stress as they continued taking lectures sitting in a classroom. We thought it better that workers should do some physical exercise and then decided to ask them to develop a futsal ground on an expanded space of the premises for nearly half of each working day. I also tried to take time to work together with them in developing the ground so that they could recognize me. Finally, the futsal ground was properly completed, and I sometimes found employees playing futsal after work. However, as they gradually came to work harder with overtime and a two-shift operation, the futsal ground fell into disuse and eventually fully deteriorated. While I regretted the deterioration in spite of our efforts to develop the ground, I also felt happy with the increase in production.

4. When You Are in Trouble...

I sometimes feel acutely aware that an important thing in living in an unfamiliar place is the link among people. KHMI operates a welding process using CO2 gas. One day, a rectifier installed on a CO2 gas cylinder had a failure, which interrupted the gas supply resulting in a production shutdown. We informed Gifu South Plant of the fact, but they replied they did not use the rectifier used by KHMI because their gas supply system for welding was different from ours. We then had to manage to obtain a rectifier of the same type in Indonesia. Since the target equipment was a product made in Japan, the Indonesian staff were at a loss with no prospect of obtaining the

equipment. Then, I happened to recall the face of a person from a trading company from which we bought hydraulic fluid and welding wires. When I got in touch with him right away, he told me he would check it out quickly. After just a few hours, I was informed that he would send a unit that had just arrived at the airport out to us. Thanks to his arrangement, we successfully minimized the line shutdown. After that, he helped us over and over again when we were in a tight corner. We are gratefully obliged to him.

Indonesia saw the outbreak of COVID-19 around April 2020. Its Delta variant raged in July 2021. Under the circumstances, we exchanged information about COVID-19 with our customers, suppliers, and friends and acquaintances, and then cooperated with each other to manage to overcome the difficulty. We finally did it thanks definitely to the network of people we had built. The pandemic reminded me anew that networks are so important for expatriates working far away from Japan.

5. Delivering Products to Customers

KHMI manufactures hydraulic cylinders for construction equipment. The company has only one assembly line. In order to avoid the risk of delay in delivery due to equipment failure or other trouble, KHMI operates the plant with a certain amount of product inventory on hand. However, in the event of a major equipment failure involving part replacement during a period with many orders, I had to spend several days feeling uneasy until the repair was done. If I found the inventory having gradually decreased in the course of making rounds of the plant, I checked out the upcoming delivery schedule in the next morning meeting. I was often waiting for replacement parts to arrive at the plant while trying to figure out until when we would be able to continue delivering products with the existing inventory. That was quite stressful indeed. When the parts arrived and we completed the replacement work to resume production, I felt very happy together with the local employees. I breathed a sigh of relief when I heard the production equipment starting to make a sound. Then I went back to work in the office.

A hydraulic cylinder consists of about 40 kinds of parts when they are counted by item number. Naturally, the cylinder cannot be assembled even if only a single part is missing. In the morning meeting one day, I was told that the production schedule had to be postponed due to a lack of seal parts. A seal product is generally compatible with other counterparts as long as they are identical in size. Unfortunately, the seal part we used had no other counterpart of the same outside and inside diameters. I heard that, if the next sea freight arrived as scheduled, the product delivery would be made with no problem at all. I knew things would usually get harder under such a situation. In fact, the freight was delayed as expected. Our staff from Production Management eventually went out to the forwarder's warehouse to meet the arrival of the container at the warehouse and receive the necessary parts from the container. They hurried back to KHMI to bring them to the assembly line and managed to successfully deliver the product at the last minute by the delivery time.

Another experience I remember was a local supplier ranking for delivery performance announced at a supplier meeting of our customer. In addition to the conventional announcement of quality failures and worst suppliers, the results of their evaluation of delivery performance were indicated at that meeting. As I was confident that we had never delayed a delivery, I tried to find the name of KHMI in the list from the top one by one, but I couldn’t see it. I finally found our name around the middle of the list. Actually, the customer evaluated suppliers by marking their delivery as "on time", "early", or "delayed". KHMI had certainly never delayed any delivery but showed a relatively high rate of early delivery. This was the cause of the lower than expected rank of KHMI. Then, first of all, we interviewed the customer to hear the evaluation criteria, successfully identifying, among the information provided by the ordering system, the parameters used to determine whether a delivery is late or early along with the reference date. Next, we looked back at the delivery performance in the past to investigate possible factors leading to the evaluation results of "early" deliveries. The investigation revealed that KHMI moved forward some deliveries in order to raise the loading efficiency of motor trucks, which were then evaluated as "early" deliveries. KHMI originally operated the plant with a certain amount of product inventory on hand and the customer was located around only 10 km away from the KHMI plant. From these reasons, we determined that we could make delivery on time by transporting the products of the models in the quantity as instructed by the ordering system in auto trucks we arranged every day. With this new delivery system, KHMI actually had to deliver products more often. So, we changed the forwarder to another located in the same industrial park as KHMI for freight cost reduction and then started to make deliveries according to the exact delivery date, item number and quantity instructed by the customer's ordering system. In the next supplier meeting, KHMI won the No. 1 prize for on-time delivery with 100% delivery achievement. I'm very glad to hear that KHMI still continues to achieve 100% on-time delivery.

6. Clothing, Food and Living

The first is "clothing". As you know, Indonesia is located in the tropical zone right on the equator. The year can be divided into two seasons: rainy and dry seasons. Since there are almost no daily temperature variations throughout the year, you do not need to change clothing by season. Still, a big and famous Japanese apparel shop that I often found in shopping malls in Jakarta sold down jackets and clothing with functions such as moisture absorption and heat generation during the Japanese winter. While these products were definitely convenient for me to temporarily go back home in the winter to Japan, I doubted if Indonesians really needed to use these goods. The winter in Japan generally corresponds to the rainy season in Indonesia. In the rainy season, the average temperature is slightly lower than that in the dry season. I actually felt the intense sunlight in the dry season and chilly in the rainy season. Taking into account these changes in climate in Indonesia, I had a hunch that's why such winter clothing was in stores even in Indonesia.

The next topic is "food". Many Japanese-owned companies had branched out into Jakarta where I lived and around the industrial park in Bekasi where KHMI was

located. These places had a variety of Japanese restaurants. Some of them directly bought airfreighted seafood from the Japanese market. As I describe in detail in the paragraph for "living" later, after work I used to take dinner at a Japanese restaurant in the industrial park before going back home because the Jakarta suburban area often had traffic jams. That restaurant served a variety of Japanese food cooked by the full-time Japanese chef. I went to the restaurant almost every night on weekdays. The Japanese meals in the restaurant always appealed to me and conversations with familiar Indonesian staff there allowed me to refresh my mind.

I often had Indonesian food for lunch after playing golf on weekends. I looked back on how I had been playing while eating Satay (skewered meat; salty or marinated chicken with coconut milk is popular) or Tahu Goreng (fried tofu). It was common practice for me to finish off a night of drinking with Nasi Goreng (Indonesian style fried rice), Me Goreng (Indonesian style fried noodle), or Soto Ayam (curry-flavored soup with chicken and rice vermicelli, sometimes containing rice). What I personally loved was Sop Buntut, which is a rather light taste, spicy soup made with oxtails. You may take Sop Buntut with plain rice and add Sambal (chili sauce) or lime to enjoy taste variations. This is one of my recommendations, although I did not eat it so often.

Photo 1 Sop Buntut (in the right bowl)

I think that most Japanese like the typical taste of Indonesian cuisine. However, those who are not fond of spicy food (like me) should be careful of some Indonesian dishes because they use a good amount of red pepper. On the other hand, most Indonesian beverages taste sweet. Even coffee and tea are very sweet as they are served with sugar already mixed in as standard. When ordering, I needed to ask them to give me a "non-sweet" drink.

The final topic is "living". I lived in an apartment in the center of Jakarta for all the six years of my expatriation. The 1st to 3rd floors of the office and apartment complex had a small-sized shopping mall including Japanese-operated supermarkets, Japanese restaurants, and ramen shops. I never felt any inconvenience during my stay in the apartment on holidays.

The industrial park where KHMI is located was about 40 km away from the apartment. It was "normally" an approximately 40-minute ride to report to duty using an easy-to-drive highway, but heavy traffic jams frequently occurred due to traffic accidents or heavy rain. Some people say that Jakarta is the world's worst city for traffic jams. Particularly, three transportation systems were under construction at that time: the Jakarta-Bandung high-speed railway, the Jakarta-Bekasi-Bogor suburban railway, and the Jakarta-Karawang high-speed railway. When roadworks related to these lines were conducted simultaneously in the same area, it often took over three hours each way for commuting, which really frustrated me.

The car I used in Indonesia was not equipped with a navigation system. When I was involved in a traffic jam or moved to a place I did not know, I used map applications, which had evolved with the spread of smartphones, to figure out the best route or predict the time to arrive at the destination. These applications were very convenient tools but required me to take care when driving on an unfamiliar open road. This is because, while map applications indicate busy traffic in color, I was often caught in a traffic jam where cars could not move an inch even after selecting a "busy" route along open roads rather than a "jammed" route. While Indonesian highways cannot be accessed by motorbikes, its open roads are available for both four-wheeled cars and motorbikes. On an open road with a traffic jam, cars certainly could not move at all, but motorbikes could drive through the jam. This apparently causes the map applications to indicate that this road is "busy". In spite of this precaution, one of my good memories was of working together with my driver trying to reach the destination by giving navigation instructions to him with my smartphone in one hand saying, for example, "Turn left at the next corner" and "Go straight for a while". Looking back on the expatriation period, the person with whom I spent the longest time was my driver. I really thank him for getting me to various destinations safely for over six years.

7. Birthday

In Japan, the person whose birthday is celebrated usually receives birthday presents from their family and friends. In Indonesia, on the contrary, the person whose birthday is celebrated usually gives presents or buys food for their family and friends. Since I had learned this custom before my expatriation, I asked local staff to order a pizza delivery for my birthday before my first birthday after being sent to Indonesia. On the day, when I was back at my desk after a morning assembly, I suddenly heard a voice singing the Happy Birthday song and saw a staff member approaching me carrying a birthday cake. All members in the office celebrated my birthday. I still remember that I was very surprised because I had not expected such a celebration at all while I was overwhelmed by the great joy of being a member of KHMI. Thereafter, all staff members continued to celebrate my birthday every year with a birthday cake they had prepared.

In the last year of my expatriation, I wanted to give the staff a gift that they could use for a long time. Indonesian people generally bring a drink bottle ("my bottle") to their workplace or a place to go out. So, I gave a plastic drink bottle as a gift to all employees, drivers, janitors, and cleaners working in the premises of KHMI, expressing my gratitude for helping me so far.

Photo 2 Birthday cake and KHMI staff on my birthday in the last year

8. The 100,000th Cylinder

KHMI rounds up actual production every month. At the beginning of 2021, we had almost achieved a total production of 100,000 cylinders. I was deeply moved by the fact that we had managed to accumulate production in spite of many different things happening up to then. Hoping to hold a company-wide celebration event, I came up with an idea. How about a quiz event for all employees to ask them "What model will the 100,000th cylinder be?". We listed up all possible models that could be produced at that time. Individual employees were supposed to vote for which model would be the 100,000th cylinder. Actually, only I had known about which cylinder on which day would be the 100,000th cylinder based on the planned and actual daily production data. Still, I was looking forward to finding out what model would be the 100,000th cylinder along with employees as the production schedule might change due to an abrupt change in orders for instance. Finally, the 100,000th cylinder was the model that was being produced most at that time, and which had been voted for by the highest number of employees. The prize money funded from my pocket was divided amongst those employees who voted for that model before the end of the 100,000th Cylinder Quiz. In commemoration of the 100,000th cylinder, we decided to exhibit it in the entrance lobby along with the first mass-produced cylinder that was already being exhibited. We also decided to post the name of all 95 employees (including retirees) who had been involved in the production of the 100,000 cylinders beside the actual cylinder. We asked them to make a banner to indicate their name. I am very proud of having been present at this memorable event that added another page to the history of KHMI.

Photo 3 The 100,000th cylinder (gold color) and banner

9. In Closing

When I was sent to KHMI, there were three expatriates including me. I was the only expatriate when I was about to be repatriated. In those days, I was in charge of a wider range of operations and had taken on heavier responsibility. Now I would like to appreciate anew the KHMI employees, who were always cheerful, for supporting me in continuing to work for KHMI until the end. I also feel that I was able to grow as a KAYABA personnel in such an environment where expatriates had to definitely do whatever they had to do.

On the other hand, I regret that I could not visit the World Heritage and other famous sites dotted throughout Indonesia partially because I was working on weekdays and went for golfing on weekends as well as being an expatriate away from my family. I hope I will visit Indonesia again with my family to enjoy the local culture before I forget the language and will take the opportunity of introducing the living environment during my expatriation to my family.

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Glossary

FMS

Refer to “Incorporation of Processing of Base Plates for Piston Motors into FMS Lines” (page 13)

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1 What is FMS?

FMS is the acronym for “Flexible Manufacturing System” and refers to a highly flexible production system that can efficiently produce batches of many different parts. The main features of FMS include systematic interfacing among parallel processing equipment and various devices including stockers, and efficient production of a variety of products by leveraging unattended operation.

2 Examples of Configuration

Based on an example of configuration of FMS systems (Fig. 1) manufactured by Makino Milling Machine Co., Ltd., the following introduces the functions:

[1] System PC

A personal computer (PC) for controlling the FMS system. The PC is linked to individual equipment units via communication lines. The system PC issues production commands, based on which instructions are sent to equipment units. The operator can view the operating status of equipment units and work instructions to the set-up station, etc., on the PC screen (Fig. 2).

[2] Stocker

Several types of jig can be stored in a stocker so as to produce many different parts that cannot share the same jig. For a set-up change, the system PC can call the relevant jig to complete the set-up. The stocker capacity is decided by the types of parts, the number of lots, the time zones of unattended operation, and other factors. The stocker can house jigs with their work installed.

[3] Machining center (MC)

In many cases, parallel type machining centers are introduced. The number of machining centers is decided by the work processing time and production volume.

[4] Guided vehicle

A vehicle used to automatically transfer materials to equipment units. Stacker cranes, loaders, and robots are used as guided vehicles.

[5] Set-up station

An area used to attach or detach workpieces. Work, after being attached or detached, is automatically transferred to equipment units for processing with a command from the system PC. Unattended operation is enabled by supplying work waiting for processing to the stocker.

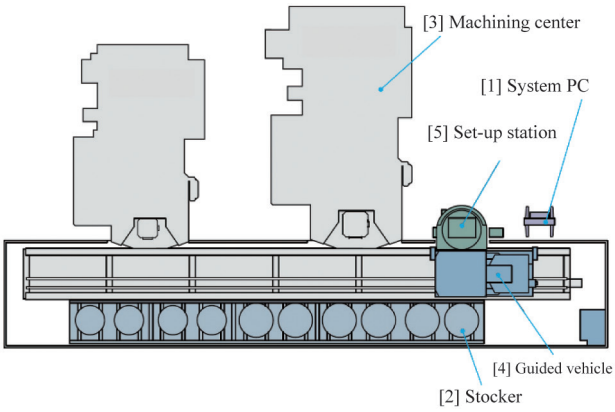

Fig. 1 Example of FMS configuration

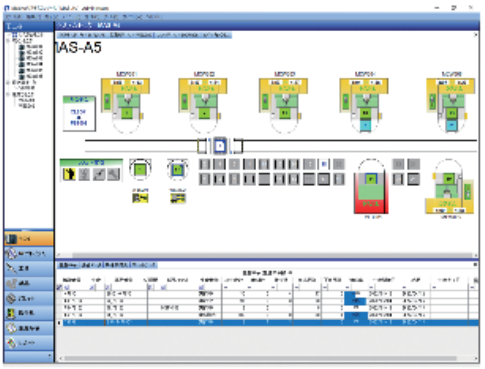

Fig. 2 System PC screen

Reference

1) Pallet Transfer System, MODULE MMC 2
https://www.makino.co.jp/ja-jp/machine-technology/automation/pallet-system

Glossary

Counterbalance Valve

Refer to “Development of Anti-cavitation Vane for Travel Motor of 7-ton Hydraulics Excavator” (page 28)

SAITO Keiji
Editor of KAYABA Technical Review

1 What are Counterbalance Valves?

Counterbalance valves are used to prevent hydraulic actuators installed in construction machinery or machine tools from dropping with their own weight or to maintain the descending speed of such actuators. The counterbalance valve limits the flow rate in one direction and lets fluid flow freely in the other direction. Actuator controls speed by generating back pressure so that is does not exceed the control speed.

Fig. 1 shows a structural drawing of a counterbalance valve. When the inlet pressure in the valve is not more than the pressure setting of the spring, the spool is kept pressed down. When the inlet pressure is higher than the pressure setting, the spool is pushed up to open the outlet port, releasing oil. If it is necessary to let pressured oil flow from the outlet port side to the inlet port side, a check valve should be installed in the circuit.

For example, the counterbalance valve can be used to prevent a vertical press machine from dropping with its own weight. Another example of an application is a drilling machine using a cylinder where the counterbalance valve is installed in a hydraulic circuit designed to prevent the piston rod from abruptly sticking out when the load resistance suddenly decreases upon completion of a drilling process.

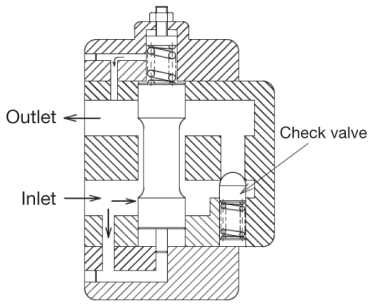

Fig. 1 Counterbalance valve

2 Counterbalance Valves for Travel Motors

Travel motors for hydraulic excavators or other open circuit applications are equipped with counterbalance valves. Fig. 2 shows a circuit diagram of a travel motor. The counterbalance valve for travel motors has the following two functions:

[1] Motor braking

The counterbalance valve is combined with a relief valve or an anti-cavitation valve to constitute a braking circuit that can apply a braking force to the piston motor so as to bring the motor gradually down to a stop.

[2] Overrun prevention

Where a piston motor is forced by an external load to be rotated at a speed higher than the rpm decided by the supply flow rate (pumping effect), the counterbalance valve is used to control the motor speed to a level suitable for the supply flow rate.

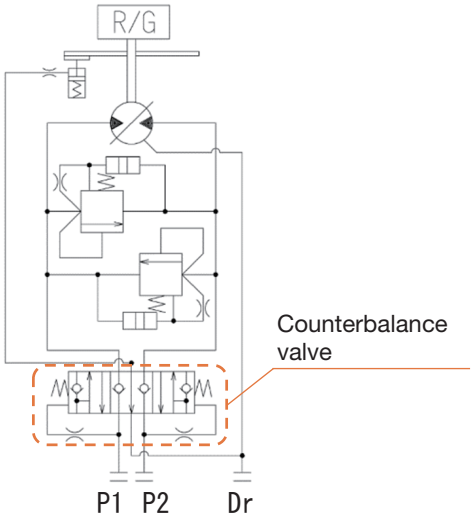

Fig. 2 Hydraulic circuit diagram of counterbalance valve for travel motor (relief valve type)

Editors Script

This issue reports KAYABA's initiatives for digitization and the use of AI for manufacturing (or Monozukuri) that converts two-dimensional data, which has been rapidly evolved, developed, and improved, into three-dimensional products contributing to society. As the size of product development data has likely grown larger in recent years, it has become difficult to determine the physical aspect of such data (i.e., parameter correlation). It is now possible to determine such parameter correlation more quickly and more exactly by the use of AI. As a craftsman of the Showa era, I am proud of my juniors who have a good command of AI using both their hands and mind simultaneously. (YAMAGATA)

I sometimes remember the words of one of my senior colleagues: "Engineers should be simple and stupidly honest". This phrase might have a bad meaning like having no wisdom or no ability to behave as circumstances demand. However, with these words, I think he wanted to encourage engineers to "keep a simple and even stupidly honest attitude to tackle everything with relentless drive to accomplish their mission until the technology is transformed into product". As surging prices and supply shortages of fuels and materials have become even more fierce due to various factors including the outbreak of the COVID-19 pandemic, conflicts, and variations in the exchange rate, measures against these challenges need to be taken. However, I also believe that engineers should keep their attitude to promote technical development initiatives in an even stupidly honest way with an eye toward the future. (UMEDA)

As an editor, I read some issues of KAYABA Technical Review back again. Although I thought I knew the product families of the company, I noticed anew how wide the fields covered by the product lineup are. Particularly I found individual businesses primarily leveraging their own expertise for product development. With my experience in concentrating on the specialty of my own business unit, I have not been interested so much in other businesses. Nevertheless, when focusing on the essence of some technologies, I noticed that they could be eventually applied to other products as well. I want to be engaged in publishing this issue with an expectation that the information contained herein will give readers helpful hints or ideas about their job. (OKUMURA)

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