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Foreword

Powering Mobility for All: Development of Robotic Legs

Xiaojun Sun*

1. Introduction

It is a great honor for me to have the opportunity to write this foreword for KYB Technical Review No.69. We, BionicM Inc., are a venture company engaged in the research and development of robotic legs. Since 2023, we have been engaged in joint research with the Basic Technology R&D Center, Engineering Div., KYB Corporation. In this article, I would like to introduce our company as well as briefly introduce robotic legs and their development, as many of you reading this foreword may not know much about prostheses.

2. Mission of BionicM Inc.

I was inspired to develop prosthetic legs in the future because my life was profoundly changed when I first encountered a prosthetic leg. Originally, I was born into a farming family in Guizhou Province, China, as an able-bodied person. But when I was nine years old, my right leg was amputated at the knee due to osteosarcoma. After the amputation, I started living with axillary crutches, which completely changed my life. For example, when I walked to school in the rain, I often slipped and fell. Another difficulty was that I could not do by myself what I could do in my daily life before, because my hands were tied by the crutches, which was very inconvenient. After living with crutches for 15 years in China, I first encountered prostheses when I was a graduate student in Japan. I will never forget the joy I felt when I walked on the street for the first time with my prosthetic leg after almost a year of rehabilitation. I could walk out in the rain with an umbrella in my hand and carry a tray in the cafeteria by myself. My hands were off crutches for the first time in 15 years. It was literally a life-changing moment.

While the word mobility may remind many of you of cars, trains, and other means of transportation, I believe that "feet" are the fundamental means of transportation or mobility for human beings. Our society has required mobility to move people and things quickly, even over long distances, in our economic activities. With the development of the machine industry, cars, trains, and other means of mobility have been developed to meet this demand. These are hardly affected by weather, terrain, and other environmental factors and allow for efficient time management, thus contributing greatly to economic development. On the other hand, foot-based mobility, which relies on physical strength, is not suitable for fast, long-distance travel due to its limited travel distance and speed. Able-bodied people, for whom bipedal walking is the norm, tend to focus on the disadvantages of their feet. However, feet can adapt to narrow streets, slopes, and other different environments sequentially according to their very fine motion control. Although the contribution of feet to economic development may be small compared to other means of mobility, I am sure from my experience that bipedal walking implemented by feet is a fundamental human movement and can greatly contribute not only to physical health, which is the foundation of human activity, but also to mental health. I want to provide technology that can help people to walk where they want to go with their own feet. This is how I see our company's mission of "Powering Mobility for All" being fulfilled.

3. Prosthetic Legs and their Development

As you know, a prosthetic leg is a device that replaces the missing part of an amputee's lower limb. Prosthetic legs are mainly divided into transfemoral prostheses (for above-knee amputees)

* Xiaojun Sun, CEO, BionicM Inc.

Fig. 1 Transfemoral prosthetic leg

and transtibial prostheses (for below-knee amputees). A transfemoral prosthesis generally consists of three components: a socket, a knee joint, and a foot, as shown in Fig. 1. The robotic knee joint Bio Leg® we have developed corresponds to and provides the function of the knee joint.

Many knee joints on the market use their springs, hydraulic dampers, and other mechanical elements to support knee flexion and extension during walking[1]. These mechanical elements are passive components that contribute to the user's gait primarily as a braking device. This means that the user must "walk" as if swinging the prosthetic leg (including its knee joint) by moving their trunk and hip joints. Such compensatory movements during walking are known to contribute to lower-back pain[2]. It has been confirmed that compensatory motions in other movements also place a physical burden on the user[3) 4)]. This is one of the major problems for transfemoral prosthesis users.

Research institutes including universities have been trying to solve problems with conventional commercial knee joints by developing a powered knee joint with a built-in electric motor. Our Big Leg®, which is also a powered knee joint, came out of my research in the second half of my Ph.D. Powered knee joints are now also used as drivers by incorporating active components such as electric motors. (Physiologically, centripetal contraction is now possible in addition to centrifugal and isometric contraction, which may mean that the basic functions of the human body's muscles have finally been added to the knee joint). As a result, a powered knee joint can now assist the user in climbing stairs and performing other movements that were difficult with conventional knee joints. Recent joint research has shown through an experiment that a powered knee joint can support the user's knee extension movement when standing up from a chair, thereby improving the symmetry of the bipedal load on the user's legs[5]. In this way, a powered knee joint has the potential to reduce the user's physical burden. I believe that in the future, amputees will be able to regain lower limb function to almost the same level as able-bodied people.

4. Development of a Powered Knee Joint

Although the user benefits of powered knee joints have been proposed, they are still very different from human knee joints. There are still several challenges to overcome in the design and development of powered knee joints. One example is their weight. While in the human body the femur and tibia are firmly connected by various ligaments, the prosthetic femur is connected to the user's stump (the end of the amputated lower leg) by maintaining negative pressure inside the socket. The user must support the weight of the knee joint on the stump. Therefore, the knee joint should be as light as possible. On the other hand, a powered knee joint requires a relatively high power output around the knee joint. It needs to provide enough joint torque to support the user's body weight in the stance phase (when the prosthesis is loaded), while at the same time providing propulsion at a relatively high joint angular velocity sufficient for fast walking in the lift phase (when the prosthesis is unloaded). I have never seen a commercial knee joint driven by a combination of an electric motor and a reduction gear that meets both the weight and power requirements. To improve the weight to power ratio, I was involved in the research and development of a variable reduction gear specifically designed for knee joints as part of my Ph.D. research[6]. However, I believe there is still room for improvement. While feeling the wonder of the human body such as the muscles and joint mechanisms, it is interesting to pursue how I can develop a powered knee joint as close to the human body as possible. I find this work very rewarding.

5. Expectations for Corporate Collaboration

As mentioned above, the design of a powered knee joint requires a comprehensive understanding of various fields including mechatronics (mechanical and electrical engineering) and biomechanics. Based on my past experience, I believe that the strength of a venture company is its flexibility in product development. Then, based on the belief that a variety of perspectives are essential in product development, our company has promoted design and development with advice from engineers as well as prosthetists, physical therapists, and other medical professionals. After about five years of trial and error (about eight years including the research period), the product is finally ready for the market.

Looking back from a management perspective, I think the long product development time is an issue that needs to be addressed in future. In recent years, universities and companies have been announcing new knee joints one after another. As I feel that the competition for knee joints has become more intense than before, the product development period should be shortened. On the other hand, because knee joints are classified as medical devices in Europe and the United States and they are used every day, safety is more important than performance. I look forward to corporate collaboration as a means of resolving the trade-off between shortened development time and high safety. During the development of Bio Leg®, we were aware that users place a high value on the sensation of knee-joint movement. This is a subjective feeling, such as whether the user can feel that the knee joint is following where they want it to go when walking, or whether they have a good feeling when using it. We have come to understand that this type of sensation is very similar to the driving comfort of automobiles. I understand that Japan is a major exporter of automobiles as an industrial product that requires superior safety. The knowledge of technology and safety accumulated in automotive manufacturing could be applied to another "mobility", bipedal walking. If this is achieved, an even safer, more secure, and more sophisticated knee joint can be developed in a shorter period of time.

The terms "startup" and "venture" have become familiar, in part, because the Japanese government established the Startup Development Five-year Plan in 2022 to create a second startup boom. In order to explore new mobility markets without letting the boom fizzle out, I believe it is necessary to combine the flexibility of ventures that can adapt to the market with the robust hardware technology of large companies. Under our mission of "Powering Mobility for All", we are committed to doing our best to explore new mobility markets. We look forward to your continued cooperation.

Finally, I would like to thank Mr./Ms. Kaneishi, Mr./Ms. Komuta, and the entire engineering staff of BionicM Inc. for their great cooperation.

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Technology Introduction

Method for Reducing Jig Resonance Using Modal Analysis

FUJIKAKE Mitsuhiko, ENDO Tomotaka

1 Introduction

With the recent widespread adoption of battery electric vehicles (BEV) and hybrid electric vehicles (HEV), automobiles have become much quieter. As the background noise in the vehicle cabin has decreased, the noise from peripheral components has come to the fore, which is expected to lead to even more stringent requirements for lower NVH [Note 1]. It is now essential to pursue noise and vibration reduction in product development through sophisticated NVH evaluation.

The conventional test bench evaluation approach, in which the product is installed in a test jig assembly, makes it difficult to identify the inherent NVH characteristics of the product because resonance occurs between the product and the jig assembly. We have established a design method using modal analysis to eliminate the jig resonance in order to identify the vibration mode during actual operation. This paper introduces the method.

Note 1) An acronym for noise, vibration, and harshness.

2 Product Introduction

With the popularity of electric vehicles, the demand for electric oil pumps used to cool/lubricate the main engine motor and battery has increased. Electric oil pumps with integrated mechanical and electrical systems are finding wider applications due to their independence from engine speed. KYB is developing downsized, high-efficiency electric oil pumps by utilizing its accumulated pump design technology. Fig. 1 shows an example of an electric pump for cooling/lubricating purposes.

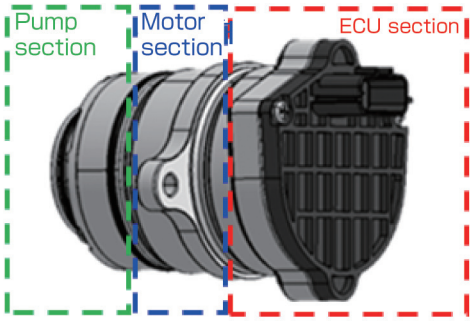

Fig. 1 Electric pump for cooling/lubrication

3 Issues with NVH Evaluation Equipment

Conventional evaluation test equipment provides an environment to evaluate a simulated vehicle. The environment actually includes various disturbances caused by the complex test jig configuration, such as oil agitation by the chain through the belt drive or sprockets, under which the vehicle has been evaluated (Photo 1). These many disturbances in the test jig assembly have made it difficult to evaluate pump NVH alone. In some cases, it was difficult to evaluate the reliability of vibration-reducing parts and to identify variations.

The disturbances can be classified into the following three main types:

[1] Transmission of drive-side vibration caused by chain drive
[2] Air entrapment in the pump due to the agitation of the hydraulic oil
[3] Resonance of test jigs

Based on the idea that the elimination of these disturbances would make it possible to evaluate the pump NVH alone, we made new NVH evaluation equipment consisting mainly of a direct-drive type performance tester (Photo 2). By replacing the conventional chain-drive type with the direct-drive type, two of the above three disturbances [1] and [2] were eliminated, but disturbance [3] (resonance of test jigs) remained. The reason for this is that the pump runs at

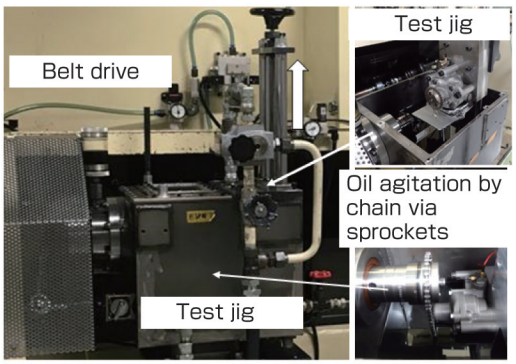

Photo 1 Conventional belt-drive type evaluation equipment

variable speeds according to the flow demand to generate vibrations over a wide range of frequencies from several Hz to several kHz, which is likely to cause resonance with the natural frequency of the jigs. Once resonance occurs, the vibration of the pump will increase significantly, making it difficult to determine the pure NVH characteristics of the pump. We then established a modal analysis technology to prevent the resonance of the test jigs and designed a test jig assembly that eliminates the resonance.

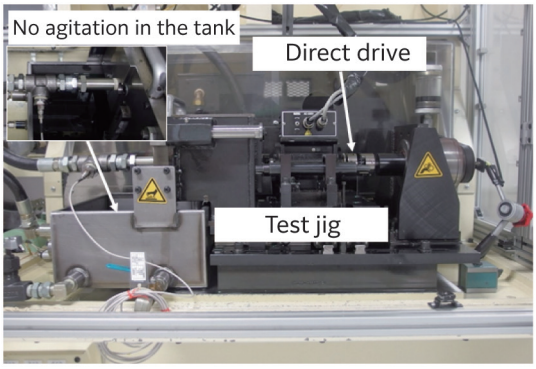

Photo 2 Direct-drive type evaluation equipment

4 Determining Resonance Frequency and Identifying Resonant Test Jigs

4. 1 Determining Resonance Frequency of Test Jigs

The color map in Fig. 2 shows the result of pump NVH evaluation using the direct-drive type evaluation equipment. The horizontal axis shows the frequency, and the vertical axis shows the pump speed. The color represents the magnitude of the pump vibration. The radial lines represent the rotational order components of the pump. The red-framed area with large vibration in a certain frequency band independent of pump rotation is the frequency band where the test jig resonance occurs. Two resonance frequency bands are observed: 1.3 kHz to 1.6 kHz and 3.5 kHz to 4.5 kHz. Resonance occurs when the natural frequency of one (or more) of the test jigs around the pump matches one of the rotational order components of the pump[Note 2], thereby influencing the pump vibration.

Note 2) Order components of pump rotation
A phenomenon that occurs once in the period of one revolution of the pump is the 1st-order component of the pump rotation. Its nth multiple is called the nth-order component.

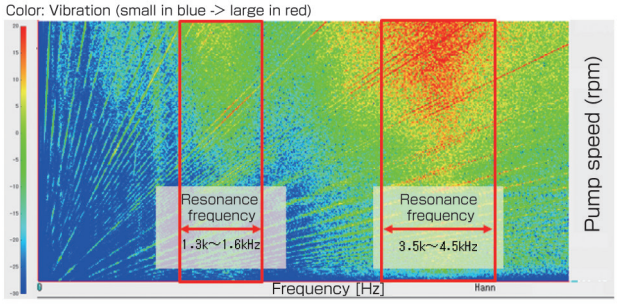

Fig. 2 Color map of pump NVH evaluation

4. 2 Subdividing the Test Jig Assembly

To identify resonant jigs, we subdivided the test jig assembly into nine jigs including the pump (Fig. 3).

We installed a three-axis accelerometer on each jig and the pump to identify resonant jigs by experimental eigenvalue analysis and to measure and analyze frequency responses during acceleration. We conducted two patterns of measurement and analysis, i.e., operational modal analysis and experimental modal analysis, to improve the accuracy of experimental eigenvalue analysis and to try to identify resonant jigs with higher accuracy.

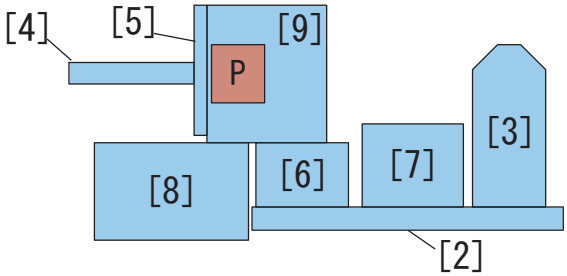

Fig. 3 Test jig assembly divided into nine jigs including pump

4. 3 Operational Modal Analysis

Operational modal analysis is a vibration mode analysis approach to pump NVH evaluation. Measurements can be made under actual test conditions to obtain analysis results that reflect the actual environment. We measured the power spectrum[Note 3] and the cross spectrum[Note 4] of the

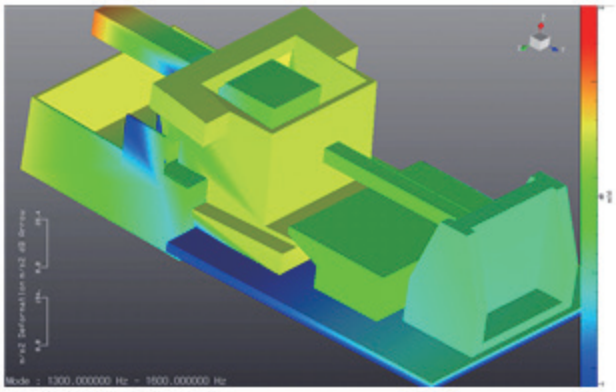

Fig. 4 Test jig vibration mode in 1.3 kHz to 1.6 kHz

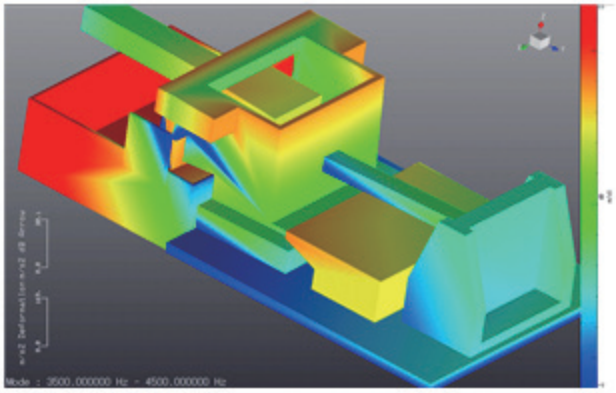

Fig. 5 Test jig vibration mode in 3.5 kHz to 4.5 kHz

test jigs and visualized the vibration mode in the resonance frequency bands as shown in Figs. 4 and 5. Like the color map, these figures use color to represent the magnitude of vibration: large vibration is indicated by red.

Note 3) Power spectrum: The signal power is divided into each specific frequency band and the resulting power for each frequency band is expressed as a frequency function. This is called the power spectrum.

Note 4) Cross spectrum: The frequency components of the spectrum of two signals are multiplied by each other and averaged. The result is called the cross spectrum.

4. 4 Experimental Modal Analysis

Experimental modal analysis is a vibration mode analysis approach based on the frequency response function obtained from excitation tests. We conducted an excitation test on the pump installed with the test jigs and on the same pump alone. This is because the vibration mode of the pump may depend on whether the pump is with the test jigs or alone.

Based on the results of the actual and experimental modal analyses, Table 1 shows the test jigs whose natural frequencies may be within the resonance frequency band. We comprehensively reviewed these analysis results and determined that the red-framed test jigs Nos.7, 8, and 9 required resonance improvement.

Table 1 Identified resonant jigs

Jig No.	Operational modal analysis	Experimental modal analysis	
	Jig ass'y	Jig ass'y	Jig alone
No. 2	×	○	×
No. 3	×	×	×
No. 4	×	×	×
No. 5	×	×	×
No. 6	×	×	×
No. 7	○	○	○
No. 8	○	○	○
No. 9	○	○	○

○: The natural frequency may be within the resonance frequency band.
× : The natural frequency is unlikely to be within the resonance frequency band.

5 Optimization of Test Jigs

5. 1 Procedure for Improving Test Jigs

After identifying resonant jigs, we attempted to modify the geometry, material, and/or other factors of these test jigs to change their natural frequency. Alternatively, we tried to increase the rigidity of these jigs to reduce the vibration level (inertance). To reduce cost, we also tried to design an efficient test jig that did not involve complex geometry. These modified jigs were analyzed with a FEM software program called ANSYS® and subjected to modal analysis by simulation. Then, we prospected the natural frequencies of the test jigs with different geometries.

However, for test jigs with low rigidity, the modal analysis produced many calculation results of the natural frequency, resulting in less accurate analysis. To improve the accuracy, low-rigidity jigs were subjected to experimental modal analysis to determine the vibration mode with actual measurements before improving them. Fig. 6 is a flowchart showing the improvement procedure. The analysis approach to be selected depends on the rigidity of the test jigs. The final jig geometry was checked by simulation modal analysis to see if it had given an improvement. If insufficient improvement was found we modified the jig geometry and repeated the process until the goal was achieved. After the simulation modal analysis verified the achievement of the goal, the test jig was manufactured and subjected to experimental modal analysis, and the effect of the improvements was verified by actual measurement.

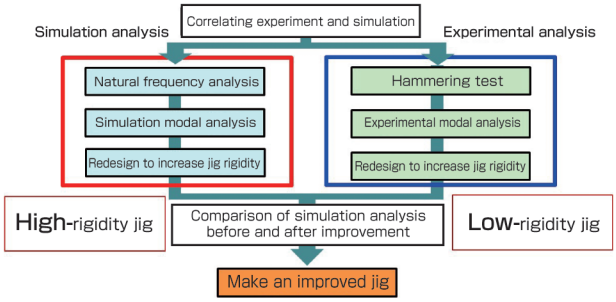

Fig. 6 Improvement flowchart

The goal of the improvement was set as a 50% reduction of the inertance of the test jig in the direction of the pump discharge over the resonance frequency band. The following section explains the improvement procedure in detail.

5. 2 Correlation of Experimental and Simulation Modal Analyses

In order to increase the accuracy of experiment and simulation modal analyses in the flowchart of Fig. 6, the two analysis approaches must have correlation [Note 5)] with each other. As a target test jig for correlation, we selected the No.5 jig with relatively simple geometry and high rigidity (Fig. 7).

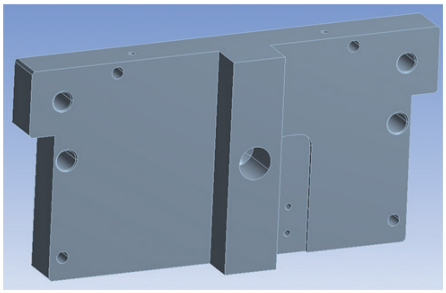

Fig. 7 Geometry of No.5 jig

Fig. 8 shows the frequency response data obtained from the experimental and simulation modal analyses before ensuring correlation. According to these pre-correlation waveforms, the natural frequency is almost the same between the experimental and simulation modal analyses, but their inertance is quite different. This was due to

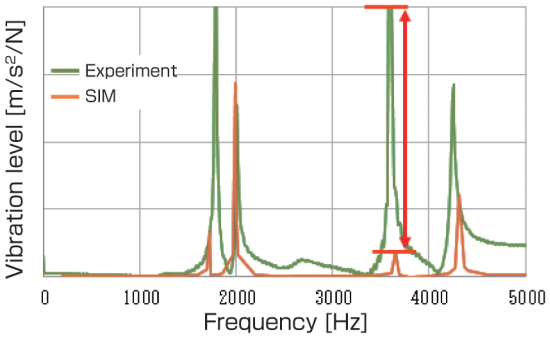

Fig. 8 Pre-correlation frequency response

differences in analysis conditions between the experimental and simulation modal analyses. Specifically, the probable causes include:

- Jig support methods
- Excitation and response positions
- Attenuation ratio setting for simulation modal analysis

We then tried to reestablish the correlation by harmonizing the test environment and conditions as well as the analysis parameters. Fig. 9 shows the frequency response after the correlation was restored by harmonizing the conditions. Comparing the post-correlation figure with the pre-correlation figure, the natural frequency as well as the inertance values between the experimental and simulation modal analyses are in better agreement. In this way, a high correlation between the experimental and simulation analyses was achieved, and a highly accurate analysis was implemented.

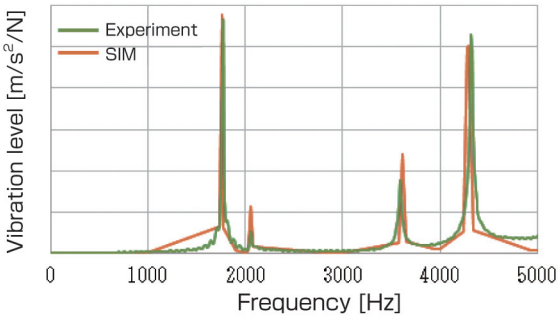

Fig. 9 Post-correlation frequency response

Note 5) Correlation: Refers to the relationship between two variables or phenomena in which they vary rhythmically together to some degree.

5. 3 Simulation Verification of Vibration Modes

Fig. 10 visualizes the vibration mode in the resonance frequency band from 3.5 kHz to 4.5 kHz. The figure shows a wave-like vibration mode in the lateral direction of the test jig. In particular, both sides of the upper end vibrate strongly. This means that increasing the rigidity of the upper part of the jig will hopefully reduce the resonance. If the simulation modal analysis has produced many natural frequency calculation results, the jig may have low rigidity, which means that the accuracy of the simulation analysis has been reduced. In this case, the analysis approach must be changed to experimental modal analysis.

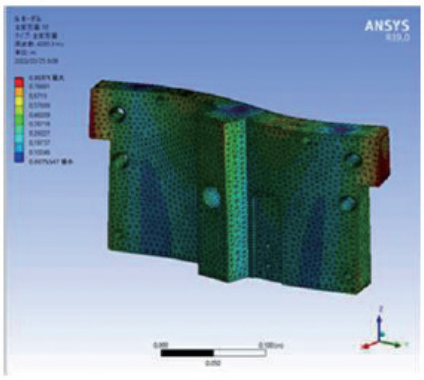

Fig. 10 Vibration mode analysis of No.5 jig

5. 4 Experimental Verification of Vibration Modes

We conducted experimental modal analysis on the No.9 test jig, which had shown low rigidity in the simulation modal analysis. Fig. 11 visualizes the vibration mode in the resonance frequency bands of 1.3 kHz to 1.6 kHz and 3.5 kHz to 4.5 kHz. Like the color map, this figure uses color to show the magnitude of vibration: large vibration is indicated by red. In both frequency bands, the analysis showed that resonance occurred due to insufficient rigidity of the open side and back side. Therefore, modifying the test jig to have higher rigidity of these two sides will hopefully reduce the resonance. In particular, the figure shows that it will be effective to increase the rigidity along the diagonal line from the upper right corner of the open side.

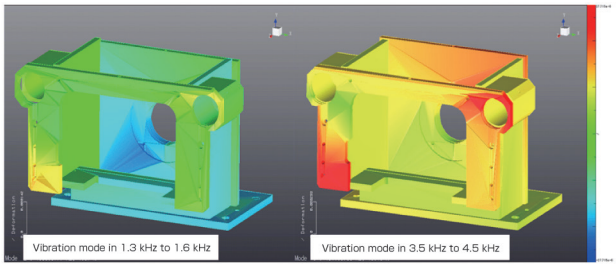

Fig. 11 Vibration mode analysis of No.9 jig

5. 5 Improving Jig

In order to reduce the inertance in the resonance frequency band from 3.5 kHz to 4.5 kHz of the No. 5 jig identified in Section 5.2, we studied to improve the geometry to suppress the deformation in the vibration mode. Considering the availability and cost of machining during jig manufacturing and the operability during testing, which are very important in jig design, we decided to add lateral ribs to the No.5 jig as shown in Fig. 12.

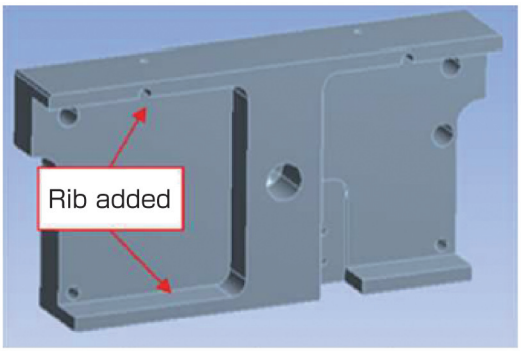

Fig. 12 Improved jig

5. 6 Analysis of Improved Jig Model

We compared the frequency response between the original and improved jigs using simulation modal analysis. The improved jig showed 64% lower inertance than the original. At this point, the goal of a 50% reduction in inertance was achieved. With a further goal of reducing inertance while taking into account analysis variations, we repeatedly changed the rib height and width to find a rib geometry that satisfied both inertance reduction and cost requirements. Fig. 13 shows the final geometry and Fig. 14 shows the frequency response results with 97% inertance reduction.

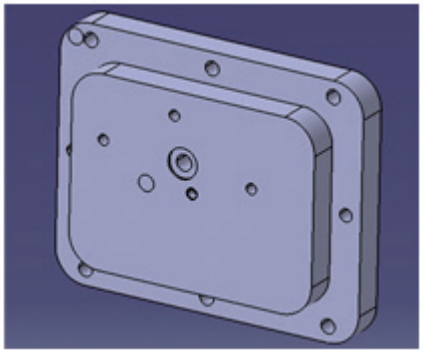

Fig. 13 Final geometry of No.5 jig

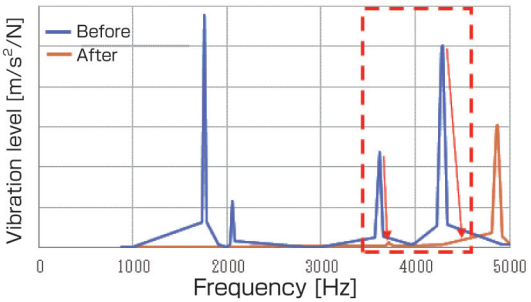

Fig. 14 Simulation comparison of frequency responses before and after improvement

5. 7 Verification of Modified Jigs through Experimental Modal Analysis

From the improved jig model, we proceeded to the jig design and manufactured the improved jig. The improved jig, whose resonance had been reduced by simulation modal analysis, was subjected to experimental verification. Compared to the expected inertance reduction rate by simulation, the actual inertance reduction rate in the experimental measurement was 93%, which was almost the same as the result of the simulation analysis. Thus, a high correlation between experiment and simulation was again verified. Fig. 15 shows the frequency response of the improved jig obtained by experiment and simulation.

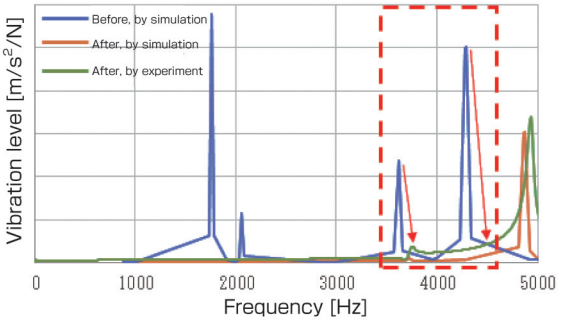

Fig. 15 Comparison of frequency responses of improved jig between experiment and simulation

Next, the frequency responses of the original and improved jigs obtained by experiment modal analysis are shown in Fig. 16. The inertance of the improved jig was 93% lower than that of the original jig. It was verified that the natural frequency and inertance of the improved jig obtained by simulation modal analysis were almost equivalent to the actual measurements.

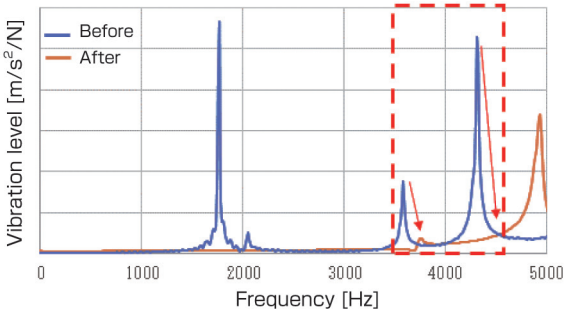

Fig. 16 Experimental comparison of frequency responses before and after improvement

5. 8 Geometry of Test Jig Assemblies Before and After Improvement

Fig. 17 shows the geometry of the original and improved test jig assemblies. We reduced the resonance and changed the complex jig configuration to a simple one to reduce the number of jigs, and successfully manufactured a high-rigidity, low-cost jig assembly.

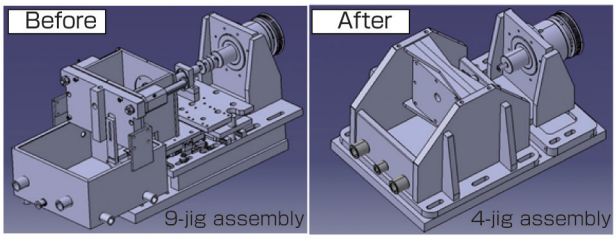

Fig. 17 Test jig assemblies before and after improvement

6 Verification Results of the Improved Jig Assembly

Fig. 18 shows the results of the NVH evaluation of the pump on the original test jig assembly and on the improved assembly with resonance prevention measures. According to the color map, the improved assembly does not show any resonance in the frequency band from 3.5 kHz to 4.5 kHz, which was one of the resonance frequency bands of the original assembly, and the order component vibration of the pump rotation can be clearly found in the frequency band from 1.3 kHz to 4.5 kHz, which was the other resonance frequency band. These results show that the resonance of the test jig assembly has been improved and all the disturbances that can affect the pump have been eliminated. Therefore, highly accurate pump NVH evaluation is now possible.

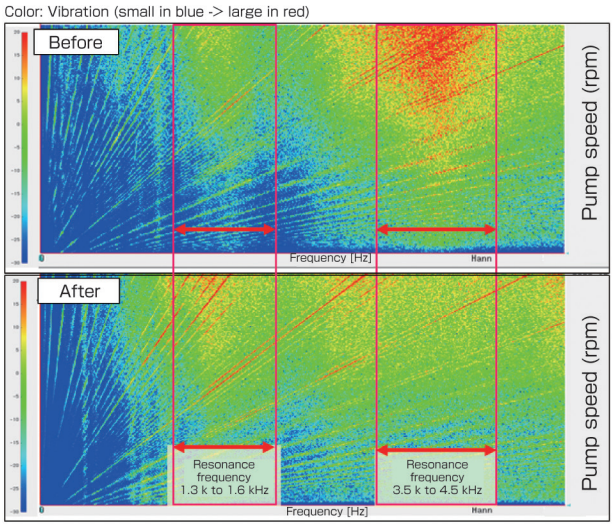

Fig. 18 Results of pump NVH evaluation before and after improvement

7 Future Prospects

NVH evaluation is indispensable for the development of automotive parts. As vehicles continue to become quieter, establishing an environment for highly accurate NVH evaluation is a top priority. The analysis methods and technical knowledge obtained in this activity can be extended to other products, thereby improving the accuracy of product NVH evaluation. It is also expected that we will reduce the trial and error in evaluation and the man-hours required to find the cause of abnormal vibration by designing and manufacturing a test jig assembly with improved resonance with the product at the design stage of the assembly. We are also committed to using this approach effectively in the development of electric pumps, which are required to be much quieter.

8 In Closing

This paper has presented our activity to address the resonance improvement of test jigs using modal analysis. In addition to conventional experimental and simulation modal analyses, we have introduced operational modal analysis to successfully visualize the vibration mode of the jig assembly under actual NVH evaluation conditions. This has identified the resonant jigs and the resonant parts of the jigs, resulting in higher analysis accuracy. By establishing a high correlation between experimental and simulation analyses, we were able to improve the resonant jigs with high accuracy. This activity has clarified the process of resonant jig improvement. Hopefully, even more accurate test jig analysis technology will be accumulated. It is important for us to make efforts to further improve the accuracy and to improve the new NVH evaluation technology day by day.

Finally, we would like to take this opportunity to express our sincere gratitude to those who have provided guidance and cooperation in building the modal analysis technology.

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Technology Introduction

Development of Electronically-Controlled Suspension for Motorhomes

INAMITSU Kazutaka, KURATA Ryohei

1 Introduction

In recent years, the number of new four-wheeled vehicles sold in Japan has been declining and the number of vehicles owned in Japan has also reached a plateau. As the shift away from automobiles by young people has become a topic, sports cars, which are purely for people's enjoyment, have tended to decline over time. On the other hand, the demand for automobiles with multiple functions, rather than just for transportation, has increased. One such class of automobile is the motorhome. The motorhome market in Japan enjoys high demand especially among family or senior users. This demand has increased partly due to the recent outdoor boom. Sales of motorhomes in Japan (including new and used) in 2022 were approximately 76.25 billion yen, which is about 120% of the previous year's sales[1]. Motorhomes are finding a wider variety of applications, including not only outdoor use, but also residence in the event of a disaster and space for remote work.

Towards this new market, KYB has made various attempts using its hydraulic control, vibration control, and vehicle fitting technologies to propose motorhomes with maximum appeal, offering both comfortable living space and driving pleasure.

A previous issue of the KYB Technical Review included an article on motorhomes, which focused on an effort by the Special Purpose Vehicles Div. using its hydraulic control and vehicle fitting technologies. The present article presents an effort by the Automotive Components Operations (AC Operations) to address motorhome user complaints, primarily from a suspension standpoint, as well as user reactions to our exhibits at a show.

2 Appeal and Solutions

We have identified motorhome user complaints in various situations and classified them into three categories with corresponding appeal (Table 1).

The first category is safety, which includes wobble at high speeds and crosswind buffeting, which are significantly affected by the height of the center of gravity and the size of the vehicle frame. The second category is comfort, which includes ride comfort and the tilt of the parked vehicle. Many users complain that their motorhome vehicle bounces a lot when driving over the step when entering a convenience store or gas station. Other complaints include sleeping in a parked vehicle that may be tilted and shaking of the vehicle due to the movement of passengers. The third category is convenience, which includes cumbersome manual control of equipment. For example, dial-adjustable dampers offer users the advantage of being able to adjust the damping force according to the vehicle's condition, but they must take the time to crawl under the vehicle to adjust the damper directly by hand.

We then discussed various components to solve these complaints (Table 1). For the safety issues including wobble during driving and the comfort issues including ride comfort, we considered "living space expansion" ("room expansion"), "semi-active suspension [Note 1)]", and "full-active suspension[Note 2)]". For the parking space issue of a vehicle and the tilt and shaking of the vehicle, we considered "room expansion", "vehicle height adjustment", and "suspension locking". For convenience issues, we considered the use of the user's smartphone or tablet as control devices. Note that, although full-active suspensions have the same appeal as those of semi-active suspensions, we took up the challenge of applying full-active suspensions, which can be called "ultimate suspensions", to motorhomes, to provide new passenger-centered value.

In addition, we have responded to complaints from motorhome users about the center of gravity, height, and width of the vehicle with "room expansion". For more information about the room expansion approach, please refer to the relevant article in the previous issue[2].

Table 1 Complaint resolution by situation

Appeal	Situation	Complaint	Room expansion	Semi-active suspension	Vehicle height adjustment	Suspension locking	Full-active suspension	Control device
Safety	Highway driving	Wobble at high-speeds	●	●			●	
	At the exit of a tunnel, on a bridge, being passed by a truck	Crosswind buffeting	●	●			●	
	On an entrance/exit ramp, on a road with an adverse cant	Fear of overturning	●	●			●	
Comfort	Use of tires with a high spring constant, high tire pressure setting	Uncomfortable ride		●			●	
	Entry/exit to/from a convenience store, bumps and dips of unpaved road	Bouncing/twisting vehicle		●			●	
	Parking	Leaning vehicle, parking space	●		●			
	Parking (passenger movements)	Vehicle shaking				●		
Convenience	Equipment control	Cumbersome operation by hand						●

Note 1) A suspension that uses its built-in damping force adjusting mechanism to adjust the damping force generated according to the expansion/compression speed to any given value.

Note 2) A suspension that has a power source to be able to generate load in both the excitation and braking directions depending on road conditions.

3 Realizing the Needs

The above solutions for implementing the required functions of motorhomes, which were extracted from the users' complaints, have been applied to three actual models of motorhomes (Table 2).

Table 2 Motorhomes and allocated functions

Vehicle	Appearance	Room expansion	Semi-active suspension	Vehicle height adjustment	Suspension locking	Full-active suspension	Device
Dutro		●	●				●
Dyna		●		●	●		●
Hymer						●	●

3.1 Improving Ride Comfort and Safety During Driving

3.1.1 Semi-Active Suspension

In motorhomes, the height of the center of gravity and the size of the vehicle frame usually lead to complaints about ride comfort and handling. If higher priority is given to handling and stability to ensure safety, ride comfort would be sacrificed due to their trade-off relationship. To achieve both handling/stability and ride comfort at the same time, we considered installing electronically controlled semi-active suspension. Semi-active suspension includes shock absorbers with a built-in mechanism to adjust the damping force. By adjusting the damping force according to the driving condition of the vehicle, it is possible to achieve both ride comfort and handling/stability, which are otherwise mutually contradictory.

The damper design is based on the proportional solenoid adjustable damper that we produce in volume for OEMs. Due to the limited space (especially in the longitudinal direction) for the damper assembly, the dumper was redesigned so that the reservoir, which had been built into the dumper, can be fitted as an external one. The original functions of the series-produced damper were distributed in the mounting space, resulting in a space-saving damper structure (Photo 1).

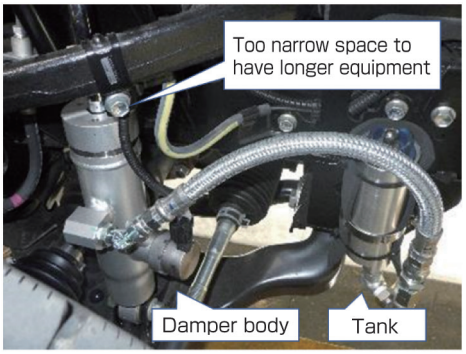

Photo 1 Semi-active suspension

3.1.2 Control System Development (Simulation)

We simulated the situations for motorhome use to develop its control system because it would be difficult to actually drive it in the typical motorhome-specific situations described later. Fig. 1 shows the simulation of the motorhome entering a gas station when it rides up a step. Fig. 2 shows a simulated motorhome exposed to crosswinds at the exit of a tunnel. In this simulation, we intentionally created animations with 3D model vehicles that would be easy for users to understand, as they would later be used in a general user exhibit. The suspension control software was designed based on the series-produced product, which successfully resulted in less man-hours to start the software development and higher development efficiency by reusing the evaluation environment.

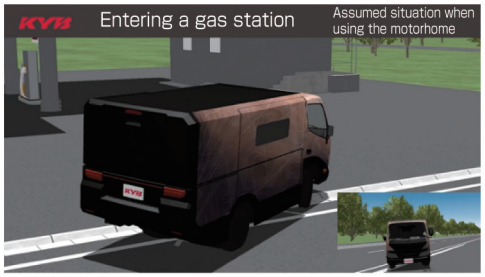

Fig. 1 Motorhome running over a step to enter a gas station

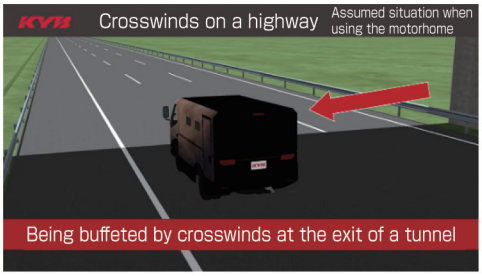

Fig. 2 Motorhome exposed to crosswinds at the exit of a tunnel

3. 2 Improving the Tilting and Shaking of the Parked Vehicle

3. 2. 1 Damper with Vehicle Height Adjustment Function

When parking a motorhome at a highway rest stop or campground, the ground may be sloped to provide drainage, which raises the problem of tilting the vehicle. For example, it may be difficult to drain water while cooking or it can feel uncomfortable when sleeping with the vehicle tilted. These problems are usually solved by inserting a leveler [Note 3] between the tires and the ground to correct the tilt of the vehicle, but the use of such a leveler may be inappropriate in some places and requires time and effort. The shaking of the vehicle caused by the movement of passengers is also uncomfortable, and may interfere with a good night's sleep. We then considered adding the functions of adjusting the vehicle height and reducing the vehicle shaking to improve comfort.

3. 2. 2 System Overview

We introduced a hydropneumatic vehicle height adjustment system (Photo 2, Fig. 3) because the common jack-type vehicle height control mechanism, which lifts the suspension springs themselves, was incompatible with the base vehicle's plate spring suspension. The hydropneumatic vehicle height adjustment system uses hydraulic power as the force transfer medium and utilizes gas compression as the spring action. By absorbing/discharging hydraulic fluid from/to the reservoir of the electric pump unit, the system changes the gas resilience of the damper to adjust the vehicle height (Photo 3). The solenoid switching valve, installed under the accumulator, can close the oil passage that compensates for the volume change caused by the piston rod of the damper moving in and out, thereby locking the damper and reducing vehicle shaking.

Photo 2 Appearance of the vehicle height adjustment system

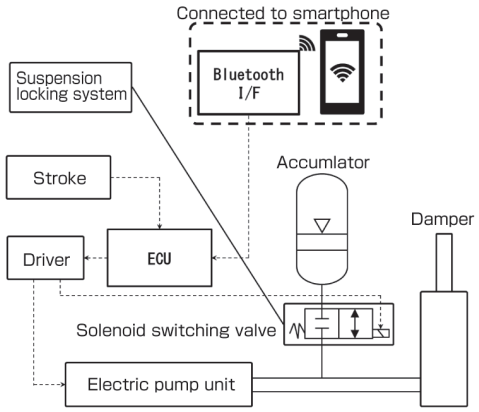

Fig. 3 Overview of the vehicle height adjustment system

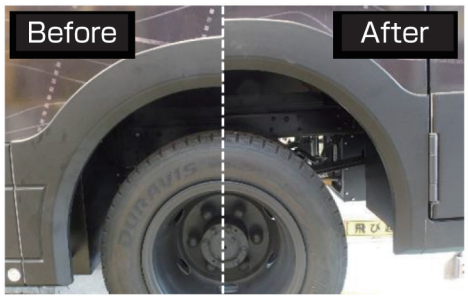

Photo 3 Comparison before and after vehicle height adjustment

Note 3) An inclined tool to be inserted between the ground and a tire of a tilted vehicle parked on a slope to correct the tilt

3. 3 Providing New Passenger-centered Value

3. 3. 1 Full-Active Suspension

Motorhomes are vehicles in which the passengers are going about their lives, not just a means of mobility. We then installed full-active suspension, which is the ultimate vibration control item, to provide a new passenger-centered value. Full-active suspension is called the ultimate suspension. Unlike a regular damper that passively provides output in response to input from the road surface, full-active suspension is equipped with a mechanism to actively output a force from its own energy source like an actuator, achieving both ride comfort and handling/safety at a high level.

3. 3. 2 System Overview

An overview of the full-active suspension system is shown in Fig. 4. Its basic structure is the same as the active suspension installed on the experimental vehicle previously manufactured by KYB[3]. However, Hymer, the target motorhome to be improved with the full-active suspension, has a larger vehicle frame and requires higher thrust. Therefor, by changing the electric pump from one system for two wheels to one for each wheel, the control range could be expanded by increasing the flow rate. By establishing such a system configuration suitable for the larger vehicle frame, we successfully implemented a sufficient full-active suspention system for the Hymer. As for the

motor and battery system, we selected a 48V type to implement the battery life for the required peak thrust obtained by simulation. Photo 4 shows the vehicle equipped with these components.

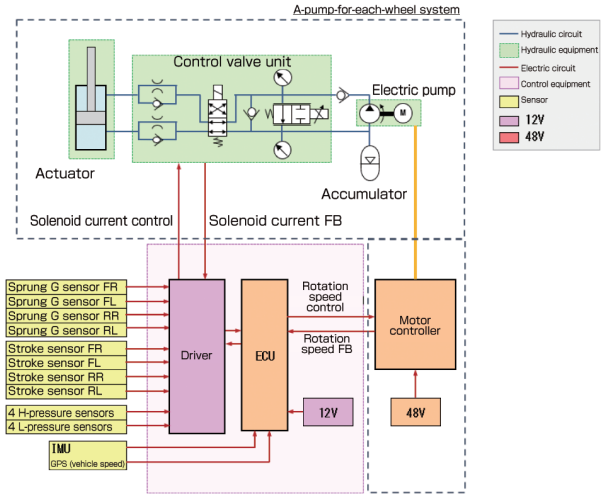

Fig. 4 Hymer system overview

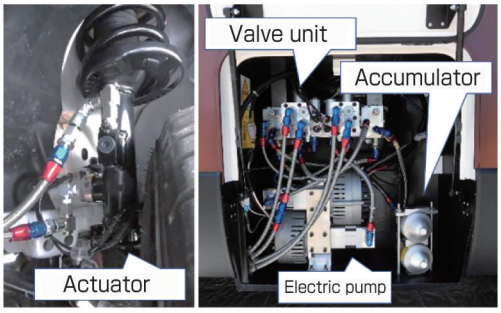

Photo 4 Actuator (left), hydraulic equipment (right)

3. 3. 3 Actual Vehicle Evaluation

Our experimental vehicle was evaluated on the KYB test track. The ride test compared the vehicle with the standard passive damper [Note 4] (without control) and the vehicle with the active damper (with control).

A slalom test was carried out to determine the inhibitory effect of these dampers on vehicle roll. The roll angle of the car with the active suspension (with control) was reduced by approximately 54% compared to the car with the passive suspension (without control). The test showed that the vehicle with the active suspension can be driven safely without fear of the vehicle rolling over (Fig. 5, Photo 5).

The extent to which vertical vibration was reduced was assessed using speed breakers. Fig. 6 and Photos 6 and 7 show the pitch angle of the vehicle as it passed over a speed breaker and the state of the cabin at that time. The vehicle with the active suspension had about 40% less pitch angle and recovered faster from the vibration after the speed breaker than the passive type (without control). Particularly in a vehicle with a long rear overhang like the Hymer, these differences would be much more noticeable in the rear cabin or trunk. This confirms that these improvements have a major impact on the appeal of passenger-centered motorhomes.

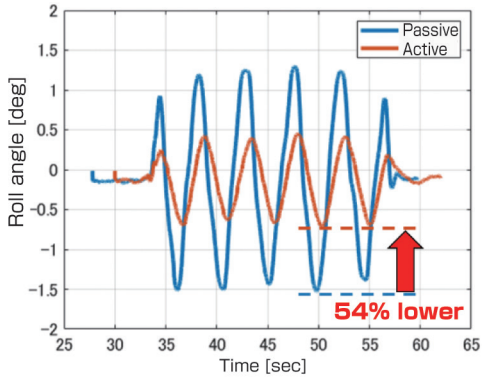

Fig. 5 Roll angle in slalom test

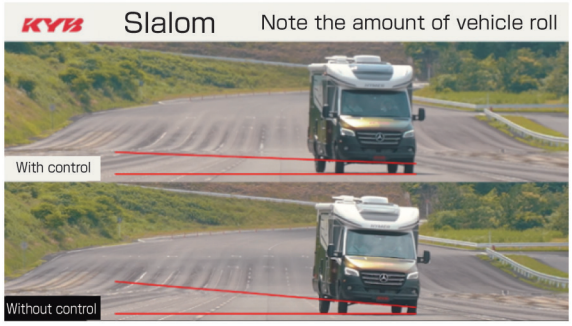

Photo 5 Slalom test comparison

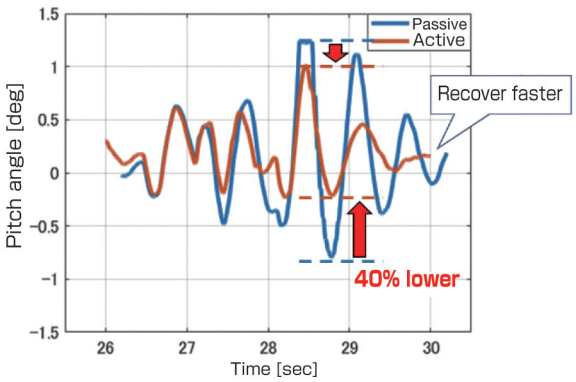

Fig. 6 Pitch angle in speed breaker test

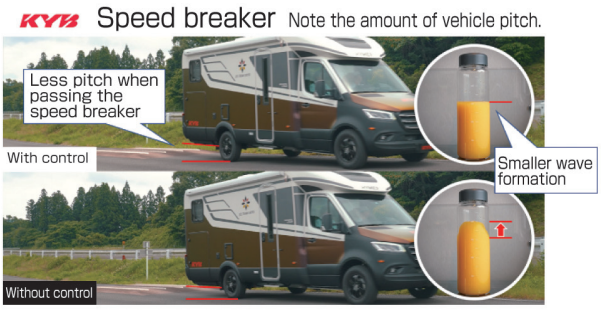

Photo 6 Speed breaker comparison

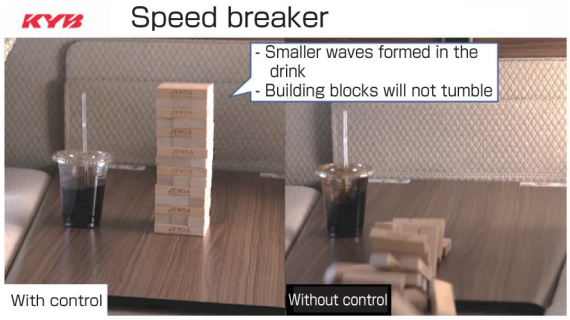

Photo 7 Speed breaker comparison (inside cabin)

3. 4 Control Devices

For higher convenience of motorhome users, we have developed an application for smartphones or tablets to remotely control the systems via radio. The communication between these control devices and the electronic control unit (ECU) is established via Bluetooth. Using the application, motorhome users can easily control the target items even from the cabin (Figs. 7 and 8).

Fig. 7 Tablet application screen (semi-active suspension)

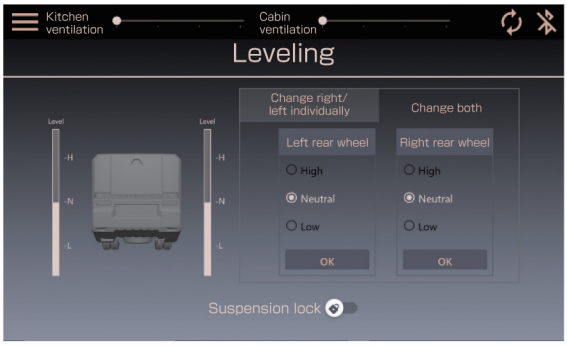

Fig. 8 Tablet application screen (vehicle height adjustment)

Note 4) A common damper whose damping characteristics are uniquely defined by its piston speed. The damping force is passively output in response to the input from the road surface.

4 Exhibition at Shows

We exhibited our vehicle at the Tokyo Auto Salon and the Tokyo Camping Car Show (Photo 8).

We demonstrated the room expansion, vehicle height adjustment, and full-active suspension so that the general public could experience motorhomes in more depth. We also played the movie of the vehicles on the test track and the simulation movie. The display included not only the actual vehicles, but also a simulator that allowed visitors to actually experience the effect of the damping force adjustment damper and the operability of the systems via the smartphone application.

Photo 8 Tokyo Camping Car Show

At these shows, we received feedback from visitors in the form of responses to our questionnaire (Figs. 9 and 10).

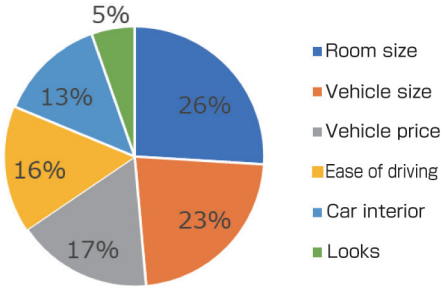

Fig. 9 Important factors when choosing a motorhome

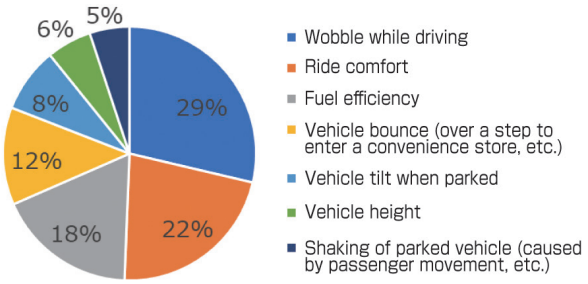

Fig. 10 Motorhome user needs/complaints

Analysis of the results of the questionnaire showed that besides "room size", "vehicle size", and "vehicle price", which were selected by many users as important factors when choosing a motorhome, "ease of driving" was selected by 16% of users with some opinion focused on suspension. This gave us the feeling that they were

expressing their expectations of KYB in their responses to the questionnaire. According to the user needs questionnaire, many users answered, "wobble while driving", "ride comfort", and "vehicle height". The first two accounted for the top two needs/complaints. These results showed that the room expansion, semi-active suspension, vehicle height adjustment, and other solutions we have addressed generally match the direction of user needs. KYB staff attending the exhibits spoke with visitors and learned that the use of smartphones and tablets as a control interface was well received by users. They also received many positive comments from users about the full-active suspension, such as "promising", "I want the product to be on the market sooner", and "I want to actually ride with it."

Several challenges were identified through the shows. One example is vehicle height adjustment. We received user requests for a larger adjustment range, because the current range was small. Another example is suspension locking. The current design certainly offers users the benefit of being able to easily lock the suspension with the solenoid proportional valve alone. However, the locking mechanism only locks the damper stroke, which does not prevent the rubber bushings that support the damper from moving or the tires from fluctuating, so it doesn't completely prevent the vehicle body from moving. To fully lock the vehicle, some other components such as outriggers[Note 5)] will be needed to support the vehicle directly and not through the tires. We also want to consider this as a means to adjust the vehicle height.

In addition to the shows, our activity was featured in the Nikkan Jidosha Shimbun and broadcast on TV programs such as the World Business Satellite (WBS) and Tokyo MX. Through these various media, KYB has actively promoted its motorhomes and technologies to users.

Note 5) A mechanism that extends from a parked vehicle to reach the ground like a brace, stabilizing the vehicle to prevent shaking. Outriggers can also be used to level the vehicle on a slope.

5 Conclusions and Prospects

This paper has introduced the activity of AC Operations to resolve complaints from motorhome users by applying solutions using semi-active suspension, vehicle height adjustment, suspension locking, full-active suspension, and control devices such as smartphones, and to produce vehicles that meet users' needs. This activity was presented at auto shows and in the mass media, through which we received many valuable comments from users. We were then able to determine what had and had not met users' needs.

By leveraging the knowledge gained from this activity, we intend to continue the cross-segment activity as a company-wide project, while seeking what type of motorhome is really needed by users.

6 In Closing

It has been said that the automotive industry has entered a once-in-a-century period of great change. With CASE (Connected Autonomous Shared Electric) as the key word, automobiles are expected to evolve into valve-added mobility including motorhomes, rather than just a means of transportation. We would like to explore how we can contribute to such a society from a company-wide, diversified perspective.

Finally, we are very pleased that through this activity we have been able to deepen the relationship with those who had rarely communicated with us in the course of regular work. They have also provided us with great cooperation. We would like to take this opportunity to express our gratitude to them.

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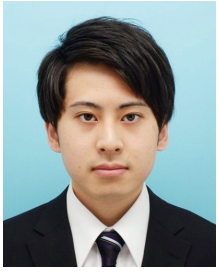

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Technology Explanation

Enhancing the Accuracy of SA Damping Force Simulation Implemented with AI Technology and Building an AI Operational Management Platform

MANTANI Hiroaki・SAGEHASHI Ryota

Abstract

The future trend of Artificial Intelligence (AI) includes the industrial application of combining AI with Computer Aided Engineering (CAE). By integrating AI and CAE, several benefits emerge, such as the acquisition of data through CAE that would be impossible to obtain in the real world for training AI models, reducing CAE computation time by degenerating Finite Element Method (FEM) tasks for AI.

Additionally, in recent years, the automotive industry has witnessed an increased adoption of Model-Based Development (MBD), leading to collaborative development where CAE models replace physical prototypes between departments or companies.

To facilitate MBD and enhance the performance prediction of our flagship shock absorber products, we developed a technology that combines Machine Learing Model(ML model) with CAE. This allows us to predict damping force performance metrics rapidly and accurately. Furthermore, a system was developed to automate the operation and management of machine learning models.

In this report, we provide a technical explanation of the implementation of machine learning for shock absorber damping force calculations and the construction of an operational management platform for machine learning models.

1 Introduction

1.1 Target Product

This report introduces a Shock Absorber (SA) for automobiles shown in Fig. 1. SAs play the role of damping the vibration of the vehicle. They can extend or contract according to the bumps and dips of the road surface and changes in the position of the vehicle. Hydraulic fluid is displaced from the SA cylinder according to the operating speed. The flow of the displaced fluid is reduced by a small-area orifice or a laminated leaf valve, creating a pressure differential to provide a damping force. The SA performance is evaluated in terms of the damping force-velocity characteristics. The laminated leaf valve is a particularly important component for performance evaluation. It consists of a thin steel plate that is installed to vary the oil passage area depending on the pressure during operation. By changing the lamination specifications (outer diameter, plate thickness, the number of leaves), the damping force is tuned to the vehicle.

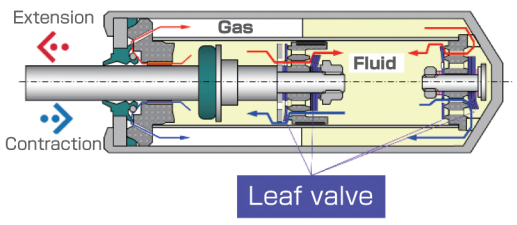

Fig. 1 Shock absorber structure

1. 2 KYB's CAE Initiative

Since the introduction of Computer Aided Engineering (CAE) in 1968, KYB has introduced various performance prediction technologies as shown in Fig. 2 to support the development of products and technologies. There are two types of CAE. One is 1DCAE[Note 1)], which develops product functions at the product planning stage (system simulation). The other is 3DCAE[Note 2)], which studies product geometry in detail (FEM[Note 3)]). KYB has accumulated prediction technologies for both types. In 1985, we put into operation the CAE Standard Execution System[1)], which is KYB's original system for easy technical calculation. The system allows users to easily utilize advanced prediction technologies from anywhere by using standardized input, execution, and output methods on various applications for either 1DCAE or 3DCAE. Approximately 2,000 programs are currently registered in the system.

KYB established the basic theory of SA damping force simulation, which is the main subject of this report, in 1981. Since then, the company has addressed the calculation as mathematical 1DCAE to be calculated on the CAE Standard Execution System.

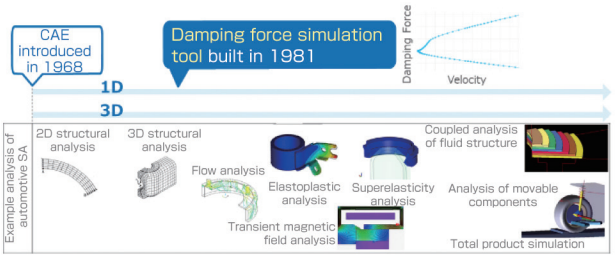

Fig. 2 Example of analysis of automotive SA

1. 3 Outline

With the recent widespread use of Model-Based Development (MBD[Note 4)]), it is necessary to develop products by jumping between 1DCAE and 3DCAE to run a cycle of studying both functions and geometry upstream in the product development stage. In addition, the need to circulate models instead of prototypes through internal departments and related companies has increased. In our initiative to address MBD, the technical challenges to be solved were as follows:

[1] In some cases, the coordination between the system study and geometry study was not well established. This was because the work of CAE specialists is divided into separate tasks due to the differences in modeling concept and skills between 1DCAE, which deals with simple and transparent models, and 3DCAE, which aims to reproduce actual machines more accurately.

[2] Geometry studies using 3DCAE tend to be expensive to analyze and take a significant amount of time to complete.

[3] Models to be circulated among related companies and internal departments must allow for high-speed computation while being highly detailed to represent actual products.

In order to solve these technical challenges and smoothly promote MBD, we needed to establish a technology that degenerates 3DCAE, which can handle detailed geometry, into a machine learning model (ML model) and implement it in 1DCAE (Fig. 3).

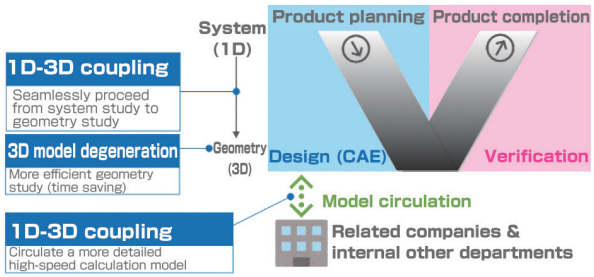

Fig. 3 Technical challenges of MBD

In order to establish technology for predicting the SA damping force accurately and quickly, we have built a technology for implementing the machine learning[Note 5)] model, which was degenerated from an FEM model of the SA laminated leaf valve, into a 1DCAE simulation tool (the 1D-CAE[Note 6)]). Its outline is shown in Fig. 4.

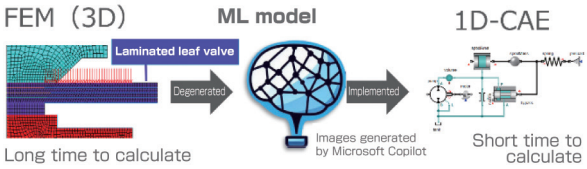

Fig. 4 Technology building for laminated leaf valve

Note 1) A CAE field that predicts product performance through mathematical system simulation.

Note 2) A CAE field that uses FEM to study product geometry in detail.

Note 3) Finite Element Method is one of the numerical analysis methods that can be used to deal with complex geometry by dividing the geometry of the product into elements (mesh).

Note 4) A design and development methodology that uses model-based simulation.

Note 5) A computer technology that learns regularities and patterns in data to determine the current state and predict the future.

Note 6) A simulation tool for 1DCAE. The hyphen is used to distinguish the tool from the CAE domain.

2 FEM Models

The FEM analysis of the laminated leaf valve, which is the target of this technology building, can be characterized as follows (Fig. 5):

[1] Allows evaluation of the deformation and stress of the laminated leaf valve during assembly (applied with an axial force due to screw tightening) and during operation (applied with a pressure due to hydraulic resistance of the orifice and other parts).

[2] Can take into account the initial deformation caused by the axial force due to screw tightening and the partial contacts inside the laminated leaf valve, which cannot be included in the theoretical calculation of the disc stiffness used to determine the SA damping force.

[3] Allows structural analysis not only with the microdeformation theory, but also with the large deformation theory.

[4] Due to its long computation time, the analysis has rarely been applied to the calculation of the SA damping force. Rather, it has been mainly used to study the geometry of parts around the laminated leaf valve.

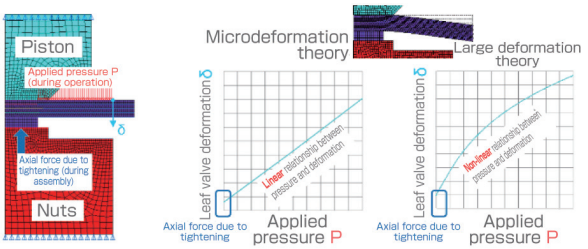

Fig. 5 FEM analysis of laminated leaf valve

3 Data Set Generation

We continuously performed the FEM analysis of a portion of the SA design series by changing the lamination specifications (outer diameter, plate thickness, the number of leaves) and the applied pressure, creating data sets necessary for building an ML model (Table 1). These data sets can also be used to calculate complex laminated leaf valves, called "preload valves", as shown in Fig. 6. A preload valve is a type of laminated leaf valve with its leaves at different heights to have an initial deformation, generating a preload to provide a high damping force.

For the continuous calculation, the FEM program codes were subjected to string processing by Python® to generate a program in advance with the lamination specifications (outer diameter, plate thickness, the number of leaves) of the laminated leaf valve randomly changed. KYB's standard CAE system was used for continuous automatic calculation 24 hours a day, seven days a week.

Table 1 Training data sets

Outer diameter of laminated leaf valve	5 levels or more
Plate thickness of laminated leaf valve	4 levels or more
Number of leaves of laminated leaf valve	3 levels or more
Preload valve	2 levels (yes/no)
Applied pressure	21 conditions
Deformation theory	Large deformation theory
Number of data sets	1,045,380

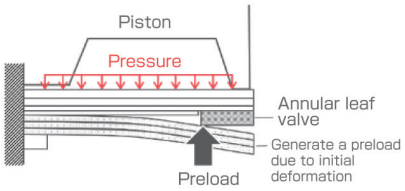

Fig. 6 Preload valve

4 Building an ML Model

After experimenting with the implementation of various machine learning algorithms, we were able to build an ML model that can infer the results of FEM analysis with high accuracy by using FLAML, a library in Python® Note 7) recently released by Microsoft Corporation. Fig. 7 shows the inference accuracy of the ML model for unknown data. The machine learning inference results (the vertical axis) and the FEM computation results (the horizontal axis) are plotted on a straight line with a slope of 1 (45 degrees). This verifies that the machine learning provides highly accurate inference.

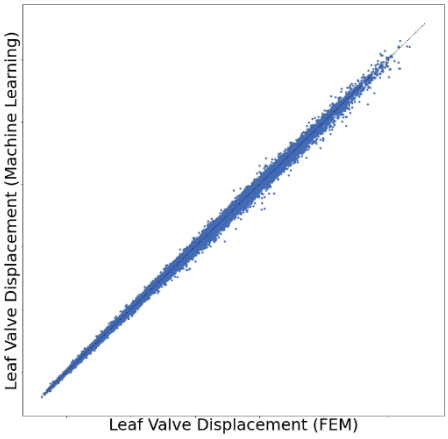

Fig. 7 ML model inference accuracy

FLAML is AutoML that can automatically select decision tree [Note 8] machine learning algorithms or hyperparameters (parameters set by the model creator to control algorithms before learning). By using FLAML, we finally decided to use the LightGBM algorithm. LightGBM, which is a decision tree algorithm characterized by lightness and high speed, has been widely used in machine learning competitions in recent years.

5 Implementing the ML Model in 1D-CAE

Together with NewtonWorks Corporation, we researched how to implement the Python® ML model in 1D-CAE SimulationX®. As a result, we decided to use coupled analysis via communication, which is easy to implement. Fig. 8 shows how SimulationX® and Python® communicate with each other to send/receive coupled analysis data. For the purpose of verifying the effectiveness of the SA damping force simulation with the ML model mentioned in Chapter 6, Fig. 8 reflects communication between applications within the same personal computer. However, such a system is difficult to use for model circulation among related companies and internal departments. Finally, we introduced the cloud communication described in Section 7.4.

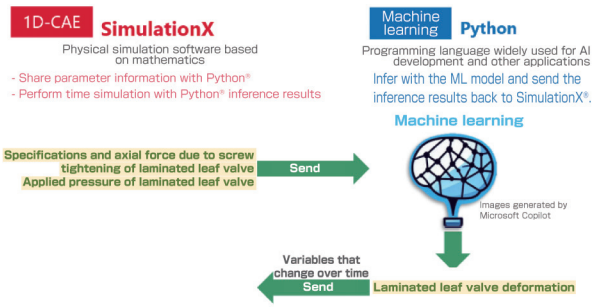

Fig. 8 Data exchange between SimulationX® and Python®

It was decided to transfer the information of variables that do not change with time, such as the outer diameter, plate thickness, and number of leaves of the laminated leaf valve, from SimulationX® to Python® only once immediately after the start of the calculation, and to transfer the information of variables that change with time, such as the applied pressure, to Python® via telecommunication at each communication time step. Based on the information of variables from SimulationX®, Python® infers the deformation of the laminated leaf valve and sends the results back to SimulationX® via telecommunication.

The computation for the coupled analysis by SimulationX® and Python® via telecommunication cannot be performed unless both tools are started to perform their own computation. In order to complete the computation by SimulationX® only, we created our own SimulationX® customized block shown in Fig. 9 to execute the Python® codes of the ML model in synchronization with the computation by SimulationX®. The customized block was created using the Modelica language [Note 9] and can be characterized as follows;

[1] Allows parameterization of ML models.
[2] Allows computation via telecommunication between SimulationX® and Python® (Fig. 8).
[3] Allows setting up the Python® virtual environment and Python® codes to be operated for calculation via telecommunication.

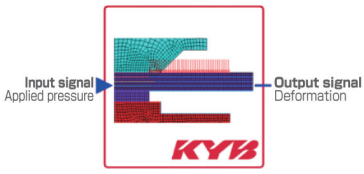

Fig. 9 SimulationX® customized block

Note 7) Python® is a trademark of Python Software Foundation.
Note 8) A machine learning algorithm that has a tree structure in which data is conditionally branched. Non-linear relationships can be identified.
Note 9) A multi-domain language for physical modeling.

6 SA Damping Force Simulation

We implemented the ML model built in Chapter 4 in the SimulationX® customized block (Fig. 9) to verify the effect of the ML model on the accuracy of predicting the damping force-velocity characteristic, which is an SA performance

indicator. For this purpose, we built a SimulationX® model by linking the ML model with KYB's original hydraulic library in the Modelica language (Fig. 10). In this model, the pressure applied to the leaf valve calculated by the hydraulic library is used to calculate the deformation of the laminated leaf valve using the laminated leaf valve ML model. The resulting deformation is converted into an area of the hydraulic orifice and then returned to the hydraulic library.

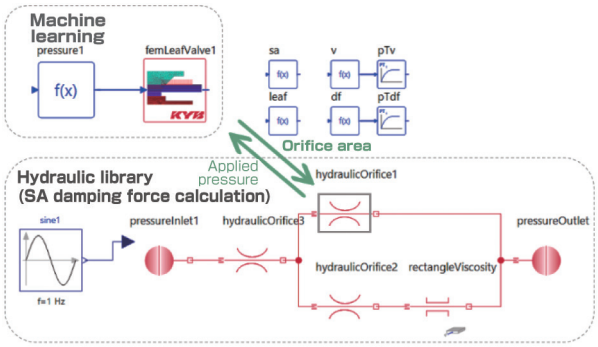

Fig. 10 SA damping force-velocity characteristics calculation model

As an example of verifying the prediction accuracy of the damping force-velocity characteristics compared to the experiment, Fig. 11 shows the results for the preload valve shown in Fig. 6. These results prove that, compared with the conventional theoretical calculation, the calculation model with the built-in ML model can predict the damping force-velocity characteristics with high accuracy.

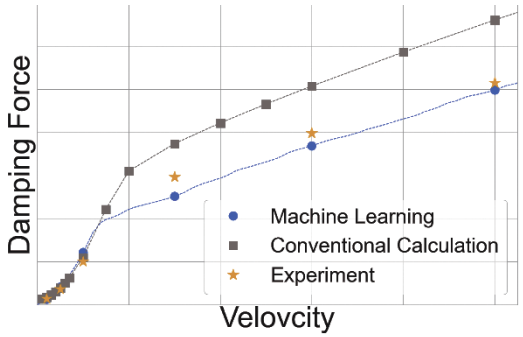

Fig. 11 Damping force-velocity characteristics prediction accuracy

By degenerating the FEM model for the laminated leaf valve to the ML model, the calculation time was significantly reduced from 93 seconds (with 23 pressure conditions) to 3 seconds (with 1,000 pressure conditions, including the time for the SA damping force calculation process).

7 Building an ML Model Operational Management Platform

7. 1 ML Model Operational Management System

In the process of operational management of the ML model technically built in the previous chapters, the following three major problems became obvious:.

[1] Complexity of building the environment and concerns about technology leakage

[2] Too many man-hours for operational management of the ML model

[3] Difficulty in managing the quality of the ML model

The environment mentioned in [1] refers to the user environment for the ML model. In general, individuals need to build a Python® programming environment to run the ML model on their own PC. In addition to the ML model data, the Python® program codes must be provided. This raised concerns about technology leakage when circulating the model among related companies and other departments of KYB. In addition, the program codes contain third-party libraries, which, depending on the user's PC environment, may disable the availability of libraries from target versions. Partly because of the possibility of this problem, it seemed likely to be complex to build the environment, raising concerns about too much man-hour burden on model users. In terms of [2], the ML model will be continually managed even after the model has been completed. The accuracy of the ML model may gradually deteriorate over time due to changes in the environment and other factors. In particular, its prediction accuracy may decrease with changes in the way the laminated leaf valve is used (design trend). To solve this problem, a model retraining process would be needed to ensure stable operation of the ML model. However, such continuous retraining usually requires a lot of man-hours for the ML model manager. If this operational process is not included in the workflow, there was a concern about too many additional man-hours. In [3], it was feared that the quality management of the ML model would be difficult even if the model was updated by retraining. This is because the ML model management itself depends on individual users as long as the complexity of the model environment mentioned in problem [1] persists.

To solve these problems, we internally developed an ML model operational management platform to realize MLOps [Note 10] as a system that allows relevant users to share and use a controlled

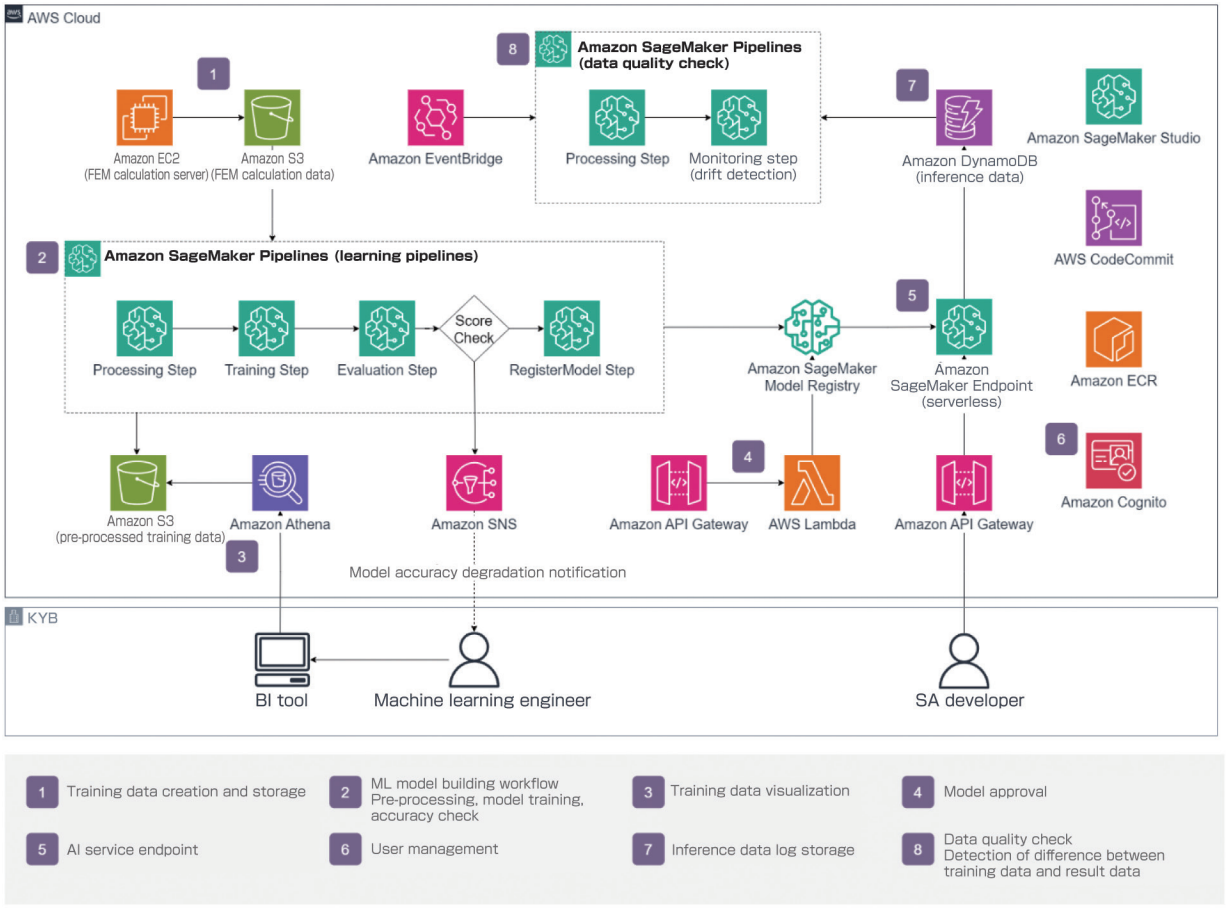

Fig. 12 Overview of the ML model operational management platform

high-quality ML model. Fig. 12 shows the overview.

The developed system can collectively manage all processes related to an ML model, including collecting, visualizing, and analyzing training data, as well as model training, accuracy checking, and developing AI services for SA damping force simulation by building an API system of the created model [Note 11]. This will greatly reduce the work of traditional ML model administrators. The system was built on the Amazon Web Services® cloud, which has advantages in functional extensibility and fault tolerance compared to the on-premises system [Note 12]. In addition, this system was developed by an internal cross-functional AI community[2] that brings together people with deep knowledge of machine learning and system development. The time required to complete the PoC[Note 13] was only one year.

Note 10) An acronym for Machine Learning and Operations. It refers to an approach or concept for improving efficiency in the development, analysis, and operation of ML models.

Note 11) A scheme (interface) that connects different systems, including software and programs, with each other to allow users to share their functions.

Note 12) A type of system deployment where an organization owns and operates the servers and networking equipment needed to build the infrastructure.

Note 13) An acronym for Proof of Concept. It refers to a series of verification tasks to determine the feasibility of an idea or technology used to implement a product or service.

7. 2 Data Collection, Management, and Visualization

This system can be used to automate the series of processes from training data generation to uploading with a script, allowing the operator to perform the work with minimal operation. The FEM analysis data, which is the basis of the training data, is generated on the calculation server in the cloud managed by the CAE department with a training data generation script when KYB's relevant CAE expert deems it necessary to retrain the model. With this script, the FEM analysis data is processed to be used as training data for the ML model, and then automatically transferred to Amazon S3 [Note 14] of

this system.

The transferred data can be visualized using a BI[Note 15] tool Tableau®[Note 16](Fig. 13). In KYB, a company-wide data analysis environment using Tableau® is available, which enhances compatibility with the BI tool used in the company. This has enabled internal ML model managers and data scientists to quickly analyze data.

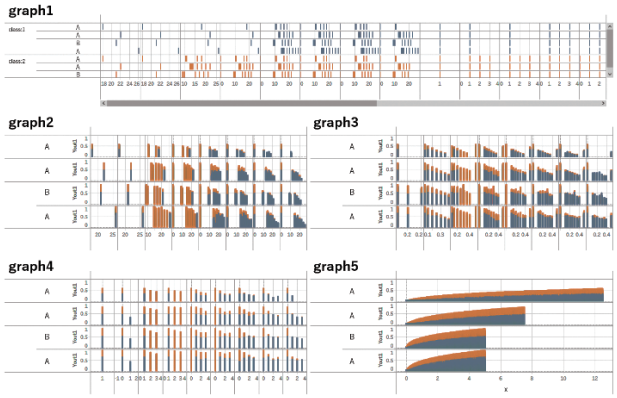

Fig. 13 Training data analysis screens

Note 14) Cloud storage that is highly fault tolerant and can store and protect data regardless of its type or capacity.

Note 15) Business Intelligence: A technology or approach that collects and analyzes necessary information from large amounts of accumulated data to be used for business management and operations.

Note 16) Tableau® is a BI tool and a registered trademark of Salesforce, Inc.

7. 3 Learning Pipelines

This system includes learning pipelines for ML model developers to develop an ML model with a low number of man-hours. Amazon SageMaker [Note 17] features are used to integrate the series of processes including data preprocessing [Note 18], model training, model accuracy verification, and inference endpoint [Note 19] into an automated workflow.

Using Amazon SageMaker allows the workflow to run on a virtual computing environment with the necessary specifications for processing. This eliminates the need to deploy physical computing servers with excessive specifications. Instead, the optimal processing resources can be quickly deployed to achieve cost-optimized processing.

The ML model is designed to be divided into two or more models according to specific computation conditions. This makes it easy to change the model design, thereby achieving flexible development that is easily adaptable to changes in demand. This model design will hopefully also help to identify data that has deteriorated the prediction accuracy, which could be caused by model retraining.

Thus, ML model developers can initiate the pipeline to train the target model by simply running a single command line that specifies the conditions of an ML model. In addition, this learning pipeline supports both the creation of a new ML model and its updating through re-learning. All processes related to model development with a view to long-term operation have been integrated into a single pipeline. On the other hand, the pipeline is designed to automatically select the workflow of creating a new ML model or the retraining workflow from the input to the pipeline. In addition, basic parameters related to model development have been given optimal values that have been previously collected, eliminating the cumbersome item setting that is otherwise necessary each time the pipeline is run. With these features, we have successfully built a pipeline that achieves the reduction of man-hours of ML model developers while increasing the reproducibility of model training.

Once the ML model training is completed, the generated learning model is automatically stored in Amazon S3. The results of the model performance evaluation are reported to the ML model administrators via the communication tool used in the company (Fig. 14).

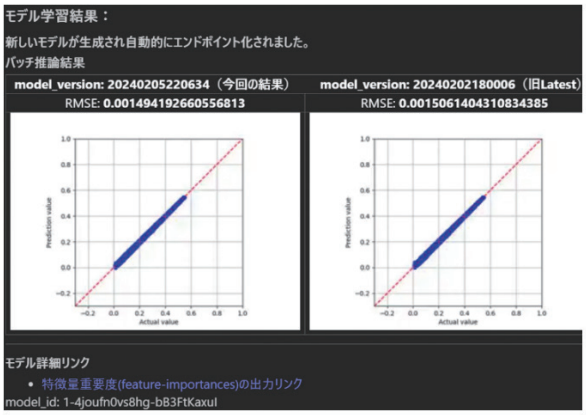

Fig. 14 ML model evaluation report screen

On the report screen, users can view the RMSE [Note 20] of the test results and the feature set importance[Note 21] of the generated model. In addition, for an ML model updated by relearning, a comparison with the results of the previous model is automatically displayed. In this way, the report screen is designed so that users can see the learning results at a glance.

Details of the ML model can also be viewed on

Amazon SageMaker. ML model developers can use the Amazon SageMaker Experiments feature Note 22) to visualize changes in the accuracy of the model being trained, changes in the optimal values of various parameters required by the learning algorithm, and the final model accuracy, and to compare the model's performance to that of any previous model (Fig. 15).

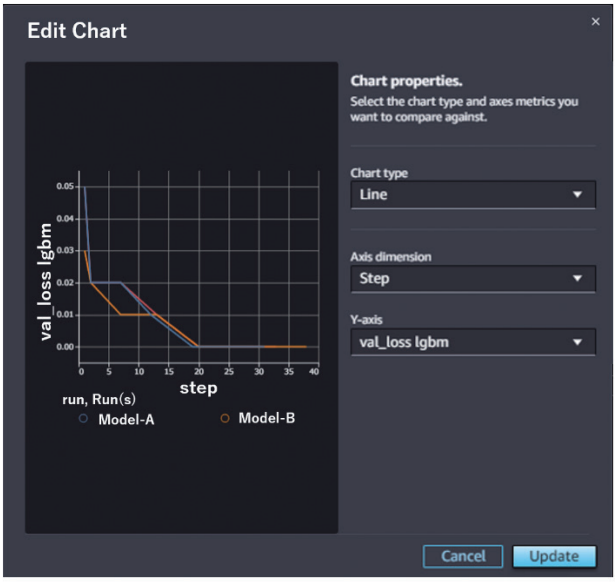

Fig. 15 Visualized changes in learning accuracy of ML model

Note 17) A cloud-based service that provides an implementation environment for rapidly developing and deploying ML models.

Note 18) A processing to integrate training data generated after data processing with a training data generation script.

Note 19) An interface that allows users to use ML models externally.

Note 20) The Root Mean Squared Error refers to the function used to determine the square root of the mean of the squares of the prediction errors. One of the general evaluation functions of ML models that focuses on regression issues.

Note 21) A metric that represents how much each feature set of the training data contributes to improving model accuracy.

Note 22) One of the Amazon SageMaker features that can track the learning record of the model.

7. 4 Deployment as an AI Service

The ML model generated by learning pipelines is automatically deployed as an inference endpoint. End users can use the ML model in real time.

To mainly enable internal SA developers to calculate SA damping force using machine learning directly from within their familiar SimulationX® tool, we have developed a custom library that can be built into SimulationX®. This custom library can be imported into the CAE tool to communicate with the inference endpoint in the cloud via WebAPI Note 23).

WebAPI is commonly used for back-end processing Note 24) of Web sites and other applications and allows the user to keep private certain processing, including model data and program code elements. Using WebAPI enables direct communication with inference endpoints from the 1D-CAE. The ML model inference results obtained through communication are reflected in the 1D-CAE. High accuracy SA damping force simulation is now available.

SA damping force simulation with this system involves communication via the Internet for inference processing with the ML model in the cloud. Therefore, we designed an original communication algorithm to optimize the number of communication times with the ML model to reduce the simulation time. As a result of applying the algorithm to the SA damping force simulation using machine learning, the communication time to determine the damping force-velocity characteristics shown in Fig. 11 was successfully reduced to about 1/10 of the time taken without the algorithm. End users can now use ML models to quickly and accurately calculate the SA damping force with a simple procedure without the need to individually build a machine learning environment.

The developed ML model is controlled for version by the system. Even if the system trains and updates the ML model to a new version, the previous version remains available (Fig. 16).

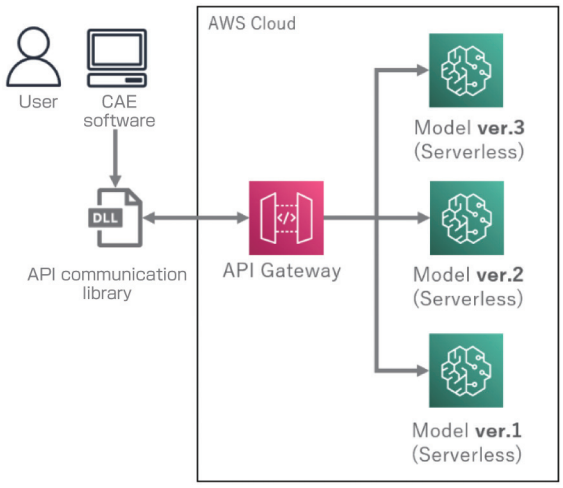

Fig. 16 Illustration of ML model version control

This version control ensures the reproducibility of the results of the SA damping force simulation using machine learning.

The custom library can be output after conversion to a data format according to the FMI standard [Note 25], providing compatibility with other types of CAE tools that support the FMI standard. In particular, all models created in SimulationX®, including the original custom library, can be converted to royalty-free FMU [Note 26]. This means that this system can also be used by external SA developers using other types of CAE tools. The system also has a user account management function mainly for external end users to expand the range of users of the service. At the same time, we are considering providing a high-security API. External end users who have registered in advance can log in to their own user account from the user login screen provided by the system. After successful login, they can receive an authentication token (Fig. 17).

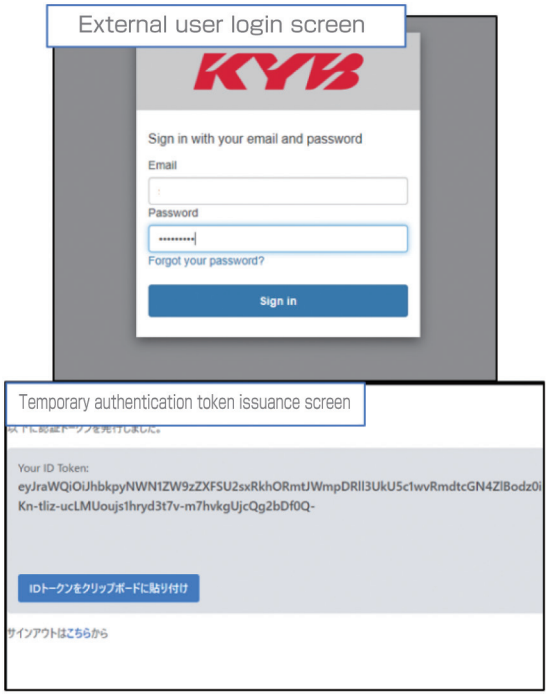

Fig. 17 External user login screen and authentication token issuance screen

External end users can enter the authentication token via the CAE tool by importing the pre-delivered FMU into the tool. The FMU only allows communication using the authentication token. Communication with the ML model cannot be established unless the access is allowed by the system. This feature allows all end users, whether internal or external, to access the SA damping force simulation using the ML model (Fig. 18).

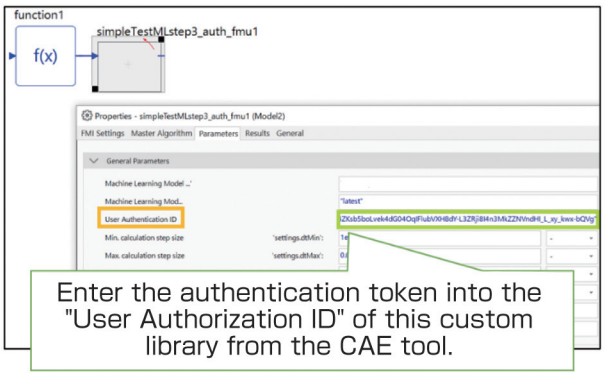

Fig. 18 API request with temporary authentication token screen

To reduce the risk of invalid use of the authentication token, the system is configured to disable the token itself after a certain period of time has elapsed since the user's login. Even if the authentication token is leaked externally, any request to the API with a token that has been disabled after a certain period of time will be rejected by the system. The system continuously keeps an access history and has a function to warn the system administrator about any suspicious unauthorized access.

Note 23) An API available on the Internet.

Note 24) Processing in the server zone that is invisible to users.

Note 25) Functional Mock-Up Interface: An open standard for exchanging and connecting dynamic simulation models between standardized tools of different types.

Note 26) Functional Mockup Unit: An execution module based on the FMI. The FMU can keep models private and use them regardless of the type of CAE tool.

7. 5 Monitoring the Quality of Training Data

To verify the accuracy of the ML model of this system, it is necessary to check the inference results of the model with the actual FEM calculation results. When specification information is input by an end user, the system outputs the prediction results of the ML model based on the inference endpoints. Obtaining accurate FEM calculated values for the results requires time and cost, so it is difficult to verify the accuracy of an ML model in operation. For the purpose of this system, we then focused on the quality of the training data that affects the model accuracy.

The SA specification information entered to use the AI service is recorded in the system as the usage history of the ML model. The system can compare the distribution of data used to train the model with the distribution of data actually used.

Statistics are automatically computed and periodically compared for verification. The results of the comparison are automatically reported to the ML model administrator via internal communication tools, so that they can be used to consider retraining the model (Fig. 19).

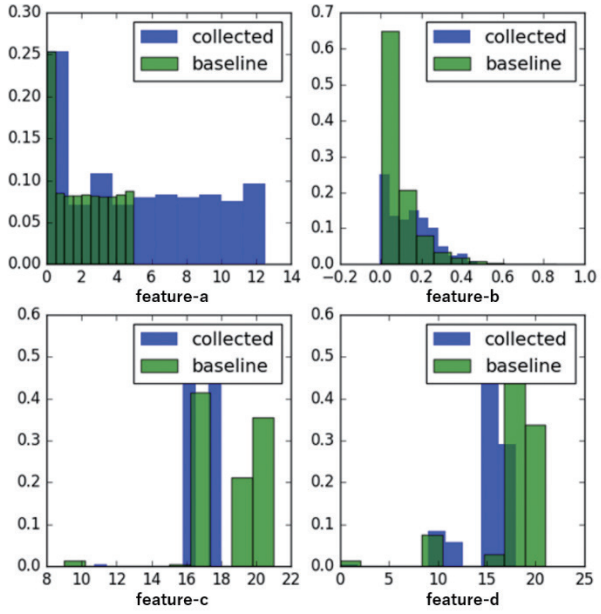

Fig. 19 Example of comparison of data distribution by feature set of training data and inference data

8 Concluding Remarks

By degenerating the detailed FEM model, which requires long computation time, into the ML model, we built the computational foundation to be implemented in 1D-CAE, which requires only short computation time despite its high accuracy. We also built the ML model operational management platform to enable staff to share the controlled high-quality ML model.

These technologies we have developed will help solve all MBD technical issues shown in Fig. 3 (seamlessly proceeding from 1D system study to 3D study, more efficient 3D geometry study, and model circulation among related companies and internal departments). We will actively apply the technologies to model development both inside and outside KYB, trying to maximize the effectiveness of the MBD.

Finally, we would like to take this opportunity to express our sincere gratitude to the CAE software vendors and cloud vendors, and staff of the related sections of KYB, who have cooperated in this project.

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Technology Explanation

Development of Stamp Inspection Technology Using AI and Construction of MLOps Platform

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Abstract

In recent years, the automation of visual inspection of product appearance has transitioned from a rule-based approach to a technique utilizing AI (Artificial Intelligence). Kayaba aims to utilize AI to develop inspection technology that is robust against individual differences in products and changes in the inspection environment.

Shock absorbers, our main product, are inspected visually for all stamps, so there is a demand for labor-saving inspection work and improved quality assurance by preventing inspection errors. Therefore, by applying AI, we aim to develop a highly robust stamp inspection technology, thereby reducing labor and improving quality assurance.

In inspections using AI, changes in the environment over time cause the AI model to deteriorate and inspection accuracy to decrease. Regular relearning is necessary to maintain the system, but doing it manually places a heavy burden on administrators. In addition, there have been problems with the consistency and reproducibility of the results. Therefore, we have newly built an operation management system aimed at reducing the burden on developers and improving the efficiency of data management and operation.

This paper describes the development of the stamp inspection technology and the newly constructed system.

1 Introduction

KYB identifies its shock absorber (SA) products with a stamped product number, which is subject to 100% visual inspection. To improve quality assurance and reduce labor, the visual inspection needs to be automated. A rule-based automation approach could hardly maintain consistent inspection performance due to variations in the brightness (contrast) of inspection images caused by individual product differences or changes in the inspection environment. To solve this problem, we have applied Artificial Intelligence (AI) to develop a highly robust[Note 1)] technology for identifying stamped product numbers.

In order to apply the AI-based inspection technology to our factories for efficient operation, we need to increase the efficiency in the AI execution cycle (data collection, AI training, accuracy evaluation, model deployment[Note 2)]) and properly manage and operate the data, thereby maintaining the AI quality at a high level. Therefore we constructed a platform to implement MLOps[Note 3)].

The following chapters describe the stamp inspection technology and the MLOps platform.

Note 1) Refers to the state of a product whose characteristics are not susceptible to changes caused by external factors.

Note 2) The process of integrating a machine learning model into an existing environment (equipment).

Note 3) An initiative to make AI easier. A word combination created from AI Machine Learning (ML) and DevOps, a continuous development approach in the software field.

2 Development of Stamp Inspection Technology

2. 1 Inspection Target

The inspection target is the product number letters stamped on the circumference of the SA cylinder (Photo 1). The inspection is performed in the final process after painting to check the stamped product code for number errors and letter fading.

Photo 1 Inspection target

2. 2 Configuration of Stamp Inspection Machine

Fig. 1 shows the configuration of the developed stamp inspection machine. The inspection target is rotated and continuously captured by a line scan camera (which continuously captures images by linear motion and processes them to obtain images as shown in Photo 2). The machine identifies the stamped product number from the captured image and determines the pass/fail of the stamp.

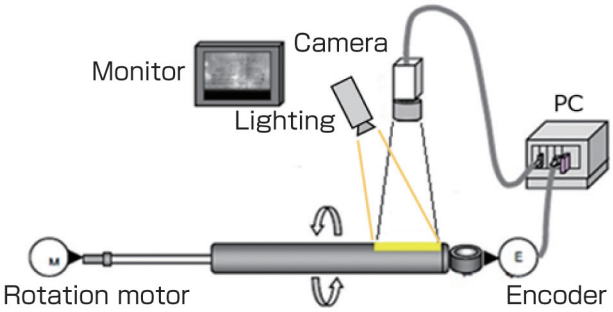

Fig. 1 Configuration of stamp inspection machine

Photo 2 Captured image

2. 3 Requirements

The following are the requirements for developing efficient, accurate stamp inspection technology:

[1] Establish a method for preparing efficient AI training images.

[2] Establish a character recognition algorithm that can maintain high recognition accuracy.

2. 4 Overview of Stamp Inspection Technology

2. 4. 1 Establishing a Method for Preparing Efficient AI Training Images

To build an AI model with high character recognition accuracy, the AI needs to learn images with various characteristics, including individual product differences and variable inspection environments. When collecting such training images in the initial development stage, two problems arose:

[1] It was difficult to uniformly collect training images of the 36 characters to be recognized, consisting of numbers, alphabets, and symbols, in a short period of time because these characters were not necessarily uniformly used in the actual products.

[2] It was difficult to collect in a short period of time training images of characters with different letter thicknesses caused by variable image brightness due to the state of surface painting or by the degree of wear of the stamping piece (a jig used to stamp the product number) (Photo 3).

To solve these problems, based on the CAD drawing (Fig. 2), we uniformly created hypothetical product number images (artificial images) for the 36 characters with different noise levels, including different letter thicknesses and color shading (Fig. 3). It was then possible to combine several tens of thousands of the artificial images with a small number of images of actual products to provide a set of training images, thereby creating a highly accurate AI model. Thus, we successfully established a method for collecting efficient training images to reduce the initial development time.

Photo 3 Images of stamped product number that look different

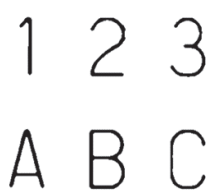

Fig. 2 Font data (sample)

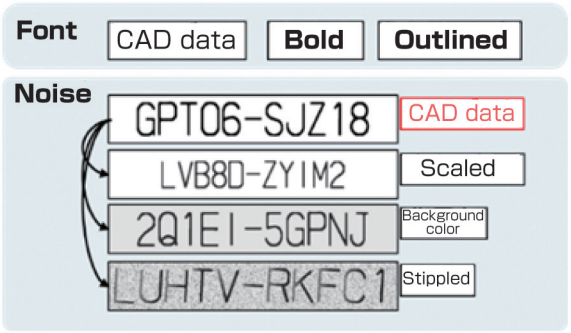

Fig. 3 Artificial image (sample)

2.4.2 Character Recognition Algorithm

In fact, the AI model, despite the introduction of the retraining approach[Note 4], produced stamped product number identification results that did not meet the target agreed with the relevant factory. Then, in addition to the retraining approach, the ensemble approach was introduced. In the ensemble approach, two or more AI models as shown in Fig. 4 are used to provide multiple results, from which a final result is output based on majority rule. In this project, the decision based on majority rule is made by YOLO[Note 5], CNN[Note 6], and an appearance check by a human operator (Fig. 5).

Specifically, YOLO and CNN recognize the stamped product number and determine if it matches the correct number provided. If both AI models answer the correct number, the product is accepted (pass). If both answer incorrect numbers, the product is rejected (fail). If one answers a wrong number (pending), the product is visually inspected by a human operator to determine pass/fail. Using this algorithm, we have established a method to identify anomalous products while keeping the false answer rate at a low level.

Note 4) An approach to re-training the AI by adding images of products that the AI failed to correctly recognize to the training dataset.

Note 5) An acronym for You Only Look Once. An algorithm used to identify "what's where in the picture".

Note 6) An acronym for Convolutional Neural Network. An algorithm used to identify "what's in the picture".

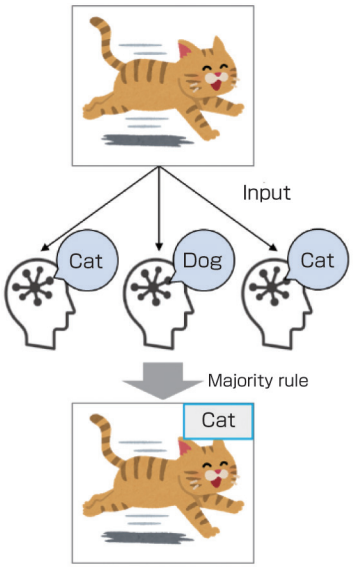

Fig. 4 Ensemble approach

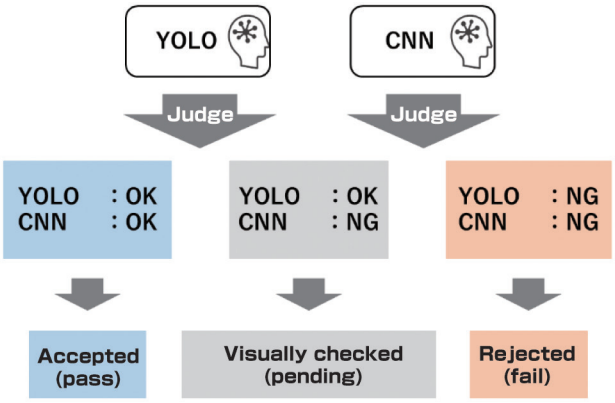

Fig. 5 Character recognition and evaluation flow

3 Construction of MLOps Platform

3. 1 Necessity of MLOps Platform

During the operation and management of the machine learning models technically built in the previous chapters, three major problems were identified. One was "complexity in setting up environments", such as a programming environment necessary for machine learning. Another was "difficulty in quality management", that is, the dependence of machine learning model management on users made it difficult to manage the quality of the machine learning models. The last one was "too many man-hours for operation and management", that is, the operation and management of the machine learning models required its administrators to spare many man-hours. To solve these problems, it was necessary to have an MLOps platform to efficiently operate the machine learning based system.

There are two major options for building an

MLOps platform: on-premises[Note 7] and cloud. Until now, the platform has been running on-premises. However, we faced several challenges. One example was "increased man-hours for maintaining model accuracy", which was necessary for compiling inspection results and re-evaluating AI models. Another example was the "ambiguous data and AI model management process" that did not ensure consistency and reproducibility of results. Faced with these challenges, we considered it advantageous to build a system in the cloud from the viewpoints of functional expandability, maintenance, future deployment, and operability. Then, we built a MLOps system series from data collection to model deployment in the AWS cloud. Fig. 6 shows an overview of the MLOps platform we built.

Note 7) A mode of operation in which the company owns and manages the software and hardware to build a system itself.

3. 2 Requirements

The following are the requirements for operating the MLOps platform:

[1] A flexible system that can also be used for applications other than the stamp inspection machine.

[2] Automate routine tasks that do not require human decision making to significantly reduce operational man-hours.

[3] Automate the human approval process to determine when to move to the next step.

3. 3 From Edge Inference to Data Storage

The platform needs to use different types of data, including retraining data (inference images that were misidentified by AI models) and inference logs. These types of data come in a variety of formats, including images and CSV. In addition, since it must be possible to use the platform for applications other than the stamp inspection machine, extensibility is required to be able in future to collect data in formats other than those currently compatible. Considering these situations, it was decided to use Amazon S3 [Note 8] to store data in a variety of formats.

It was also decided to transfer the data generated in the edge terminals[Note 9] to Amazon S3 via an intermediate server instead of uploading it directly. The reasons for this decision were twofold:

[1] Concerns about communication with external networks (instability).

[2] Concerns about the operational stability of the edge devices (no production impact).

The intermediate server must have an authentication to allow uploading to Amazon S3. It was decided to use AWS IoT Core[Note 10] for authentication management. The service allows only devices registered with AWS (in this case, the intermediate server) to use the temporary authentication to allow secure data upload.

Note 8) A storage service that can store and protect data regardless of type or capacity.

Note 9) Terminal devices connected to a network to collect and process data. For the purpose of product stamp inspection, they are responsible for a series of processes from camera capture to stamp identification with AI models.

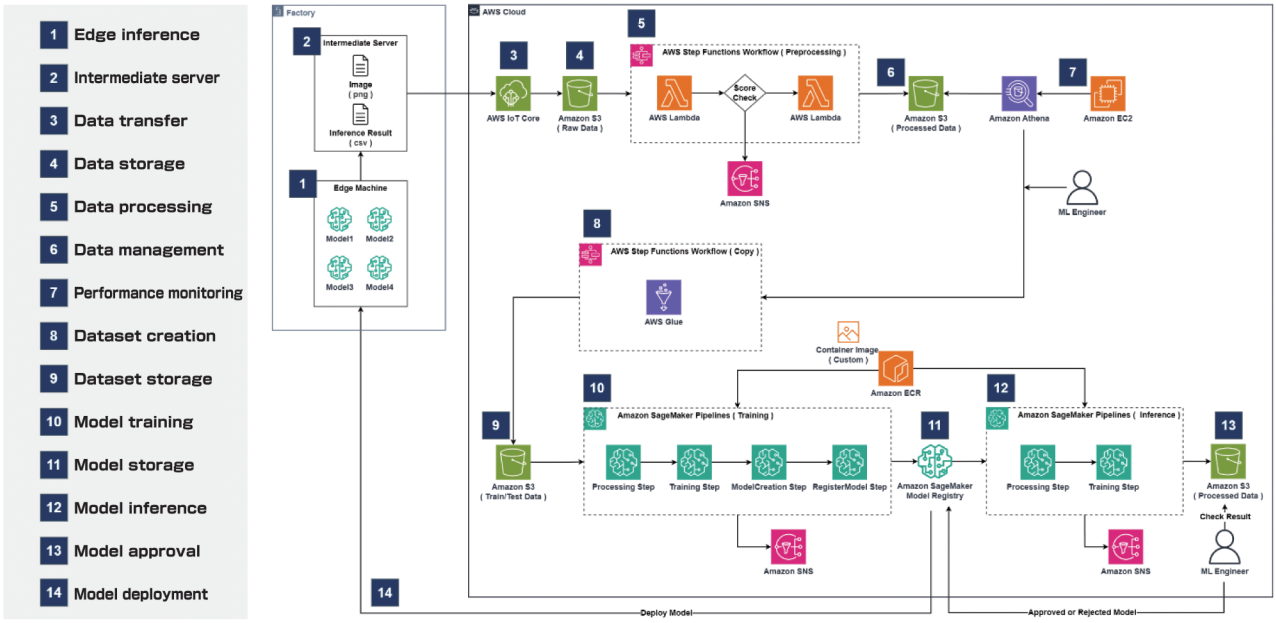

Fig. 6 Overview of MLOps platform

Note 10) A service that connects IoT devices to various AWS services.

3.4 From Data Processing to Performance Monitoring

Traditionally, human administrators would periodically determine if the AI models needed to be retrained. This way of working puts a heavy burden on the administrators and may not work in the future when the AI models need to cover more machines. Therefore, we established an automatic evaluation system to determine whether the AI models have degraded in performance. The evaluation is based on the following two criteria and determines whether the performance is below a threshold. Criterion [1] detects an abrupt decrease in the performance of the AI models. Criterion [2] detects a decline in AI model performance over time.

[1] Evaluate model performance on the day of processing (daily check).

[2] Evaluate model performance over the last five business days (weekly check).

The check results are notified to the Microsoft Teams chat via Amazon SNS[Note 11)] (Fig. 7). The notification allows the administrators to identify the need for retraining, which significantly reduces the operational burden.

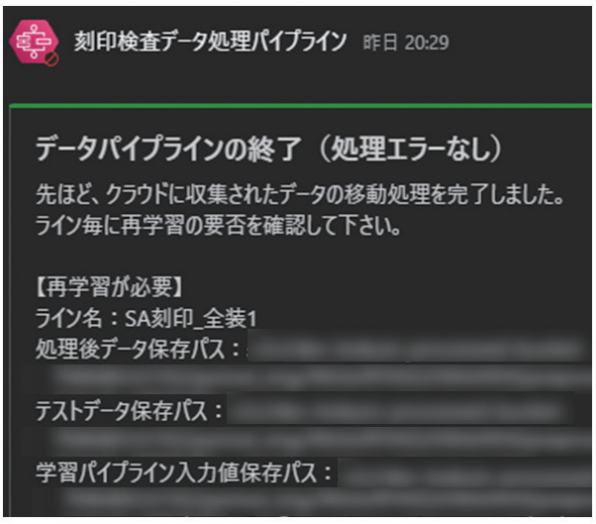

Fig. 7 Example of data processing completion notification

In addition, a dashboard was created using a BI tool[Note 12)] to identify the routine performance and availability of the AI models (Fig. 8). The BI tool is Tableau[Note 13)], which is provided as a data analysis environment across the company. On the dashboard, the administrators can not only view the performance and availability of the AI models, but also perform simplified ad hoc analysis[Note 14)].

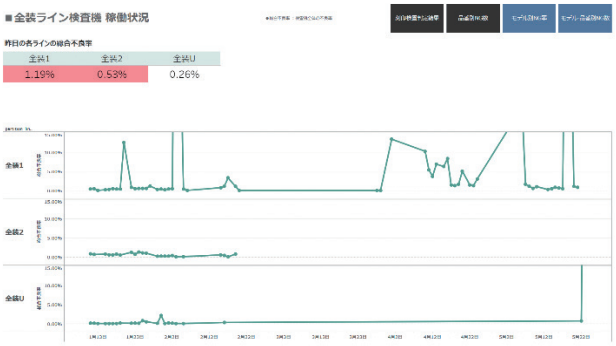

Fig. 8 AI model performance monitoring dashboard

Note 11) A service for exchanging messages between applications and different AWS services.

Note 12) A tool that compiles necessary information from large amounts of data accumulated in a company and analyzes it to be used effectively for management and operations.

Note 13) An application designed specifically for visualizing large amounts of complex data.

Note 14) A type of data analysis with no fixed analysis items or target that is performed as a one-time operation on an as-needed basis.

3.5 From Dataset Creation to Model Deployment

The processes from dataset creation to model deployment, which are the critical processes of the MLOps platform, are performed as follows:

[1] Create training/test datasets

[2] Retrain and approve AI models

[3] Deploy AI models

3.5.1 Creating Training/Test Datasets

When the function described in Section 3.4 deems it necessary to retrain the AI models, the creation of datasets is performed. To create the dateset, it was necessary to add data that had been manually annoutated[Note 15)] to the source dataset. We automated the creation of the source dataset. The automated system notifies the Microsoft Teams chat when it is complete. Upon notification, the administrators can simply add the annotated data to complete the dataset creation process.

Note 15) A task of providing the correct response information needed to train an AI model.

3.5.2 Retraining and Approving AI Models

As an implementation environment for fully-managed[Note 16)], high-speed learning, and inference, we use Amazon SageMaker[Note 17)]. In particular, Amazon SageMaker Pipelines[Note 18)], which is one of its functions to build ML pipelines[Note 19)], is used to fulfil the purpose of this project, which is to reduce the operational burden of the administrators by building an MLOps platform. The pipelines can relatively easily automate the

series of MLOps processes, including model training, testing, registration, and deployment.

The stamp inspection system uses a total of four AI models, including the one for pre-processing. When one of the four models is retrained in the ML pipelines, it is necessary to check the inference results of the whole system. So, it was decided to have four kinds of performance evaluation in the inference pipelines as shown in Fig. 9. In this way, we have built a mechanism that can not only improve the performance of a single AI model but also evaluate the whole system.

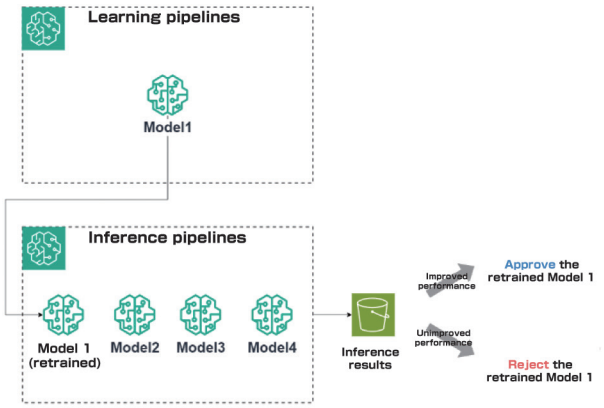

Fig. 9 Learning and inference pipeline processing flow

The system is designed so that when the processing reaches the output of the inference results, it notifies the Microsoft Teams chat of a request to check the results (Fig. 10). This notification allows users to determine the pass/fail of the AI model by simply interacting with the Microsoft Teams user interface (UI), such as "approve the retrained model" if the performance has improved, or "reject the retrained model" if the performance has not improved. The approved model is registered in the Amazon SageMaker Model Registry[Note 20]. It is then stored in Amazon S3 for deployment to edge devices.

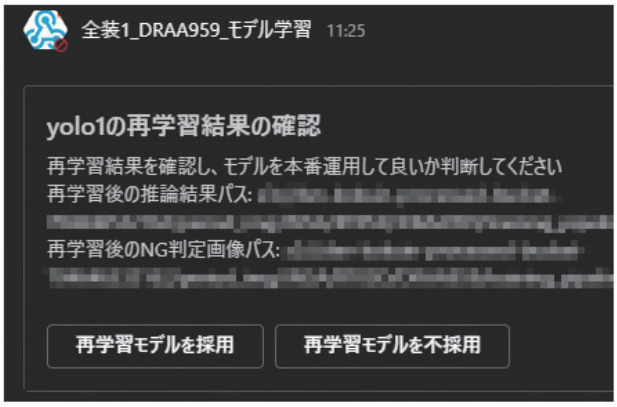

Fig. 10 Request to check inference results

Note 16) A service mode in which the contractor performs "operational tasks" such as "computer failure monitoring, data backup, and software version control" for the user.

Note 17) A service that provides an environment for rapidly developing, training, and deploying AI models.

Note 18) A workflow orchestration service that automates MLOps steps.

Note 19) A workflow of a series of steps/processes from data preprocessing, model training, evaluation, and deployment.

Note 20) A service that supports the management and deployment of AI models.

3. 5. 3 Deploying AI Models

For the same reason as the concerns about the data upload mentioned in Section 3.3, it was decided to deploy the AI models through an intermediate server. The intermediate server checks daily where the models are stored in Amazon S3. If a current model exists, it is temporarily downloaded to the intermediate server and then deployed to the edge terminals at a time that does not impact production.

3. 6 Retraining Process

To implement the retraining process described in Section 3.5, it was necessary for the administrators to perform data download from Amazon S3, and other tasks based on commands (CUI[Note 21]). In order to simplify such tasks, we created applications that can be operated on a GUI[Note 22] as shown in Fig. 11, which enables easy retraining. This has successfully reduced the manual work required for retraining.

Fig. 11 Retraining GUI

Combining these applications with the AWS cloud has improved the efficiency of the AI run cycle and ensured proper data operation and management, allowing AI quality to be maintained at a high level.

Note 21) A method that allows users to interact with (or operate) the computer by entering text commands.

Note 22) A method that allows users to interact with (or operate) the computer using visual elements such as icons and menus.

4 Future Prospects

The stamped product number identification technology has been introduced in four mass production lines at a single site as of June 1, 2024. As many of KYB's mass production lines still rely on 100% visual inspection by human operators to identify the stamped product number, we will continue to roll out this technology laterally to other sites, contributing to labor savings for operators and improved quality assurance.

Since we have established the AI model maintenance and management system, it is now possible to easily identify the reduction of man-hours for retraining AI models and the status of their operation. Repeated application of the system to mass production has achieved reliability, although the short operation time alone has not yet yielded a substantial result. For efficient deployment of the system, it is essential to cooperate with various departments in the factories. We will promote the introduction of the system by discussing the operation aspect of the system with the departments in charge.

We also plan to apply the AI-based inspection technology to processes other than the inspection of stamped product numbers. By promoting the deployment of the MLOps platform to such processes, we will contribute to higher productivity and product quality.

5 Concluding Remarks

This development project has achieved the labor saving of stamp inspection and the improvement of quality assurance.

Finally, we would like to take this opportunity to express our sincere gratitude to those from related departments who have provided substantial support and cooperation in this development project.

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Introduction

Virtual Exhibition 2023: Company-wide Technical Presentation

HASHIMOTO Yuna

1 Introduction

In December 2023, KYB held its internal company-wide technical presentation, "Virtual Exhibition 2023."

The exhibition was held online, which was a new style converted from the traditional one held in a physical location due to the outbreak of COVID-19. The virtual exhibition was very impressive and attracted 107 entries.

This report describes the background and impact of the virtual exhibition.

2 From Physical to Virtual Exhibition

2. 1 Company-wide Technical Presentation

KYB holds a company-wide technical presentation every year in order to deploy technologies horizontally, share information, and increase motivation for development. Preliminary presentations in the three fields of production engineering, hydraulic electronics, and automobile (block presentations) are held as a competition. The top two topics in each presentation are selected for the company-wide technical presentation.

2. 2 Exhibition

Prior to the COVID-19 pandemic, the exhibition was held on the same day as the block presentations. After applying for the presentations, engineers exhibited presentation boards showing their research and development (R&D) results and actual R&D products to share information with each other and promote their technologies to visitors. Each block attracted applications to exhibit nearly 100 topics each year.

The biggest advantage of the exhibition was that visitors could hear the explanation of R&D directly from the engineers at the exhibition booth. Visitors who usually did not have the opportunity to see R&D products could also look at actual exhibits to identify the features of products that they could not clearly imagine just by listening to the presentation. On the other hand, the engineers at the booth could exchange opinions and get reactions from the company's directors and managers of other departments/sections who were visiting the exhibition to increase their own motivation.

The exhibition was so popular every year that the aisles were crowded with people, making it difficult for them to move around (Photo 1). However, the outbreak of COVID-19 in the winter of 2020 limited the holding of internal events. The company-wide technical presentation accordingly had to be held on a smaller scale, resulting in the cancelation of the on-site exhibition to avoid the three Cs (closed spaces, crowded places, and close contact settings)

2. 3 Reviving the Exhibition

During the three years from FY2020 to FY2022, when the exhibition was canceled, there were calls to revive a place to share and display the results of daily R&D. When the Japanese government reclassified COVID-19 as Class 5 under the Infectious Diseases Control Law, we considered resuming the exhibition. However, we finally gave up because holding the exhibition at physical locations as before still carried the risk of the three Cs, as the number of infected people happened to be increasing again. Another reason was that the traditional exhibition was held for only one day at each development site. Visitors and participants had to travel to different locations to see the exhibition, and in some cases they might not be able to visit all the locations due to work or other reasons. We then considered holding a web-based exhibition so that anyone in the company could view the exhibition as long as they had the necessary environment. Finally, in FY2023, we decided to hold the company-wide technical presentation as Virtual Exhibition 2023.

Photo 1 Exhibition room

3 Developing a Virtual Exhibition Site

There were only four months of preparation from the decision to create a virtual exhibition to the opening. We considered a method that would be accessible to all employees and allow the exhibition to be developed in a short period of time.

3.1 Tools Used

We used Microsoft365® SharePoint®, which is used throughout the company, to develop a virtual exhibition site. Although there was a plan to hire an external website development company to develop the site, we decided to use SharePoint® as it was advantageous when comparing cost, creation time, and quality.

SharePoint® is a web-based information sharing tool. Users can share files and schedules, communicate with each other, and easily develop websites. It is possible to develop a generic site with general-purpose features, although one drawback is that it is limited in what can be freely configured. Still, users can develop websites at low cost in a short period of time without knowledge of the web source code[Note 1)].

Note 1) A programming language used to build a website. It includes HTML and CSS.

3.2 Other Virtual Exhibition Sites

To determine the trend in virtual exhibitions, I visited virtual exhibition sites for various events. During the COVID-19 outbreak, many organizations presented virtual exhibitions. These included product explanation through movies, public images of products taken from all possible directions, and product explanation by an avatar exhibitor[Note 2)]. Among them was an impressive exhibition where visitors could be an avatar and move around in 3D space to see the exhibits as if they were actually in the room.

In fact, I had thought that an exhibition was "something I should go to see". However, experiencing virtual exhibitions gave me a positive impression as I enjoyed the advantages of saving the time and trouble of traveling to the site and allowing me to view many exhibits in a short time. I also thought it was good to learn the outline of a product in a virtual space and then make an individual appointment for an interesting product before traveling to the site to see it.

Note 2) A character that represents the user in digital space.

3.3 Considering Configuration of the Virtual Exhibition Site

Despite the limited functions available in SharePoint®, we considered a configuration of the virtual exhibition site that could easily express the characteristics of the exhibition theme while maintaining the traditional exhibition impression using presentation boards (Fig. 1). We designed the virtual exhibition site to be able to add R&D product introduction movies, related images (without numerical limitations), and URL links (if the relevant departments have a public website), in addition to the conventional content. It was also

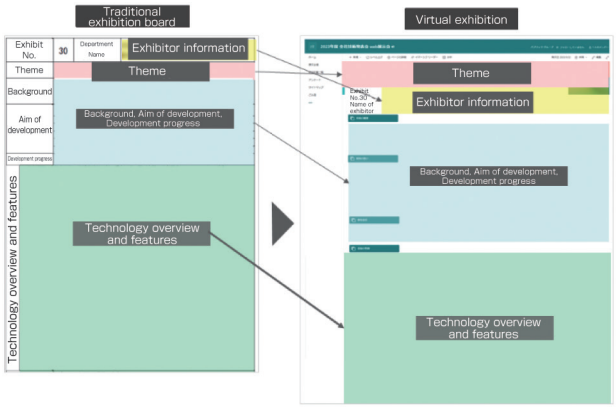

Fig. 1 Comparison of traditional exhibition board and virtual exhibition

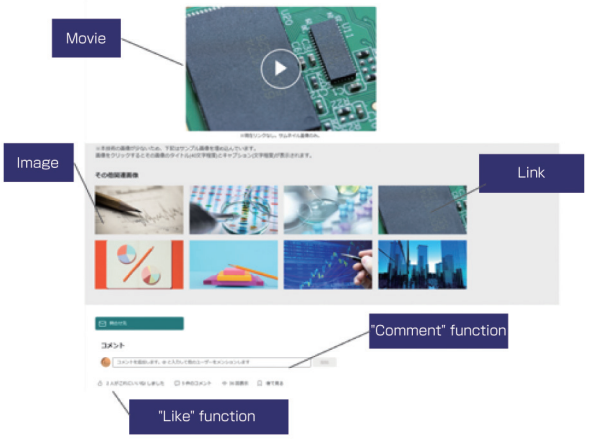

Fig. 2 What to add

decided to use the SharePoint® "Comment" and "Like" functions to facilitate communication with visitors (Fig. 2).

3. 4 Designing the Virtual Exhibition Site

Through trial and error, we used SharePoint® Space Note 3) to create a 3D environment for the main page of the virtual exhibition site so that the site represented virtual space as much as possible (Figs. 3 and 4). The main page was designed to be categorized under each department in order to move to relevant exhibit pages for different topics (Fig. 4).

For the 107 topics applied, the engineers promoted their R&D full of movies and images that represented their personality. The exhibition was so wonderful that I became obsessed with it, even though the editorial deadline was approaching.

Note 3) One of the SharePoint® features. It allows 3D object web parts, 360° images, 2D images, and text to be placed in the same space.

Fig. 3 Virtual exhibition site main page [1]

Fig. 4 Virtual exhibition site main page [2]

4 Opening the Virtual Exhibition Site

The virtual exhibition site was complete when the exhibition pages had been created, and the Secretariat had finished editing and final checking. We made the exhibition known to employees by creating a promotional brochure about our internal exhibition activity (Fig. 5). On December 13, 2023, the company-wide technical presentation Virtual Exhibition 2023 was opened to the public.

There was no specific time frame set for viewing the website (internal employees can still view it). The number of "Likes" for the exhibition and chat communications were made public for about two weeks until December 28.

The total number of viewers was 591 and the cumulative number of hits during the exhibition period was 5,557.

Fig. 5 Virtual exhibition promotional brochure

5 Questionnaire

We conducted a questionnaire to determine what could be improved for the next exhibition. Out of 111 exhibitors, 87 answered the questionnaire. Some of the results of the questionnaire are presented below.

In order to determine their willingness to participate in the exhibition, the questionnaire asked the exhibitors why they applied for the virtual exhibition (Fig. 6). While many of them applied under the guidance of their supervisors, some others did so to actively promote their own R&D.

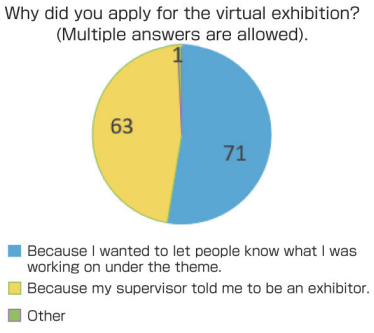

Fig. 6 Questionnaire results (Why I became an exhibitor)

In order to determine the likelihood of exhibiting again in the next year (tentative), the questionnaire asked respondents if they would like to exhibit again in the next year. They were also

asked why (Fig. 7). Almost half of the respondents said that they would like to exhibit again next year. The reasons are listed below:

- It was an interesting experience.
- I could always take time to visit the virtual exhibit to see what other departments were working on.
- The exhibition site helps promote our technology.
- I would like the virtual exhibition to be held again next year with almost the same degree of freedom as this year, without any restrictions or limitations.

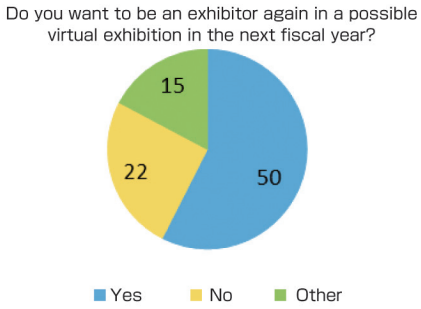

Fig. 7 Questionnaire results (If I want to be an exhibitor next year)

The following are some of the reasons they did not want to exhibit and other items that could be improved:

- It takes many man-hours to prepare an exhibit.
- I think the exhibition should be promoted more actively.
- I think the exhibition should have an exhibit award.
- I would like to communicate more with the viewers.

During this exhibition, only a few people used the "Like" function. I thought it was necessary to develop a system that would make viewers want to press the "Like" button, but the promotion was actually insufficient. In addition, some exhibitors could not get much feedback from viewers even though they put a lot of effort into creating the exhibit, which resulted in lower motivation. The biggest challenge for the next exhibition may be the two-way communication between exhibitors and viewers.

While we were able to gather many opinions for improvement, we also heard some positive opinions: "The virtual exhibition is something I can visit anytime I want. I was able to spend more time looking at the exhibits than I would have at a physical location"; "I could imagine how we could use the technology to work in our department"; "The exhibition could be used for us to disseminate information". I was happy to hear such positive comments and would like to work hard with these opinions as an incentive.

6 About the Next Virtual Exhibition

Based on the results of the questionnaire on the FY2023 exhibition, we are planning to hold an exhibition in FY2024 with higher motivation of exhibitors. We are trying to design the next exhibition in such a way that questionnaire responses such as "I got an idea for a new product from the exhibition" and "Communication among engineers has gained momentum" will be generated.

7 In Closing

We were able to open a web-based exhibition, which was the first trial in KYB, with the cooperation and support of many people including the exhibitors, although we were quite busy throughout the whole process from preparation to opening.

When I checked the number of hits after the exhibition period, I found that about 130 viewers visited the site in one month. I am very pleased to see that the site is being used as a place to share information. I would like to continue planning activities where researchers and developers can discover something new and get information useful for their own development.

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Introduction

KYB Museum Exhibit Renewal

KOMUTA Kumi, FUJISAWA Kyoko

1 Introduction

The KYB Museum is located at the Sagami Plant (Sagamihara City, Kanagawa Prefecture, Japan). As part of the company's 70th anniversary project, the museum was completed in 2005 and is now in its 19th year. The original purpose of its establishment was to provide a place for human resource development and other internal uses. Today, the museum is used as a place for both internal matters and external communication. It is open to customers and business partners who visit a KYB plant or R&D center and is used for recruitment activities and summer vacation events for elementary school students.

We have recently renewed the exhibits, including presentation boards, to help visitors better understand KYB's history and high engineering prowess.

2 KYB Museum Layout

The general layout of the museum is shown below (Fig. 1). The building has two floors to display KYB's history and original products, as well as products manufactured by Group companies.

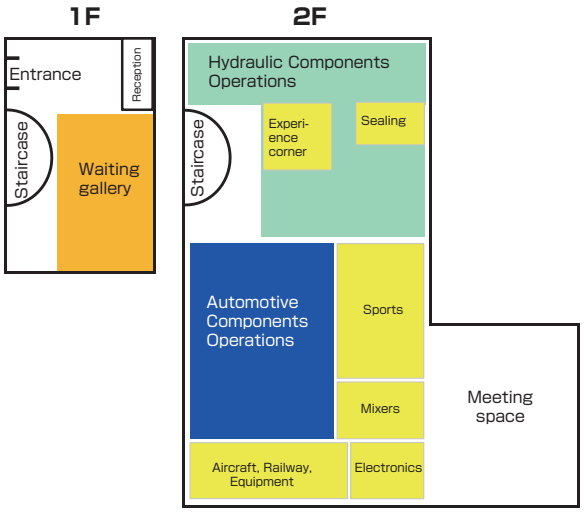

Fig. 1 KYB Museum Layout

3 Waiting Gallery

The first floor is always open as a waiting gallery for people visiting the museum for business meetings. The gallery actively casts digital signage, such as the plant introduction films newly created by the Public Relations & Investor Relations Sect. (Photos 1 and 2).

The videos of the KYB plants are also available on YouTube.

Photo 1 Waiting gallery

Photo 2 Digital signage

On the wall is a Chronology of KYB's Major Products. Positioing Oleo (hydraulic buffer strut) as KYB's DNA (Photo 3), the chronology shows how vibration damping, power control, and other technologies have been inherited by various product families (Photo 4).

Photo 3 KYB's DNA

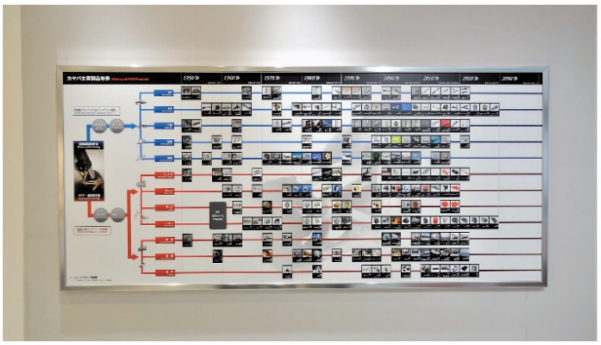

Photo 4 Chronology of KYB's Major Products

While the chronology currently displayed includes products released up to 2023, the major products are shown in a way that looks towards 2035, when KYB will celebrate its 100th anniversary. Visitors who have viewed this timeline have commented on their amazement at KYB's history and diverse business development.

4 Hydraulic Experience Corner

The museum has a dynamic exhibit for visitors to experience Pascal's Principle (Photo 5), which is the basis of power control technology. Visitors can experience how hydraulic pressure can produce a large force.

During the summer vacation of elementary school students, the museum hosts events for them to build original syringe excavators and learn about hydraulic and frictional forces (Photos 6 and 7).

Photo 5 Pascal's Principle experience machine

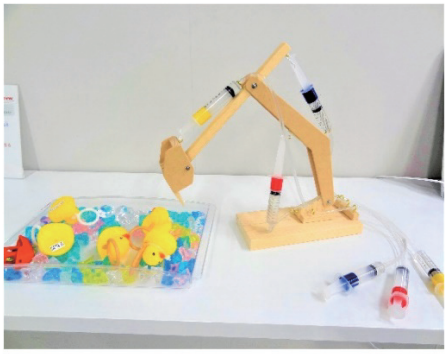

Photo 6 Original syringe excavator

Photo 7 Pascal's Law experience with large and small syringes

5 Hydraulic Components

One of KYB's core technologies is high-precision surface polishing in the micrometer order for surface mating. Our technical prowess in this technology has not been showcased before. Therefore we designed the experience corner so that visitors could actually pick up and touch the piston and spool.

We also created movies showing the production process of casting control valves and how the piston of the piston pump moves. These movies helped visitors better understand what was otherwise difficult to explain verbally (Photo 8).

Photo 8 Pump and valve corner

In addition, the travel motor exhibit was modified by disassembling the motor into components. The revamped exhibit allowed visitors to identify real parts they had only previously seen in illustrations.

We decided to exhibit the hydraulic system set of mini excavators, one of KYB's strengths, connected with piping. The new exhibit allows visitors to better understand how the hydraulic oil flows from the piston pump to the cylinder, the travel motor and swing motor via the control valve. We are always very happy to see the faces of customers who have understood it well (Fig. 2, Photo 9).

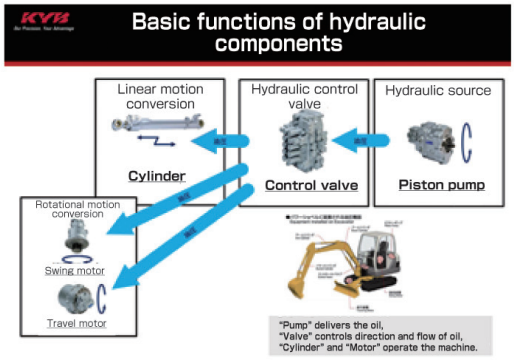

Fig. 2 Basic functions of hydraulic components

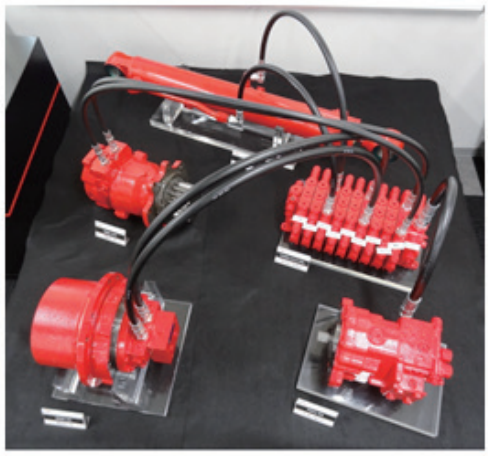

Photo 9 Mini excavator hydraulic system set

KYB can be characterized by its production capability of small to ultra-large cylinders, which should definitely be introduced in the museum. We have exhibited a full-scale model of the boom cylinder of mining excavators so that visitors can experience how big it is. Unfortunately, we decided not to display the real cylinder because of its weight (about 10 tons with a total length of 5 to 10 meters), but we accurately reproduced cut samples from the 3D model to display on the exhibit (Photo 10).

6 Automotive Components

This section has a series of presentations to introduce KYB's automotive components, from the cue for the company to become a shock absorber (hereinafter, referred to as SA) manufacturer (Fig 3) to the types, structure, evolution, and latest technologies of SA.

Visitors may include those who do not even know the word “SA” and those who are involved in manufacturing. It is therefore necessary to explain KYB's SA with an approach that covers all types of visitors. The Automotive Components section provides an explanation of related technical terms including "damping force".

In addition, visitors can watch a comparative movie showing a vehicle with SA with/without damping force driving over a step as shown in Fig. 4 and Photo 11 to understand the need for SA.

Photo 12 shows an exhibit of a disassembled SA. The exhibit explains that the damping force varies with the number of leaf valves stacked in the valve and other factors, which affects ride comfort.

Photo 10 Full-scale model of mining excavator boom cylinder

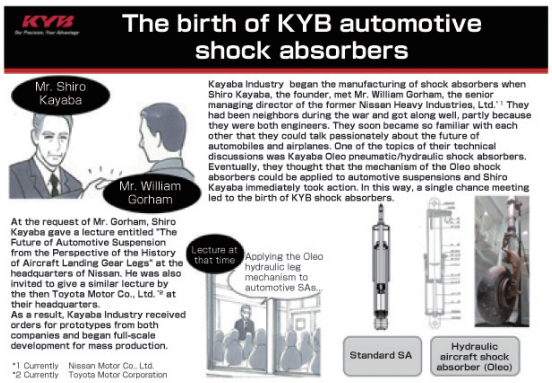

Fig. 3 History as the cue for KYB Industry to become an SA manufacturer

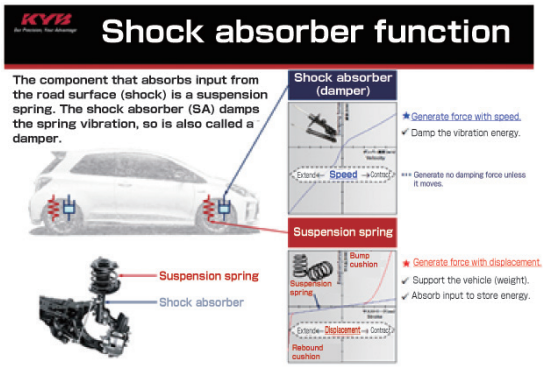

Fig 4 Description of SA mounting locations and functions

Photo 11 Comparative movie of SA with/without damping force

Photo 12 Disassembled SA and valve description

The latest technology on display includes SwingValve and Prosmooth®, which means that KYB is an SA manufacturer that can even offer ride comfort specifically designed for the ultra-low speed range.

Since becoming able to internally develop the formulation of the hydraulic oil to be encapsulated in the vehicle's SA, KYB has developed the environmentally-friendly hydraulic fluid SustainaLub™. This development has involved the engineers/researchers' passion for tribology, which is described in the tribology exhibit corner (Photo 13).

Photo 13 Tribology corner

The tribology corner also highlights that a World Rally eXperimental (WRX) vehicle with SA using the formulated hydraulic oil won the World Rally Championship (WRC) for Team and Driver (Photo 14).

Photo 14 WRC corner

7 Future Challenges

There are products from other departments that we have not introduced in this report. We are also striving to provide easy-to-understand exhibits of these products with unified

presentation boards for all types of visitors, from those who are not familiar with technical terms to engineers, as mentioned above.

After the COVID-19 pandemic was over, various exhibitions have been held. KYB's exhibits in these exhibitions can be used in the KYB Museum. As public relations of technology, we believe that one of the roles of the museum is to let visitors know how wonderful KYB's core technologies are.

By learning from the museums and science halls of other companies, for example by participating in the KANAGAWA COMPANY MUSEUM LIAISION COMMITTEE, we intend to further develop the appearance of exhibits through digitization.

8 In Closing

The KYB Museum is open to the public on certain days. If you are interested in the exhibits, you are welcome to visit the museum (Open: 14:00 to 16:00, Thursday. More information can be found on the KYB website).

KYB employees are also encouraged to visit the museum with their families. It would be a great opportunity for your family to learn about the company you work for.

Finally, we would like to express our deep gratitude to all those involved in the relevant operations and departments who have provided support and cooperation on a daily basis. We would like to take this opportunity to express our gratitude to them.

Please continue to support us.

KYB website, KYB Museum

KYB YouTube

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Essay

Essay from Expatriate in China

GOTO Takashi

1. Introduction

I was an expatriate at Hubei Henglong & KYB Automobile Electric Steering System Co., Ltd. (HKE) for about four and a half years from December 2018 to May 2023. The joint venture company (JV) was established in Jingzhou City, Hubei Province, China, to produce electric power steering (EPS) for the first time. I had been involved in the company since its establishment in the previous year, 2017. This was more than six years' work totally.

I had valuable experiences there in various ways, including the culture of a foreign country, the difficulty of expatriation at a minority site, the first overseas production of EPS, and the response to the new coronavirus infection (hereinafter, referred to as COVID-19). Some of these experiences are presented below.

2. Introduction to Jingzhou City

Jingzhou is a city about 300 km west of Wuhan city, where COVID-19 was first identified. Guan Yu, who is famous for the Romance of the Three Kingdoms, was based in Jingzhou City. A monument to Guan Yu, over 50 meters high, stood in the ancient city of Jingzhou, surrounded by a fence with a circumference of 10 km. However, it was removed in 2021 due to illegal construction (Photo 1).

Before the time of the Romance of the Three Kingdoms, the city was also a base of Chu, which was one of the great states during the Spring and Autumn Period and is depicted in the famous Japanese manga Kingdom. The monument to the king of Chu is worth seeing (Photo 2).

Photo 1 57.3 m high statue of Guan Yu

Many remains from the pre-Christian era like these make Jingzhou a quite historic city, although today it is not as developed as the coastal regions.

Photo 2 Remains of the king of Chu

Jingzhou City is home to only a dozen or so foreigners, despite its population of over six million. In urban cities like Shanghai, many people do not know the name of Jingzhou, even if they are Chinese. People who live in a "rural" town are not familiar with foreigners. If you go to a restaurant, you will be welcomed as a rare customer. Of course, there are Japanese restaurants in town, but they serve Japanese food adapted to the local people. I almost never encountered Japanese cuisine as I expected.

The Yangtze River (Chang River), which is the largest river in China, flows through the center of

the city, and can accommodate tankers and other large ships. Jingzhou City neighbors Yichang City, where the Three Gorges Dam, the largest dam in the world, is located. In 2020, the news of the Three Gorges Dam failure crisis due to torrential rains made headlines in Japan. Although the central city was damaged by the flooding from the rain, there was no concern about the failure of the dam (Photo 3).

Jingzhou City holds a marathon competition every year as a big event of the city. More than 20,000 runners take part in the competition, supported by many local people ringing Chinese gongs along the marathon route and students cheering. I was fortunate enough to participate in a half marathon race twice, in 2019 and 2023 (Photo 4).

Photo 3 Sand beach of Yangtze River

Photo 4 Marathon competition in Jingzhou city

3. Launch of the Company, Establishment of a New Factory, and the Impact of COVID-19

The new company started operations in November 2018. Many events, including recreational activities, were held to promote teamwork with active communication between departments (Photos 5 and 6).

In September of the following year, 2019, the company moved to a new factory. The move itself was a big activity with a concerted effort by the expatriates and local employees (Photo 7).

Photo 5 Recreational activity

Photo 6 Basketball competition

Photo 7 Lunch during the move of the new company

By the end of January 2020, COVID-19 was widespread. Since Jingzhou is close to Wuhan City, I returned home to Japan two days before the lockdown began because I was informed that traffic would be blocked. At first, I thought it would be easy to return to China soon after the effects of COVID-19 had subsided in a few weeks. However, the effects spread all over world, and I had no immediate prospect of returning to China. All the nine expatriates at that time could not return to China together. They had to return in four different groups. I was in the first group to return. We took a chartered flight from Kansai International Airport and arrived in Wuhan in July 2020. I was isolated in a hotel in Wuhan for two weeks after our arrival, and at home in Jingzhou City for another two weeks, for a total of 28 days of isolation. During my stay in Wuhan, a nearby Japanese supermarket, AEON, supplied me with Japanese food. I was surprised that I could eat Japanese food, which was much more delicious than the Japanese restaurants in Jingzhou City.

It was November 2020 when all the expatriates had returned to Jingzhou. Until then, we mainly communicated with each other through e-mails and online meetings, and our communication gradually deteriorated. In addition, various disruptions continued to occur due to the effects of COVID-19 in China. As a result, the JV performed poorly. A gap began to appear between the expatriates and the local staff in China. The differences of opinion and culture between the two led to a lot of conflict, partly because the company was only a minority site that could not win new business and could only continue existing business with other Chinese joint venture companies.

I also had various difficulties in general life. When someone in the apartment where I lived was infected with COVID-19, the whole apartment building or even the apartment zone in the city was isolated.

4. Working in China

As a member of the research and development department (engineering department) of the JV, I was mainly responsible for promoting the sales of dual pinion EPS, which is KYB's core product, and applying KYB's technology to improve the reduction gear of column EPS, which is the JV's core product.

In the early stage after the establishment of the JV, I made presentations of these products to several dozen OEMs and suppliers in China by leveraging the strengths of KYB and the JV. Just as we were striving to expand the business a year after the JV started operations, COVID-19 hit and forced us to go through a prolonged period of difficulty.

Nevertheless, we were able to launch the first mass production of dual pinion EPS. This product won an order from a leading Indian OEM. The vehicle using the dual pinion EPS was selected as the Indian Car of the Year. I attended the event to celebrate the 1st production vehicle off the line (Photo 8). It was great that we successfully promoted HKE's technical strength there.

After the start of mass production for the order, the dual pinion EPS product also enjoyed more orders from Chinese automobile manufacturers (OEMs). Their total annual production together with column EPS exceeded one million vehicles. On the other hand, Chinese manufacturers developed products very quickly. In some cases, we had to prepare mass production for a new order in a year or even half a year.

Photo 8 1st production vehicle celebration event

5. Eating and Traveling in China

Jingzhou City is located inland, and most of the local cuisine has a spicy taste. Many local people like the typical Chinese liquor Baijiu. When many people gather to eat together, they usually sit around a circular table and toast with Baijiu (Photo 9). Be careful when toasting in China. In general, you should not drink Baijiu at your own pace. Instead, you should take it slowly with occasional toasts. Because of the high alcohol content, you should be careful how you drink it. However, it is true that drinking together brings people closer.

With its huge area of land, China has a variety of cuisine by region. Noodles are especially interesting. Some of them are the product of fusion with Islamic culture. Many noodle dishes are popular among the Japanese. Among them is Dalian Noodle, which is said to have originated in Jingzhou City and tastes light and very good (Photo 10). Eating noodles for breakfast or lunch is very popular in China. I often ate noodles at restaurants near the company on workdays and went out to eat at a restaurant near my apartment on holiday mornings. In general, mutton was more popular than pork. Grilled whole lamb was sometimes served at the company banquet (Photo 11).

One of the famous dishes in Jingzhou is crayfish (Photo 12). It tastes quite good and is similar to shrimp. When you order crayfish dishes, you will get an all-you-can-drink of beer.

Remember that alcoholic beverages are often served at room temperature. It is important to find restaurants that sell cold beer or ask for it the next time.

Photo 9 Circular table

Photo 10 Dalian Noodle

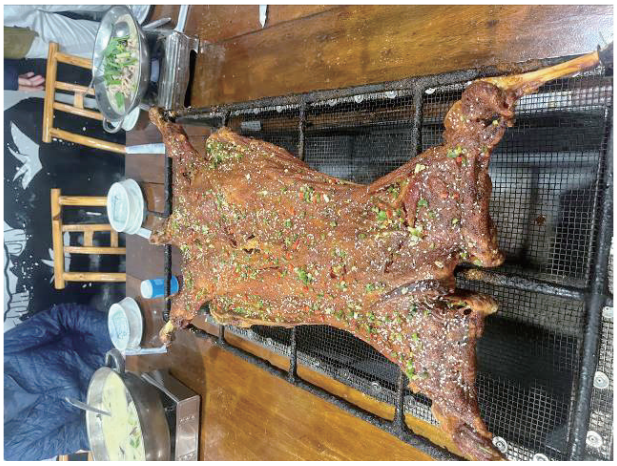


Photo 11 Grilled whole lamb

Photo 12 Steamed crayfish dish

Due to COVID-19, I was required to take a PCR test every day in China. Foreigners had difficulty traveling in the country for a while because they had to prove negative with another PCR test application on their smartphone every time they entered a new city. Actually, it was not easy to move around due to movement restrictions, even though I was an expatriate in China away from home. Therefore I bought a bicycle. I joined a local cycling team and rode 100 km or more in a day with the team members (Photo 13). I also enjoyed several other unexpected hobbies, including camping (Photo 14).

Photo 13 Cycling team in Jingzhou City

Photo 14 Camping on the Yangtze River beach

I was able to do some limited travel despite the restrictions of COVID-19. I had one trip to see the Terracotta Army that was placed around the tomb of Shi Huangdi of the Qin dynasty. This was the last sightseeing trip during that period.

In December 2022, the number of people infected with COVID-19 increased dramatically throughout China. I was also infected and had a high fever of 42°C. After that, the movement restrictions were completely lifted. From January to May of 2023, I visited various sights as much as possible during one holiday and consecutive holidays. It was a really good experience for me to visit Wulingyuan, which is the model of Avatar, the pandas in Xi'an, the Silk Road ruins in Dunhuang, the Great Wall, Tibet, and other places. Of these, Tibet was the place that moved me the most. Tibet is an autonomous region that requires visitors to obtain an entry permit. Initially, due to COVID-19, no entry permits were issued to foreigners. In April 2023, just before my repatriation, the restriction was lifted. I was then able to visit on Labor Day in May.

Lhasa, the capital of the Tibet Autonomous Region, is at an altitude of nearly 4,000 m. The center of the city is as high as Mount Fuji (Photo 15). The first day I was fine, but after the second day I suffered from altitude sickness and the headaches did not stop. I tried medicines for altitude sickness and oxygen absorption, but they had little effect.

Nevertheless, Tibetan Buddhism, Potala Palace built at the "roof of the world" (Photo 16), and the magnificent scenery (Photo 17) were all overwhelming. The trip to Tibet was full of excitement.

Photo 15 At an altitude of 5190 m near the Himalayas

Photo 16 Potala Palace

Photo 17 Fantastic sky and lake

6. In Closing

In retrospect, it was a very short four and a half years of expatriation. Although I had many difficulties, I would like to use what I experienced there to continue contributing to the company.

I would like to express my gratitude to those who supported me during my expatriation and sincerely wish HKE further growth and success (Photos 18 and 19).

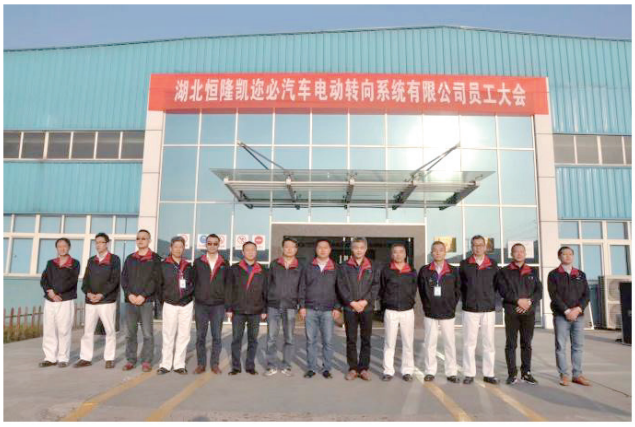


Photo 18 Commemorative photo of founding of the new company

Photo 19 Commemorative photo of repatriation

Author

GOTO Takashi

Dedicated section manager, Overseas Marketing Dept., Global Business Unit, Marketing Div.
Taken present post after working in Steering Engineering Dept., Product Planning Dept., Corporate Planning Dept., and HKE.

Glossary

Modal Analysis

Refer to “Method for Reducing Jig Resonance Using Modal Analysis” (page 4)

FUJIKAKE Mitsuhiko, Development & Experiment Sect., Engineering Headquarters, Automotive Components Operations

1 What is Modal Analysis?

All objects and structures have their own natural frequency at which they can easily vibrate. Modal analysis is used to determine how they vibrate at the natural frequency or other frequencies and how they resist external forces. Modal analysis can be used to determine the following:

[1] Natural frequency of target objects and their deformation at the frequency

[2] Natural mode of the target objects

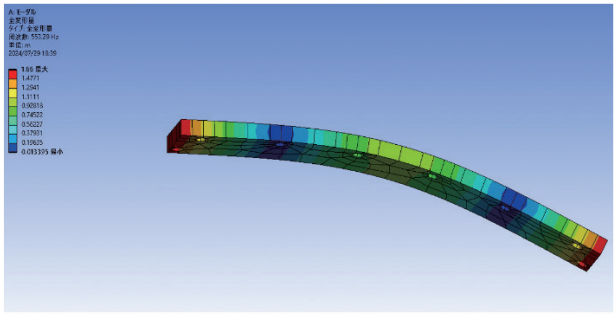
2 Natural Frequency and Mode

The natural frequency of an object is apparent when the object has free vibration. It refers to a specific frequency at which the object can vibrate. The vibration speed is expressed in terms of the number of back-and-forth movements that occur in a unit of time, which is called the frequency. All objects have their own natural frequency. When an external vibration is applied, the object will vibrate strongly with resonance if the external vibration matches its natural vibration. When resonance occurs, the object may emit a large, unusual sound or, in the worst case, break. Therefore, it is essential to avoid resonance. The natural frequency is lower for heavier objects and higher for stiffer objects.

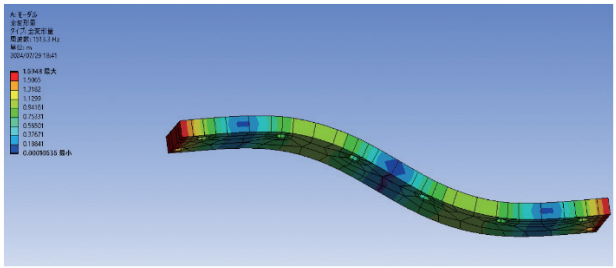
The natural mode refers to the deformation of an object that represents how the object vibrates at its natural frequency. Objects have a fixed shape of deformation at their eigenvalue. The natural mode is called the primary mode, the secondary mode, and so on, in order of increasing frequency.

3 Natural Mode Determined by Simulation Analysis

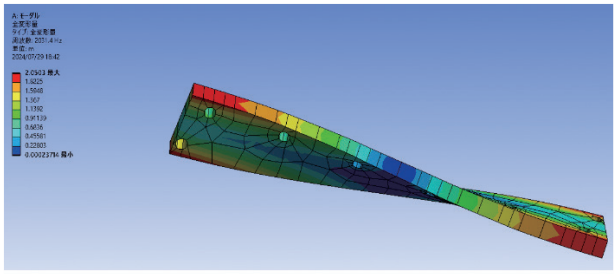
As an example, the following shows the natural modes of a flat bar determined by analysis:



Primary mode



Secondary mode



Tertiary mode

Software used:
ANSYS®

Glossary

Laminated Leaf Valve

Refer to “Enhancing the Accuracy of SA Damping Force Simulation Implemented with AI Technology and Building an AI Operational Management Platform” (page 16).

MANTANI Hiroaki, Gifu Office, CAE Dept., Engineering Div.

1 Laminated Leaf Valve Structure[1)]

The automotive shock absorber has a laminated leaf valve (a disc-shaped thin high-tensile steel plate) to vary the oil passage area according to the operating speed of the shock absorber, as shown in Fig. 1. When the shock absorber is operating slowly, the laminated leaf valve remains closed to allow the hydraulic oil to flow into an orifice of a very small area. When the shock absorber operates quickly, the valve is opened and the hydraulic oil flows into the opening.

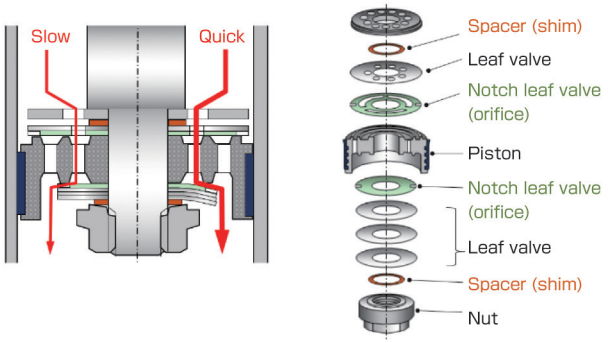


Fig. 1 Structure of laminated leaf valve

The valve structure shown in Fig. 1 realizes the damping force-velocity characteristics shown in Fig. 2. At low operating speeds, increasing the damping coefficient (damping force divided by speed gradient) suppresses the abrupt acceleration and deceleration of the vehicle and the changes in vehicle position during lane changes. At high operating speeds, decreasing the damping coefficient reduces the transmission of vibrations from the road surface to ensure the vehicle's ride comfort.

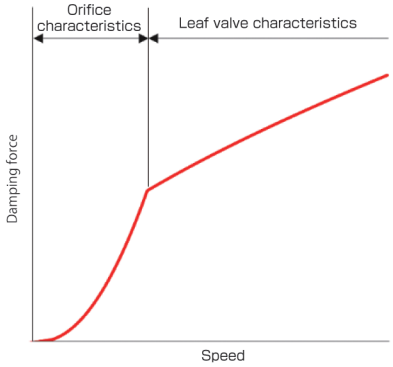


Fig. 2 Damping force-velocity characteristics diagram

2 Required Performance of Laminated Leaf Valve

It is possible to change the outside diameter, plate thickness, and the number of leaves to be laminated to form a leaf valve. A large number of combinations of these elements are available to adjust the damping force in fine increments. In this way, ride comfort can be tuned to the vehicle.

In addition to tuning the ride comfort of the vehicle, the laminated leaf valve, like general pressure control valves, must be hermetically sealed so that the valve cannot be opened until the pressure reaches a predetermined level. In addition, the laminated leaf valve must have fatigue strength so that it will not break during repeated operation, since a broken valve will cause a loss of damping force.

References

1) KYB Corporation: “Automotive Suspension -Structure, Theory, and Evaluation-“ (January 2024).

Glossary

「MLOps」

Refer to “Development of Stamp Inspection Technology Using AI and Construction of MLOps Platform” (page 26).

MITSUO Takashi, R&D Sect. No.2, Production Technology R&D Center, Engineering Div.

1 What is MLOps?

MLOps is a coined term of a combination of Machine Learning and Operations. It refers to an approach or concept for efficient development, implementation, and operation of machine learning models. MLOps facilitates the introduction and use of machine learning at production sites. Specifically, MLOps can be characterized by:

[1] Collaboration between development and operations: Enables development and operations teams to collaborate to facilitate the machine learning processes from model development to operations.

[2] Automation and efficiency improvement: Automates data processing and other tasks to reduce manual task errors and time loss.

[3] Continuous improvement: Monitors machine learning models for performance degradation over time and retrains and improves them as needed to maintain their optimal state.

2 Machine Learning Cycle

Machine learning refers to an algorithm or field of study in which a computer learns from experience to automatically improve itself. Specifically, it is a technology that learns from data and uses the results to perform various tasks (e.g., image recognition, natural language processing, predictive analytics). The quality (predictive accuracy) of a machine learning model can degrade over time due to changes in the environment in which the model was deployed, changes in inspection targets, degradation of data collection sensors, and other factors. Then, a machine learning cycle as shown in Fig. 1 can be performed periodically and continuously to maintain the model quality at a high level to achieve high accuracy stamp inspection.

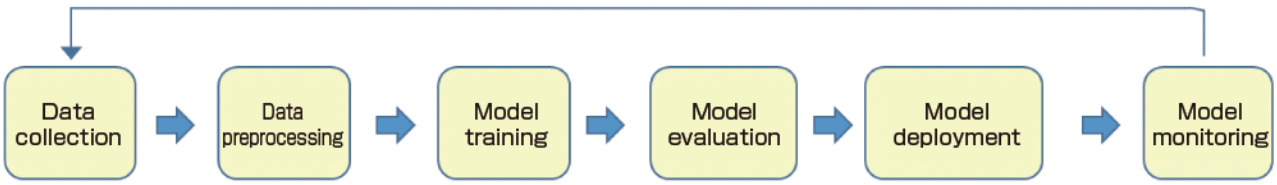


Fig. 1 Machine learning cycle

Editors Script

"You can learn one new thing a day. In a year you will have learned several hundred new things. You will be a professional when you have learned a thousand". These words were given to me by a senior employee during my training. It is certainly true that when you have learned various things, you can have a wider vision around you and start thinking how to make things even better. You will have new ideas and the "desire" to realize them. You can let the people around you share that desire. You may have difficulties, but if you successfully go through with it without compromising, the experience will boost your confidence and become an asset. All pages of the KYB Technical Review are full of such desire. I would be very happy if you read it and feel that desire. (SAITO)

In the Tokyo gubernatorial election held some time ago, an almost unknown candidate received the second highest percentage of the votes and became a hot topic. The presumed reason was that the candidate had posted a large number of movies on social media in order to be recognized by a wide range of people in a short period of time. Regardless of the pros and cons of voting behavior, it might have been an indication that one's actions can be surprisingly influenced by the diverse information media available through the internet today. We should now be media literate not only about the traditional major mass media, but also about web-based media including social media. In particular, we should also be aware of how these media are transmitted, i.e., their technical characteristics (including algorithms). We are already living in a world like the one depicted in William Gibson's science fiction (SF) novels. (KUBO)

In recent years, unprecedented weather conditions have caused floods, heavy rains, and heat waves in Japan and around the world. News of these extreme weather events has become commonplace. I am very frightened when I imagine how the world will change dramatically in ten years and beyond. In this situation, the movement toward carbon neutrality (CN) is accelerating. In particular, it is obvious that motor vehicles driven by gasoline engines will be replaced by electric vehicles (EVs) in the future. There is still no clear answer whether this change is really the right choice for human beings. In any case, I sincerely hope that the product development I am involved in will contribute to the improvement of the environment in the future. (ISHIGURO)

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