Market Environment and Product and Technology Developments in the Precision Machinery Field

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Introduction

The products we are dealing with in the precision machinery field have been used in various industrial fields, contributing greatly to progress in relevant technologies. Combined with electronic control technology in an increasingly sophisticated manner, our business is expected to expand further with overwhelming power and high responsiveness, reliability, and flexibility.

In this article, I'd like to introduce the present market environment and our activities in the precision machinery field.

1 Features of the Precision Machinery Business Division

The Precision Machinery Business Division, formerly known as the Hydraulic Machinery Division, was established in 1968, marking its fiftieth anniversary in 2018. Currently, we are continuing to develop products in the fields of construction machinery, industrial machinery, and marine machinery that suit the needs of each of these fields with the aim of further expanding our business. We have been maintaining a high market share especially in the excavator field, which shows that the Kawasaki brand has penetrated into this field. Also, we are actively developing products in new fields, for example, hydrogen gas valves for fuel cell vehicles and motion control systems for construction machinery. We are constant working to further develop our business under the 2025 vision of becoming a "global-standard" motion control manufacturer that creates and offers total solutions with hydraulic devices and robots that overwhelm our competitors in terms of performance and quality, and total solutions as core products in automobile, construction machinery, electronics, and other industries and in the medical field.

2 Market environment and product developments in the precision machinery field

(1) Excavator field

Because of an expanding global market, including China and India, the excavator market has become intensely competitive, and excavator manufacturers are working hard to differentiate their products. Developed in the pursuit of energy saving, hybrid systems are evolving rapidly, and excavator manufactures are developing models that can be used for computer-aided construction with ICT and IoT technology with the aim of achieving automation and full automation.

Also, they are working toward electrification to respond

(a) K7V Series (b) ERU2-7.0 (c) KMX Series

Fig. 1 Hydraulic equipment in the excavator field

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to a future shift in power sources, and the excavator market is now in a state of major change.

Offering high-performance products and responding closely to customers' requests, we have been increasing our market share in hydraulic pumps, motors, and valves (**Fig. 1**). Today, however, we are required to offer not merely hydraulic equipment but also hydraulic systems that can contribute to enhancing the value of excavators. Therefore, we are developing hydraulic systems with sophisticated controls and hydraulic equipment for these hydraulic systems.

Hydraulic equipment is required to have high performance that contributes to energy saving, high reliability for use in emerging countries and automation, and high controllability for use with sophisticated systems, and we have developed technologies necessary for individual products and put those products on the market. For hydraulic pumps, which greatly affect the energy efficiency and reliability of excavators, we have developed the K7V Series, which features high efficiency and high power density, to enhance the lineup of this series. We used the research results we have accumulated over the course of many years to design the rotary of the K7V Series, thereby achieving the world's highest level of efficiency. As for KMX Series control valves, we have developed a new series that significantly reduces pressure loss with fluid analysis and supports electronic control that enables advanced control with the aim of pursuing energy saving and higher operability. In addition, we have put low-hysteresis, compact electromagnetic proportional solenoid valves and electric joysticks with high operability on the market, both of which are essential in electronic control systems. We will be working to develop technologies necessary to reduce pump noise and increase pump speed for future electrification of drive systems.

(2) Mobile machinery field

The "mobile machinery field" is a generic term for fields other than the excavator field. Various machines including construction machinery are used in a variety of fields. These machines are manufactured by many different manufacturers, including large manufactures and small niche manufacturers, forming a larger market than the excavator market. In the mobile machinery field, manufacturers are required to show their presence to be recognized as a global-standard company, and we are also working with our group companies to make a full-scale entry into this field.

The equipment specifications and load conditions required in the mobile machinery field are different from those required in the excavator field, so the products made for excavators may not be suitable in this market. Therefore, we have been developing products suited to the specifications and characteristics required in the mobile machinery field by using the technologies we have developed for excavators (**Fig. 2**).

(a) M7V Series

(b) K8V Series

(c) KLSV Series

(d) K3VLS Series

Fig. 2 Hydraulic equipment for the mobile field

† 1 The K7V Series, a high-efficiency, low-noise, compact, and high-reliability hydraulic pump, has been widely used for construction machinery (mainly excavators).

We developed six different sizes of the K3VLS Series middle pressure pumps, which have already been adopted for machines in various fields. Also, we developed M7V Series swash plate motors as high-speed motors used mainly for crane winding. Moreover, we developed K8V Series pumps for closed circuits, as well as a controller for this series, making a full-scale entry into the HST (Hydro-Static Transmission) system market with the combination of the M7V Series and K8V Series.

We are developing valves for various machines as well. We are offering various control valves for load sensing systems, which are most commonly used in the mobile machinery field, with the KLSV series, including valves for concrete pump trucks. We often receive orders for these products made for the mobile machinery field from big manufacturers we have earned trust with in the excavator field, so further sales expansion can be expected.

Currently, we are offering technologies and products for the mobile machinery field and developing pumps and control valves for tractors with the aim of making a full-scale entry into the agricultural machinery field.

(3) Industrial machinery field

We are offering various kinds of hydraulic equipment and systems characterized mainly by high-responsiveness, high-accuracy control technologies, especially equipment for high-pressure, large machinery, for a wide range of fields, including steal making plants, press machinery, and other kinds of industrial machinery.

Environmental and resource issues are still gathering attention, so technologies must take the future global environment into account. Kawasaki has put hydraulic equipment and systems that can contribute to energy saving on the market. For industrial machinery, we put ECO SERVO (**Fig. 3**) on the market, which is an electro-hydraulic hybrid system characterized mainly by its high energy saving effect, small size, high maintainability, low noise, and high controllability. Also, we have added products combined with a high-pressure, high-capacity pump with a discharge pressure of 35 MPa and displacement of 500 cm^3 to our lineup for the forging press market where high pressure, high flow rate, and high accuracy are required.

(4) Marine machinery

We offer two kinds of marine machinery: steering gears (**Fig. 4**), which are installed in the stern and used to move the rudder according to the order signal from the steering stand on the steering bridge, and deck machinery typified by windlasses, which are used to raise and lower the anchor when anchoring a ship at sea, and mooring winches, which are used to wind and unwind the rope when berthing and mooring a ship.

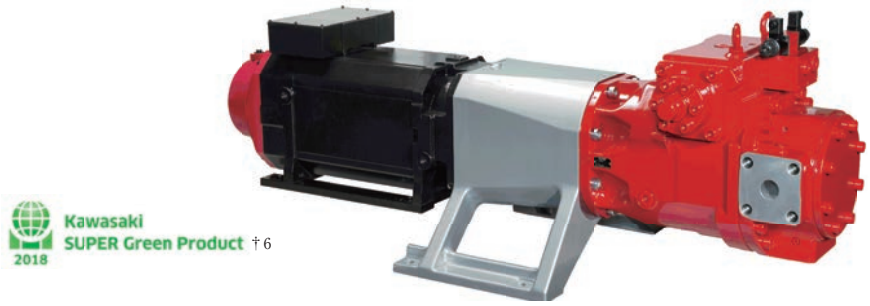

Fig. 3 ECO SERVO

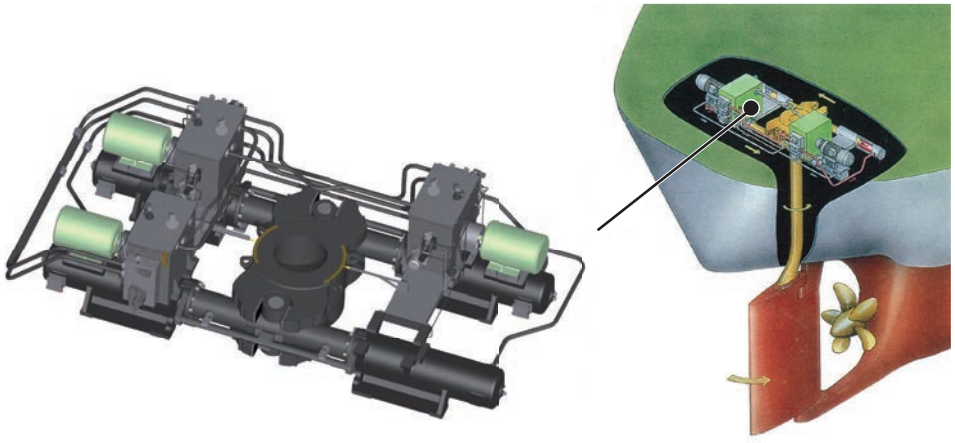

Fig. 4 Steering gear

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† 2 ERU2-7.0, an electric joystick used for operating construction machinery, has significantly reduced power consumption and best-in-class durability at the same time.

† 3 The M7V Series, a hydraulic motor with the world's highest power density and low noise, is suited mainly to HST drive and winch winding systems in industrial vehicles.

Steering gears and deck machinery use oil pressure to generate and transmit power, and our products have been installed in many ships, contributing to safe navigation. Considering its reliability and output characteristics, we expect the electro-hydraulic system to continue to be the mainstream.

Steering gears are one of the most important pieces of equipment in ship handling, so the systems are made redundant, and the crew check the condition of these gears for failure prevention in the conventional way. However, as the automation of ships progresses and they come to be operated with smaller crews, failure prediction technology will become more important, by which problems are predicted by means of sensors and data analysis to prevent failures. It is possible to collect detailed data on the condition of the steering gear by installing sensors onto the steering gear to monitor pressure, flow rate, oil temperature, motor power consumption, and so on and installing a high-speed data logger with large-capacity storage in the ship. The collected steering gear data is analyzed to detect abnormal parameters and predict failures, thereby notifying the ship owner of the appropriate timing for maintenance and enhancing the reliability of the steering gear.

We have installed a steering gear with sensing technology and a high-speed data logger in a very large crude oil carrier (VLCC) and are collecting data. Based on this data, we are developing our failure prediction technology, which is scheduled to be completed in fiscal 2020.

(5) New business fields

Amid a growing interest in global environmental issues, including efforts toward zero CO_2 emissions, fuel cell vehicles (FCVs), which allow hydrogen stored in the vehicle to react chemically with oxygen in the atmosphere in the fuel cell and drive the motor to run, are drawing attention. FCVs are characterized by their shorter fueling times and longer cruising ranges than electric vehicles (EVs) and are expected to spread if sufficient infrastructure is provided. It is said that by the 2040's, electrically powered vehicles will have spread all around the world and that FCVs and EVs will both be in use all over the world.

Based on high-pressure gas control technologies we have accumulated for defense products, we began developing hydrogen gas valves for fuel cell vehicles in 2001. We developed and delivered prototypes with automobile manufactures and industrial vehicle manufactures, and began full-scale development for mass production around 2014. Today, we are mass-producing and delivering tank valves, which are used to open and close the tank, and high-pressure regulators that reduce the tank pressure from 70 MPa to approx.1 MPa, as core products, to automobile and industrial vehicle manufactures. Daimler AG has adopted our hydrogen regulator (**Fig. 5**) for the Mercedes-Benz GLC F-CELL, and we began shipping it in January 2018.

We are dedicated to using hydrogen energy, which is friendly to the environment. These products play a part in the realization of the "Hydrogen Road" in terms of hydrogen use. Through these developments, we desire to show a new future brought about by hydrogen energy to people all around the world.

3 Technological developments for the future

(1) Machine control technology

We have been designing and manufacturing the various kinds of hydraulic equipment that moves construction machinery, including the hydraulic pumps that work as if the heart of construction machinery. In recent years, we

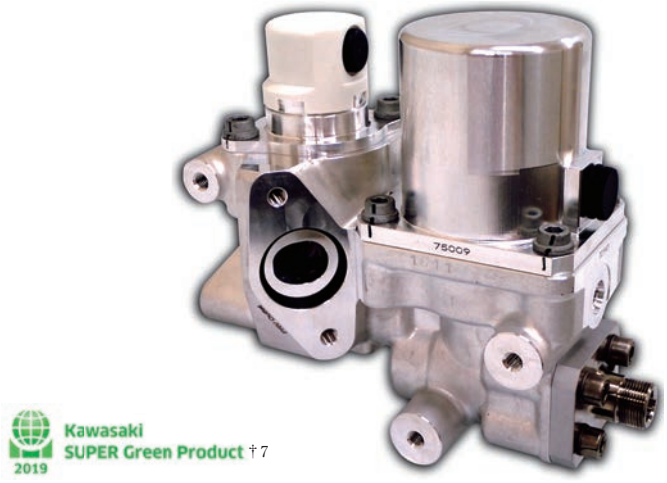

Fig. 5 The KGPR65D high-pressure hydrogen regulator for fuel cells

† 4 The K8V Series, a dual-tilting hydraulic pump with the world's highest-level pump efficiency and low noise, is suited to closed-circuit systems, such as HST drive systems, in industrial vehicles.

have started developing controllers that integrally control hydraulic equipment, covering everything related to the motion control of construction machinery.

In the construction industry, improvements in efficiency, safety, and working environment are required, as they are lagging behind other industries. In addition, the workforce shortage due to the aging population is a big issue. Given this situation, automating construction machinery and improving the efficiency of construction work using electronic control technology, ICT, and IoT technology is becoming a major trend.

Aiming to achieve a global standard in the motion control of construction machinery, we have started developing machine control technologies in addition to hydraulic systems for automated construction machinery to address the automation of construction machinery. For example, excavators can perform various types of work but their operation relies on skilled operators. Automating such machinery requires a good understanding of the characteristics of hydraulic equipment as well as excellent control technologies. We are professionals in the fields of hydraulic equipment and hydraulic control technology and have excellent know-how on controls in the robot business field, such as tracking control and damping control.

We first developed the 2D machine control system by combining hydraulic technologies and ICT, IoT, and robot technologies (**Fig. 6**). The 2D machine control assists operators to enable even unskilled operators to work almost in the same way as skilled operators. We are continuously developing the 3D machine control systems with higher levels of sophistication by using the global navigation satellite system among other means.

(2) Electro-hydraulic actuator-related technologies

We are developing humanoid robots, which can work in place of humans in areas that are dangerous to humans, such as disaster sites, or in severe environments, such as high temperature and radiation environments. These robots use electric actuators, but we are thinking of adopting electro-hydraulic actuators, which use oil pressure, to further enhance robustness, including shock resistance. Currently, we have put a variable speed control electro-hydraulic actuator for industrial equipment on the market, which uses a servo motor to drive a hydraulic pump. Using this electro-hydraulic actuator technology, we are developing Hydro Servo Muscle (**Fig. 7**), which is an ultra-compact and -lightweight electro-hydraulic actuator with a variable capacity pump that can be mounted in humanoid

Fig. 6 2D machine control

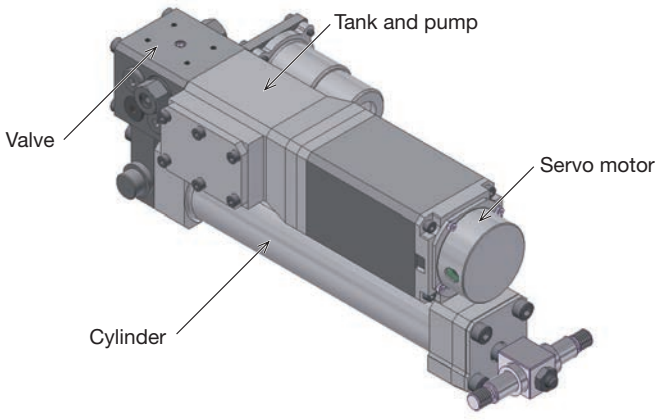

Fig. 7 Hydro Servo Muscle

† 5 The K3VLS Series, a hydraulic pump for mobile machinery with the industry's highest-level pump efficiency and low noise, contributes to improving the fuel consumption of construction machinery.

† 6 ECO SERVO, an electro-hydraulic hybrid system controlling the pump speed according to the hydraulic pump power that runs the hydraulic drive system, achieves energy saving and noise reduction.

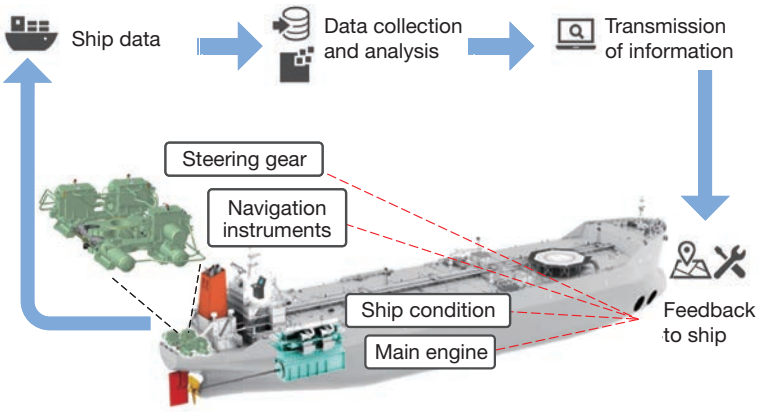

Fig. 8 Advisory service

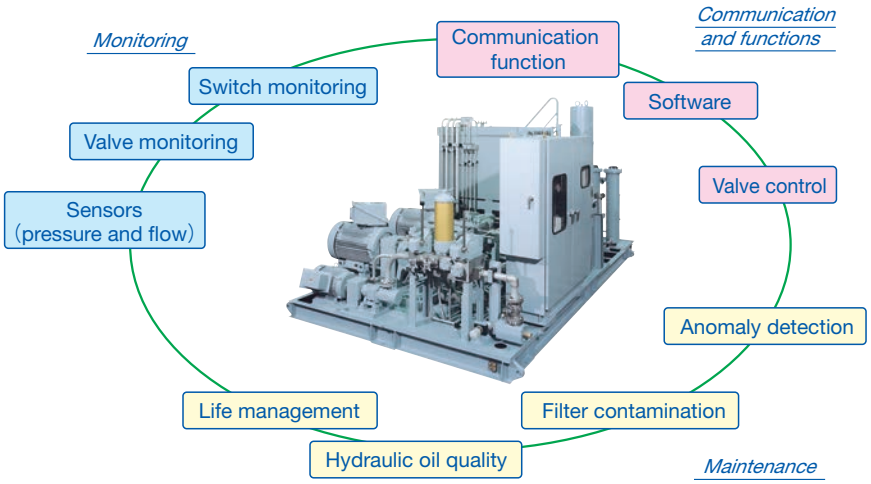

Fig. 9 Condition monitoring of hydraulic unit

robots. In addition, we are developing compact electro-hydraulic actuators for industrial applications.

(3) Utilization of ICT and IoT technology

ICT and IoT technology are used more and more in the marine machinery industry, including, for example, advisory services for monitoring ship conditions and optimizing maintenance. Sensors are used to collect various kinds of data in a ship, and that data is then sent to an on-shore facility. After the data is analyzed, feedback, including ship condition and maintenance timing, are sent to the ship (**Fig. 8**). Also, for steering gears, failure diagnosis sensing will be performed for condition monitoring and maintenance. The data will be analyzed in the ship to identify a faulty part and notify the ship owner of the faulty part via the Internet.

This shift is even taking place in the industrial equipment industry as well where ICT and IoT technologies are not commonly used. N-ECST, the controller for ECO SERVO, whose development began in 2015, is a system that enables remote control and data collection via the Internet. Applying these technologies to equipment used in hydraulic units makes it possible to monitor the condition, communication, and control necessary for maintenance with the condition monitoring function (**Fig. 9**).

Conclusion

In the medium-term business plan "FY2019 MTBP", the Precision Machinery Business Division is aiming to more than double its consolidated sales from fiscal 2018 by fiscal 2030. To achieve this goal, we will be promoting the development and sales expansion of products and at the same time creating new products and businesses with synergy of the precision machinery business and robot business.

† 7 The KGPR65D, a hydrogen regulator with high-precision gas control, contributes to achieving zero CO_2 emissions of running fuel cell vehicles (FCVs).