Product Introduction

Development of New Stroke Sensing Cylinder for Middle-Sized Machine Control and Machine Guidance Excavator

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1 Introduction

Information communication technologies (hereinafter referred to as "ICT") are now being utilized in various industries more than ever before. In recent years, movements to utilize ICT are becoming increasingly active in the construction equipment industry. Utilization of ICT is being promoted as comprehensive computerization called "i-construction" under the lead of the Ministry of Land, Infrastructure, Transport and Tourism.

In this report, I would like to introduce a cylinder with a stroke-sensing function (hereinafter referred to as "SSC") which aims to comprehend the equipment attitude of ICT construction equipment used in computerized construction technologies included in Fig. 1.

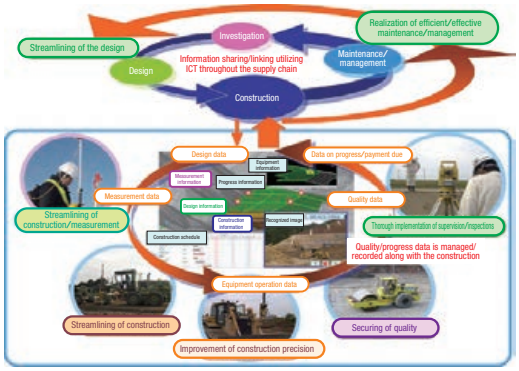

Fig. 1 Computerized construction image
Excerpt from the computerized construction promotion strategy by the Ministry of Land, Infrastructure, Transport and Tourism (2013)

Computerized construction is being promoted with the aims of improving productivity, resolving the lack of labor force, and improving the field safety in the construction industry, and its purpose is to optimize construction itself.

In computerized construction, measurement using the 3D measurement technology is performed by UAV (unmanned aerial vehicle), etc., and the obtained 3D data and the design data are both transmitted to ICT equipment. The ICT equipment performs the construction through machine control (semiautomatic operation) or machine guidance (operation support) based on this information. Ultimately, the construction is completed with an inspection using the construction information from the equipment and 3D measurement, so this method allows us to not only improve the construction efficiency compared to the conventional construction method but also omit prior measurement, inspection of the progress, etc. Due to this, we expect that construction periods can be significantly reduced. Support systems, such as tax incentives, for these technologies have been in effect since the certification of recommended general technology in 2013.

2 Development Background

In 2014, when we first started the development, add-on-type angle sensors were attached to various oscillation pins in most excavators that were compatible with computerized construction. However, due to the characteristic of excavators which operate the bucket in a 3-dimensional manner to perform construction, only the bucket cylinder near the construction surface had the problem of being damaged from coming in contact with the construction surface. This was restricting use.

Under such circumstances, the objective of this development was to incorporate the stroke sensing function within the cylinder to resolve this problem.

KYB also developed an SSC in 1987. This cylinder used the incremental method (relative position detection) to measure the cylinder's stroke fluctuation volume by in-

Fig. 2 ICT excavator ZX200X-5B made by Hitachi Construction Machinery

stalling nonmagnetic sections on the piston rod at regular intervals. In the new product development, we developed a new model for ICT construction equipment that utilizes absolute output (absolute position detection) and is standard-cylinder compatible in order to make an SSC that is easier to operate and has better precision.

This product is currently used on ICT excavator ZX200X-5B (Fig. 2) made by Hitachi Construction Machinery.

3 Product Specifications

3.1 Development Requirements

Since this cylinder was developed based on the assumption that it would be installed on the existing excavators, many aspects are the same as the current hydraulic cylinder KCH (KYB-Cylinder-High pressure) series.

The development requirement was that it would have additional high-precision position detection function while maintaining the same functions as the standard KCH. In addition, due to the fact that the hydraulic cylinder would be an electronic component incorporating a sensor, responding to the harsh usage environment of construction equipment was difficult for the sensor.

Furthermore, mass-productivity was also added as a development requirement in order to be able to produce them in the standard KCH mass production process of KYB.

(1) Development requirements

① Durability that can be used in the same manner as the standard KCH
② Installation compatibility with the standard KCH
③ Sufficient position detection precision and absolute position detection
④ Output characteristics according to the equipment specifications (CAN J1939)

(2) Mass production requirements

⑤ Structure that allows mixed-flow production in the standard KCH mass production process
⑥ Structure that can respond to size variations of the standard KCH

3.2 Basic Specifications

Basic specifications of the standard KCH are as follows:

① Maximum usage pressure: 35MPa (Maximum pressure in temporal increase: 40MPa)
② Fastest cylinder speed: 60m/min
③ Working fluid temperature range: -20˚C to 100˚C

3.3 Additional Specifications

Below are additional SSC specifications to the standard KCH.

① Stroke detection resolution: 0.1mm
② Stroke detection precision: +/- 1.5mm (Actual value: +/- 0.5mm)
③ Anti-vibration performance: 700m/s^2 maximum (70G) Note 1)
④ Anti-shock performance: 1,000m/s^2 maximum (100G) Note 1)
⑤ Ambient temperature range: -40 to 105˚C (When stroke is detected)
⑥ Protection level: IP69K
⑦ Electrical specifications: ISO standards, EN standards, and JASO standards compatible
⑧ EMC specifications: ISO standards, EN standards, and JASO standards compatible
⑨ CAN communication: SAE J1939
⑩ Power source: DC24V 1.5W or less

Note 1) Anti-vibration/anti-shock values are this product's specification values.

Fig. 3 Stroke sensing cylinder (developed product)

3.4 Stroke Detection Sensor

In this development, we focused on development period reduction and technical reliability for the stroke detection method. We selected the magnetostrictive type stroke sensor (Fig. 4) made by MTS Sensors Technology Corporation (hereinafter referred to as "MTS Sensors"), due to the fact that the sensor has been installed in other cylinders. By designing unique inner components for the sensor in response to the stroke sensor's integration into KCH, we have satisfied ① and ③ of the development requirements.

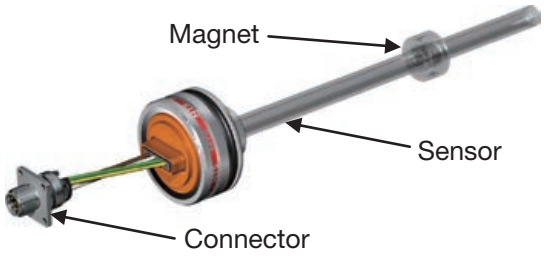

Fig. 4 Magnetostrictive type stroke sensor made by MTS Sensors

4 Development Issues

4.1 Basic Structure

In order to satisfy the previously-mentioned development requirements, the cylinder had to be in the form that allows the same mountability as the standard KCH and that the stroke sensor was attached with sufficient precision. In addition, sensor assembly including wiring needed to be completed in the standard KCH mass production

process, which is horizontal assembly.

In order to resolve these issues, we adopted the new structures shown below.

(1) Newly adopted structures

① A structure that can be assembled in the standard KCH automatic assembly line by temporarily assembling the stroke sensor onto the piston rod ((g) and (i) in Fig. 5).

② Assembly is to be performed with the cylinder positioned horizontally, and the design involves cylinder bottom wiring holes to simplify the process ((a) and (l) in Fig. 5).

③ The collar was set to simplify the cylinder bottom process. The configuration allows press-fitting in the existing press-fit process, and the structure can improve workability and ease of assembly ((a) and (k) in Fig. 5).

④ The sensor is attached with set screws in 2 locations to prevent inner components from falling off due to vibrations and shock. A structure that prevents assembly mistakes and components from falling off even when they are loose by achieving the optimal design for the set screw length and groove depth ((i), (j), (n), and (o) in Fig. 5)

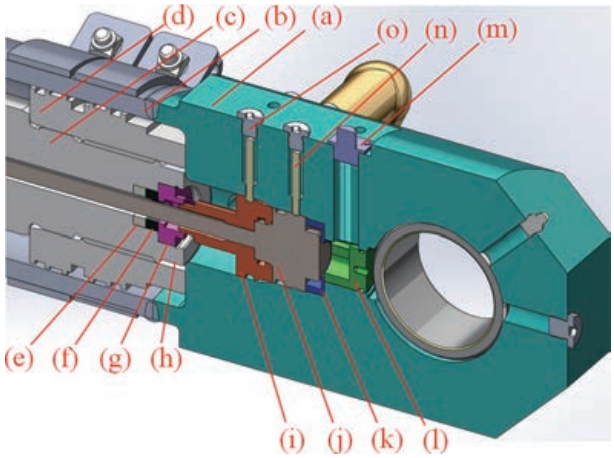

Fig. 5 Internal structure of the stroke sensing cylinder

(a) Cylinder bottom: Special design
(b) Cylinder tube: Standard product
(c) Piston rod: Additional deep hole process
(d) Piston: Standard product
(e) Spacer: Added to detect position
(f) Magnet: Added to detect position
(g) Magnet holder: Added to detect position and for assembly
(h) Snap ring: Added to fix (e) through (g)
(i) Sensor holder: Added to fix the sensor
(j) Sensor: Added to detect position
(k) Collar: Added to simplify the process of (a)
(l) Cover: Added to protect the back of the sensor
(m) Connector: Added for output
(n) Set screw: To fix the sensor/holder
(o) Plug: Added to protect the set screw

We developed this new SSC by combining these structures and the basic design of the standard KCH.

4.2 Anti-vibration/Anti-shock Performance

In this development, SSC was required to have the anti-vibration performance to install electronic components and acceleration specifications related to anti-shock performance, in addition to KCH specifications. In order to be able to use SSC in the same level of environment as the current KCH, SSC had to achieve the specifications that would not break in the environment in which customers had been using KCH.

In actual work, excavators are used for more than just excavation. Since they can perform various types of work by utilizing the flexible movements of the equipment body, they would sometimes perform smooth crane work and sometimes perform work involving strong shocks, such as fracturing work by using a special attachment.

There are some equipment bodies among the existing excavators, which are compatible with computerized construction, that restrict such harsh work. However, having restrictions on the above work with the installation of a stroke sensor would mean that excavators' functions are lost.

Unless they can withstand the maximum level of acceleration in actual work, SSC is not usable in the same manner as the standard cylinder.

We established certain criteria for these equipment body vibration environments based on KYB's past actual equipment test information and conducted the tests. As a result, we discovered the following facts in the prototype stage:

- Acceleration exceeding the acceleration generated by the cylinder is generated in the sensor depending on how the sensor is attached.
- The sensor's standard specifications cannot satisfy KYB's durability tests, resulting in damage in the sensor itself.

To respond to the above issues, we took vibration measures not only through optimization of the cylinder design but also by specially designing the components within the sensor with the cooperation of the sensor manufacturer MTS Sensors in this development. As a result, we were able to improve the anti-vibration performance and anti-shock performance.

4.3 EMC-related Matters

Since this SSC is a product that uses electronic components, we performed EMS evaluations for the cylinder. In terms of test conditions and evaluation criteria, we performed tests as per the general standards as well as additional tests in accordance with customer requirements.

Although there are not many hydraulic cylinder products that contain electronic components, we manufacture vehicle-related products containing electronic components, such as steering by a wire system.

In this development, the Electronics Technology Center, which is the designated department to perform development evaluations for these electronic components, performed the evaluations. We were able to swiftly perform the evaluations on SSC, which is a hydraulic cylinder product, by utilizing the expertise and evaluation technologies of the above department.

Fig. 6 Developed stroke sensing cylinder

5 Conclusions

This newly developed SSC turned out to be a product that can satisfy all of the development requirements in the existing evaluations.

While SSC is a hydraulic cylinder, evaluations may differ with each customer due to the fact that it is an electronic component. KYB's testing facilities and evaluation technologies also enable us to individually perform such evaluations.

As with the standard KCH, this SSC is also designed so that it is compatible with output wiring guards, wiring brackets, etc. to respond to individual customers.

6 Future Outlook

There are 2 basic functions of hydraulic cylinders for construction equipment – to make telescopic movements and to be a structure. There are a number of issues in enhancing the functions of KCH, which is already almost a perfected model in terms of functions.

The same can be said about other hydraulic cylinders made by KYB.

We expect that the needs for stroke sensing will grow further in response to the sophistication of attitude control for construction equipment. KYB was able to respond to the needs for SSC, which can achieve highly sophisticated absolute position detection and the same level of equipment mountability as the standard KCH, with cylinders. In the future, in order to expand the product lineup for similar cylinders in addition to those for excavators, we must not compromise the model cylinder functions in the same manner as this development. Based on this concept, we hope to develop new products by utilizing the cylinder know-how that KYB, who has produced various types of cylinders, has accumulated as a cylinder manufacturer so that we can provide high quality stroke sensing cylinders for each environment.

We are currently developing an SSC (Fig. 7) for KCM (KYB-Cylinder-Middle pressure), which is a hydraulic cylinder for compact excavators, as the first project. KCM SSC is already in the prototype stage. In the same manner as KCH, we have incorporated a design that excels at quality and mass productivity, and we are currently evaluating the prototype with the aim of achieving the same user-friendliness as the standard KCM.

In this development, we enhanced the function to "sense strokes". We will continue proposing other sensing technologies such as cylinder function enhancement and promote development that can contribute to the enhancement of equipment.

Finally, I would like to express my sincere gratitude for various internal departments and relevant affiliated companies that have provided us with their cooperation in the course of the development of this product.

Fig. 7 Stroke sensing cylinder (KCM prototype)

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