Product Introduction

Development of Control Valve KVSX-12C for Small Size Excavators

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1 Introduction

Two- to four-ton class small hydraulic excavators are used in many different places and applications including excavation and ground leveling for roadwork, as well as various jobs in building sites in towns. The demand for these excavators has recently expanded. The hydraulic systems for small excavators can be divided into an open-center system and a closed-center system (or load sensing system). The open-center system has a pump continuously discharging a given flow and operates an actuator while letting an adjustable flow drain into a tank using a bleed-off circuit. This system has been used from the early days of commercialization of small hydraulic excavators (Fig. 1).

The load-sensing system includes a variable displacement pump to which the hydraulic pressure is fed back to control the swash plate thereof, keeping the pressure difference over the meter-in orifice constant in accordance with the actuating variable. The system can be controlled only with the minimum required amount of oil (Fig. 2). As the pump is only required to discharge as much as needed, the load-sensing system involves less power loss compared to the open-center system.

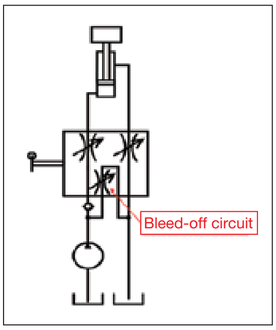

Fig. 1 Open-center system

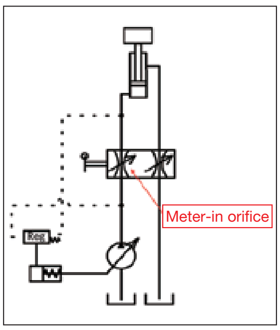

Fig. 2 Load-sensing system

KYB manufactures KVSX-12 Series control valves for load-sensing systems in small hydraulic excavators. In the KVSX-12 Series, Models A and B have been commercialized to this point. To further improve the functionality and performance, KYB has just developed and commercialized a third-generation KVSX-12C (hereinafter referred to as "the new model"). This paper introduces the new model; the appearance thereof is shown in Fig. 3.

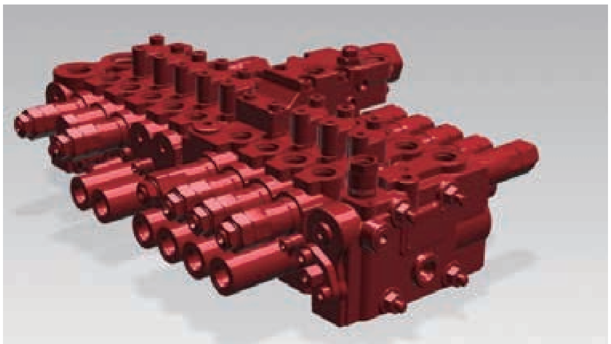

Fig. 3 Appearance of KVSX-12C valve

2 Development Challenges

The development of the new model involved the following challenges:

① Alleviating an operation speed reduction at high temperatures

② Improving fuel efficiency by reducing the pressure loss

③ Reducing the machining cost

In terms of challenge ①, KVSX-12B (hereinafter referred to as "the conventional model") involved a problem in which the operation speed was lower when the oil temperature was higher. For the new model, we have modified the valve structure to alleviate the speed reduction.

With regard to challenge ②, hydraulic excavators are generally required to improve fuel efficiency during actual use in order to achieve higher environmental performance. To reduce the pressure loss in the valve, we have changed the outside diameter of the compensator spool (hereinafter referred to as "the comp. spool") from ø12 (conventional) to ø14 (new).

Challenge ③ was a bottleneck in the valve housing machining process for the conventional model. The process included drawing (oblique machining) to provide the comp. spool with a damping effect. For the new model, we have designed a comp. spool consisting of another set of parts to ensure higher machineability without drawing, in order to reduce the machining cost.

3 Overview of New Model

3.1 Configuration

Fig. 4 shows a comparison of circuit diagrams between the conventional and new models. The new model has been improved in performance with respect to the conventional model in the following points (1) and (2):

(1) Improving warmup performance

The layout of the unload valve has been modified. The conventional model had the unload valve located in the inlet. For the new model, the unload valve has been relocated to the outlet so as to make up a circuit (heating circuit) where the oil supplied from the pump (P) port flows through all the sections and returns to the tank via the tank (T) port even during standby. This heating circuit helps the overall valve body increase in temperature to achieve higher warmup performance.

(2) Improving operability at low temperatures

The conventional model has no LS drain orifice because the model is designed so that the LS passage included in the circuit diagram of Fig. 4 is linked with the tank via the main spool when the spool is in the neutral position. The new model in turn is provided with an LS drain to keep the LS passage constantly connected to the tank (drain orifice type). This new design contributes to higher warmup performance of the LS passage and is particularly unlikely to cause hunting at low temperatures, resulting in higher operability.

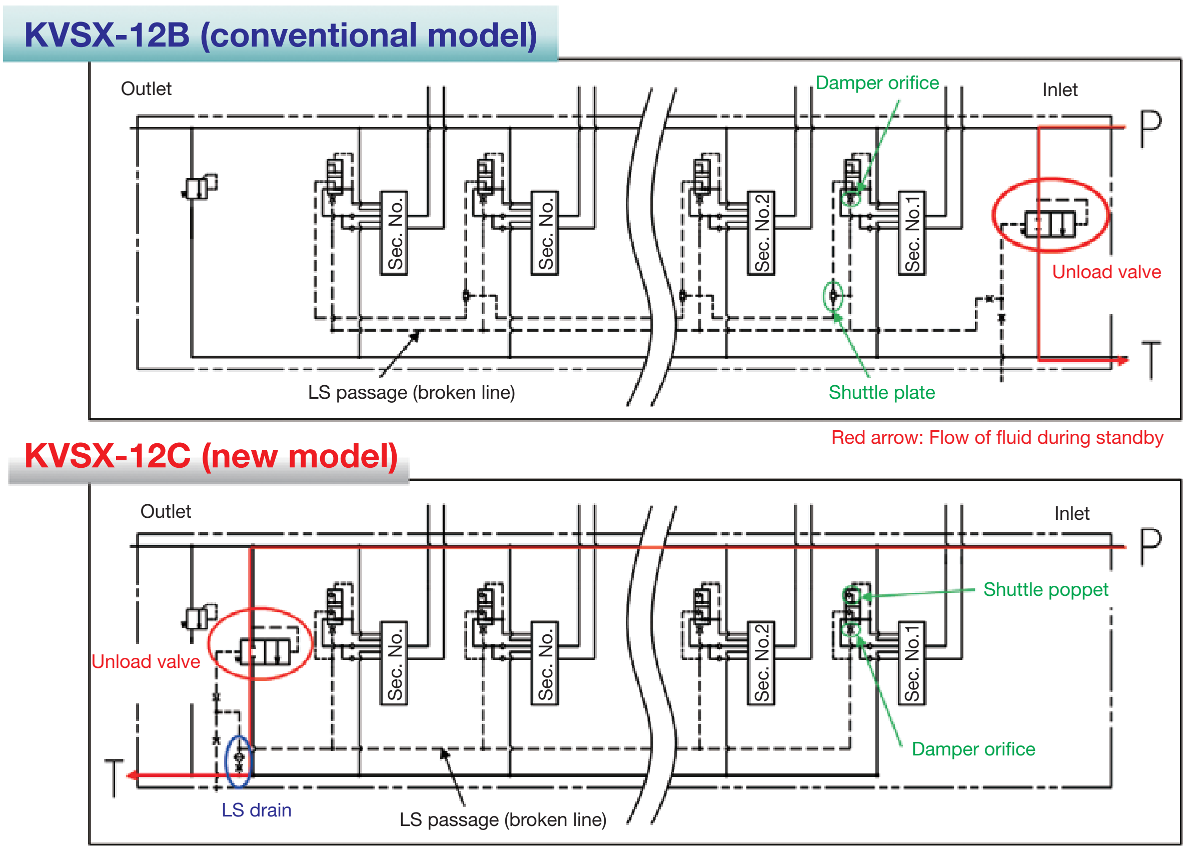

Fig. 4 Circuit comparison

3.2 Alleviating Operation Speed Reduction at High Temperatures

In the conventional model, the high-pressure selection of the LS passage was implemented by a shuttle plate structure (a metal seal system) between the mating surfaces of the valve housing. The LS passage itself also has a metal seal structure between its mating surfaces (Fig. 5). Thus, the likelihood of the valve having internal LS pressure leakage depends on the workmanship related to flatness and surface roughness of the seal sections of the shuttle plate and valve housing. With this structure, the LS pressure leakage would be larger at a higher oil temperature and lower oil viscosity. As the LS pressure decreases due to the leakage, the pressure feedback to the pump decreases. With the lower pressure, the pump discharge decreases, that is, the control flow supplied to the actuator decreases, because of the characteristics of the load sensing system, which always tries to keep the pressure difference constant. This results in the issue of the operation speed being lower.

The new model has been modified so that the high-pressure selection is implemented by a shuttle poppet structure in the comp. spool, leading to higher seating performance and less leakage. The mating surfaces of the LS passage now use O-ring seals. This sealing system ensures a leak-free structure independent of the workmanship related to flatness and surface roughness (Fig. 6). Thus, the higher seating performance and the modified sealing structure of the mating surfaces have successfully reduced the leakage from the LS passage. The control flow reduction due to an increase in oil temperature has also been improved from approximately 6.8% for the conventional model to approximately 1.5% for the new model.

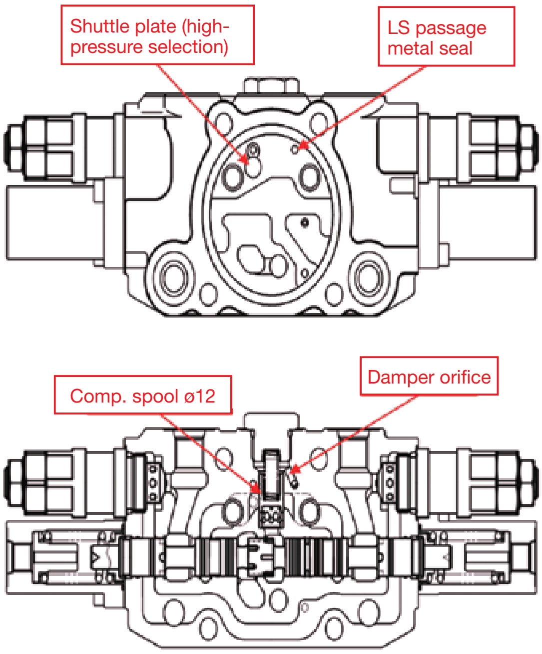

Fig. 5 Section structure of conventional model

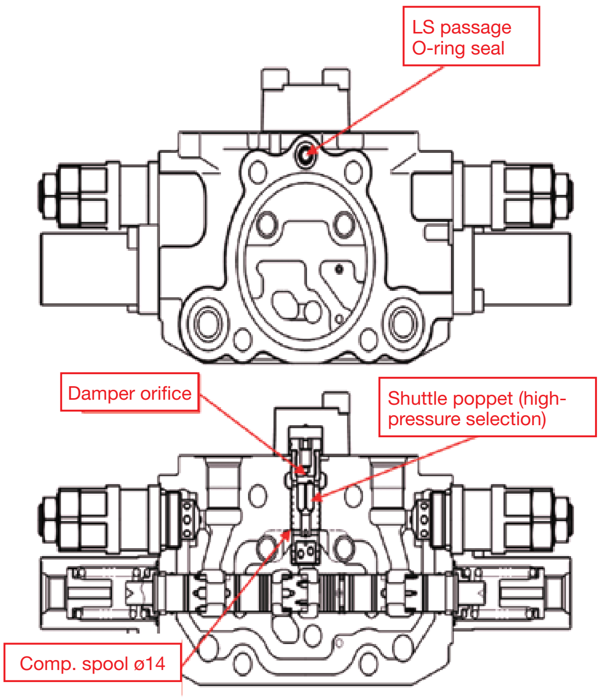

Fig. 6 Section structure of new model

3.3 Reducing Pressure Losses

As shown in Figs. 5 and 6, the conventional model had the comp. spool of an outside diameter (OD) of ø12, which has been enlarged to ø14 for the new model. This OD enlargement is intended to increase the maximum opening area to reduce the pressure loss.

When supplying oil to the actuator at 50 L/min, the conventional model caused a pressure loss of approx. 0.27 MPa during passage through the comp. spool. The new model has the larger opening area to have a pressure loss of approx. 0.16 MPa, which is approx. 0.1 MPa lower than the conventional case.

Since the load sensing system controls the pump discharge to keep the LS control pressure difference constant, the above-described pressure loss reduction enables increasing the operation speed with a control pressure difference similar to that for the conventional model. It is also possible to diminish the LS control pressure difference by the same amount as the decrease in the pressure loss, resulting in energy saving.

In fact, it was feared that the enlarged comp. spool of the new model would require the valve housing to be wider. However, we have optimized the geometry through stress analysis as a front-loading approach, successfully meeting the quality objectives with a valve housing which is the same size as the conventional one (Fig. 7). This means that the new model can offer improved performance while maintaining the same ease of vehicle mounting as the conventional.

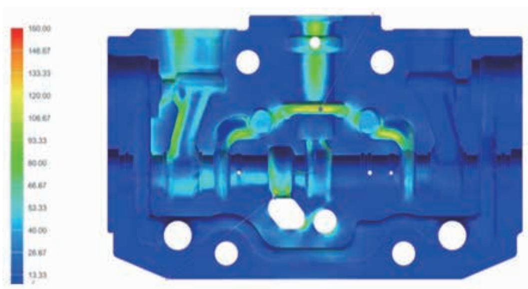

Fig. 7 Results of stress analysis

3.4 Reducing Machining Cost

In the conventional model, the valve housing was obliquely drilled to have an orifice so that the comp. spool would have a damping effect (Fig. 5). For oblique drilling, the machining process needed to be changed, which was one of the factors in the high machining cost. It is also necessary to change the drill hole diameter according to the required size of the orifice. Thus, a valve housing had to be specified for each specification of the orifice.

The new model has eliminated the oblique drilling by assembling a plug already provided with the orifice into the comp. spool, thereby reducing the machining cost (Fig. 6). Since the orifice is allocated to the plug, it is no longer necessary to specify the valve housing for each specification of the orifice size, making it possible to standardize the machining process. Note that while the above-described shuttle plate structure required machining of the valve housing to create a pocket into which the shuttle plate would be inserted, the shuttle poppet structure introduced for the new model can eliminate the machining, leading to lower machining cost.

4 In closing

This paper has provided an overview of the control valve developed for the load sensing system for two- to four-ton class small hydraulic excavators. In addition to the required functions, the issues with the conventional model have been tackled.

The load-sensing system can be readily adapted to support electronic control for atomization and is expected to be increasingly demanded by the market. The market demand is always changing. By anticipating the market need without falling behind the changes, we would like to continue making efforts to develop competitive products.

Finally, I would like to deeply thank all those from the related departments for their support in developing the product.

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Joined the company in 2011.
HC Design Sect., Design Dept., KYB-YS Corporation
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