Product Introduction

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

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1 Introduction

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

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

2 Overview of the Product

2. 1 Background

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

Table 1 MAG Series product lineup

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

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

2. 2 Functions and Features of Relief Valve

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

[During traveling]

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

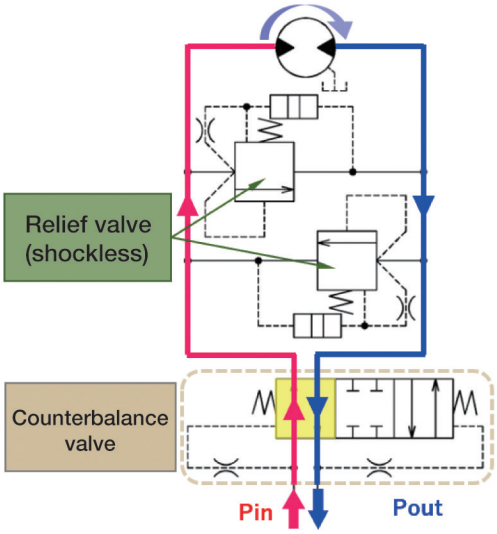

Fig. 2 Hydraulic circuit diagram of relief valve (during traveling)

[During braking]

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

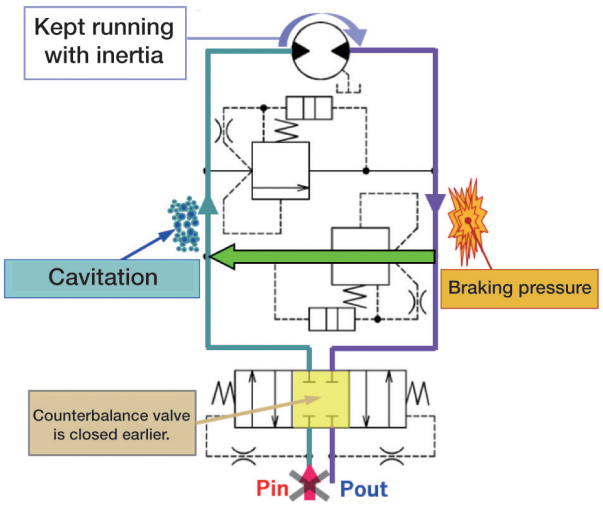

Fig. 3 Hydraulic circuit diagram of relief valve (during braking)

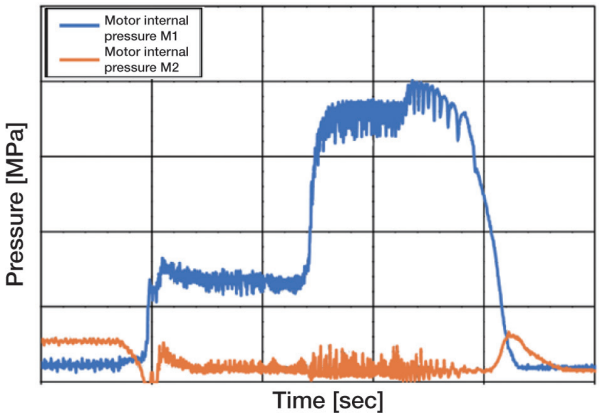

Fig. 4 Braking pressure characteristics of motor with relief valve

2. 3 Functions and Features of Anti-cavitation Valve

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

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

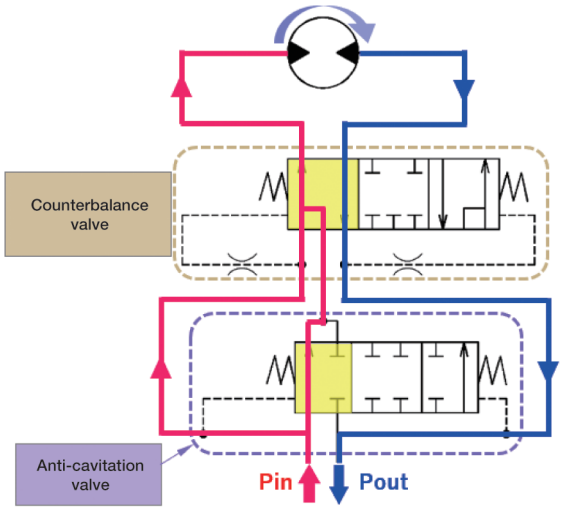

Fig. 5 Hydraulic circuit diagram of anti-cavitation valve (during travelling)

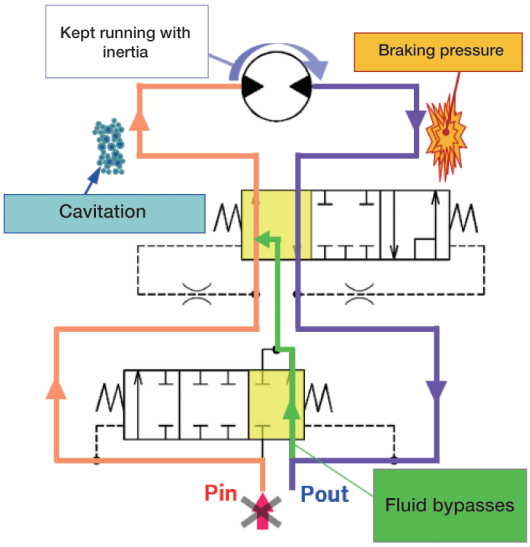

Fig. 6 Hydraulic circuit diagram of anti-cavitation valve (during braking)

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

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

2. 4 Comparison of Valve Structure

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

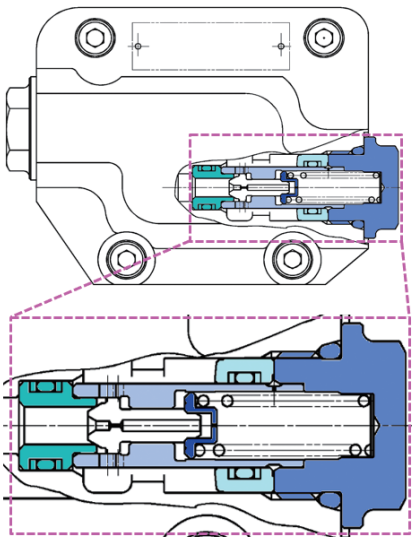

Fig. 7 Section view of relief valve

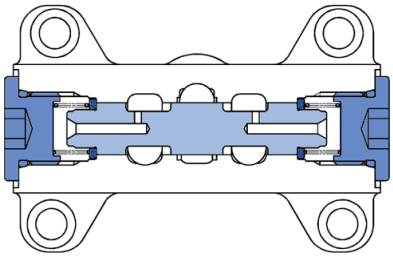

Fig. 8 Section view of anti-cavitation valve

3 Technical Challenges in Introducing Anti-cavitation Valves

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

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

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

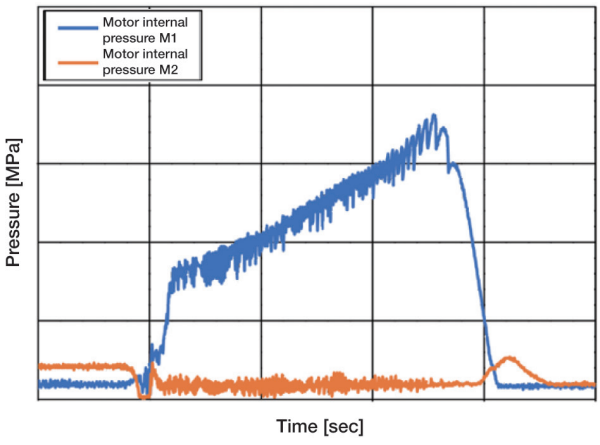

Fig. 9 Braking pressure characteristics of motor with anti-cavitation valve [1]

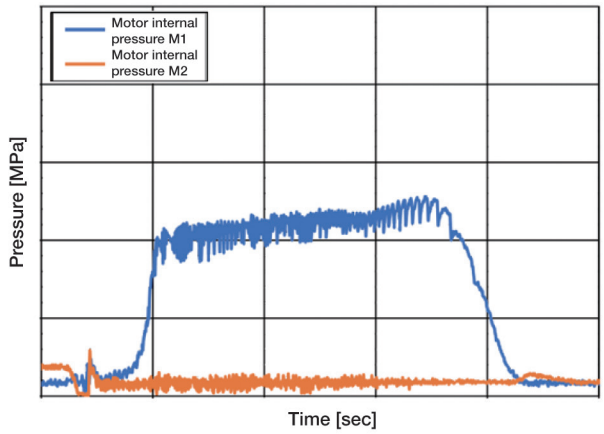

Fig. 10 Braking pressure characteristics of motor with anti-cavitation valve [2]

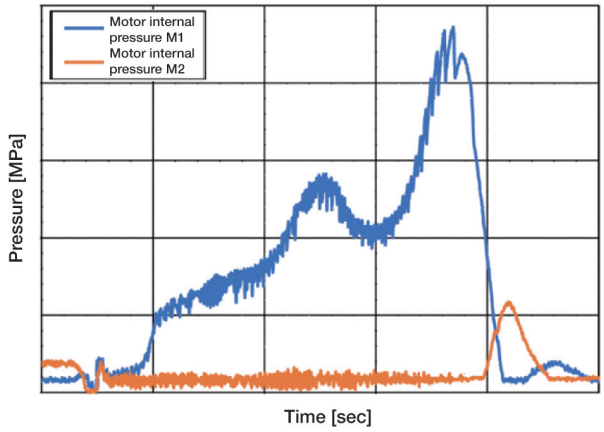

Fig. 11 Braking pressure characteristics of motor with anti-cavitation valve [3]

5 In Closing

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

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

Author

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Joined the company in 2007. Pump and Motor Design Sect., Sagami Hydraulic Engineering Dept., Engineering Headquarters, HC Operations
Engaged in design and development of hydraulic motor products.