

Introduction of Duplex Pump HPD71+71 and Short-Stroke Pump HPV112+112

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Komatsu has come up with a high-pressure, large-capacity, duplex swash plate pump, HPD71+71, as the main pump for PC160-7 and a short-length, tandem swash plate pump (short-stroke pump), HPV112+112, as the main pump for PC210N-7. This paper describes the salient features and technical contents of these new products.

Key Words: *Hydraulic Piston Pump, Duplex Pump, Short-Stroke Pump, Noise/Vibration Reduction, High Self-Priming Ability, Rotational Stability, High Efficiency, High Pressure, Compact Size, Reduction of Overall Length.*

1. Introduction

Many of hydraulic piston pumps are used as the main pump for a hydraulic excavator. When a hydraulic excavator is remodeled, the main pump that is used for it is improved or remodeled as required.

In recent years, there is growing demand for reduction of the overall length of main pumps to permit decreasing the rear turning radius of hydraulic excavators (as a means of improving the safety) and reducing the width of vehicle bodies (as a means of meeting the new transport regulations). There is also demand for reduction of the size of hydraulic pumps by increasing their power density.

In order to meet those demands, it is necessary to increase the pressure, rotational speed, and efficiency of hydraulic pumps. This requires solving a number of problems described later. So far, our R&D efforts have produced tangible results in the following tasks.

- (1) Reducing vibration and noise
- (2) Increasing self-priming ability
- (3) Improving rotational stability of internal parts

This paper describes the notable features and technical contents of two newly-developed pumps that incorporate the above R&D results.

The first half of this paper concerns a high-pressure, large-capacity, duplex swash plate pump, HPD71+71, developed as the main pump for the PC160-7 medium-sized hydraulic excavator that employs a duplex pump system which is also used in mini-sized hydraulic excavators and PC78US (Fig. 1).

The second half deals with a short-length, tandem swash plate pump (short-stroke pump), HPV112+112, developed as the main pump for PC210N-7 which is a PC200 series model having a reduced body width (Fig. 2).

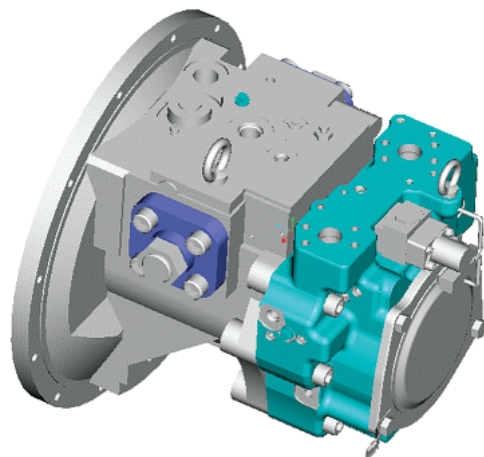


Fig. 1 Appearance of HPD71+71 (3D-CAD)

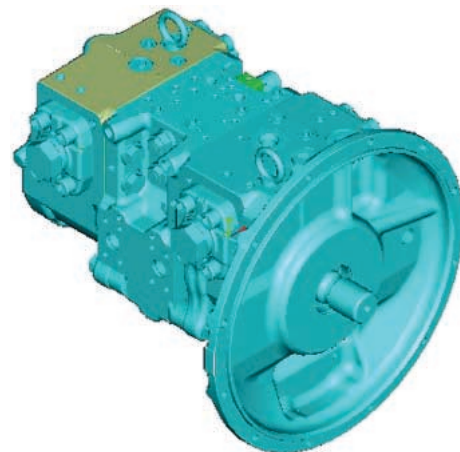


Fig. 2 Appearance of HPV112+112 (3D-CAD)

2. HPD71+71

2.1 Product series and specifications

As a series of duplex pumps which has been mass-produced by Komatsu, there is the LPD series of medium-pressure pumps which are installed in mini-sized hydraulic excavators and PC78US. The maximum rated pressure of this series is 27.5 MPa (280 kg/cm²).

The newly-developed HPD71+71 has attained a maximum rated pressure of 41.2 MPa (420 kg/cm²), the same as that of the HPV series of single pumps and tandem pumps. Thus, the new pump has significantly expanded the scope of application of the series of duplex pumps (Table 1).

Table 1 Duplex pump series

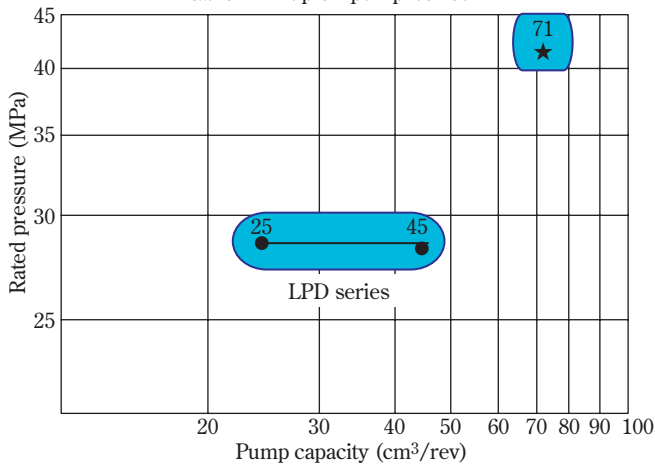


Table 2 shows the principal specifications of HPD71+71 which is mass-produced as the main pump for the PC160-7 medium-sized hydraulic excavator.

Table 2 Specifications of HPD71+71 (on board PC160-7)

	Item		Unit	
(1)	Capacity	MAX	cm ³ /rev	71+71
(2)	Rotational speed	Rating	rpm	2200
(3)	Pressure	Rating	MPa {kg/cm ² }	37.3 {380}

2.2 Outline of duplex pump

2.2.1 Structure and operation

(1) Structure

A duplex pump has one suction port and two discharge ports in the end cap of the pump casing. The cylinder block inside the pump casing consists of 10 cylinders. Cocoon-shaped ports in the circumference of the plane making contact with the valve plate (two sets of five cylinders) are connected to two systems of discharge grooves (inner and outer grooves) in the valve plate, and the two systems are capable of discharging working fluid at the same flow rate at different pressures.

(2) Operation

During excavation work, the duplex pump operates as one pump (single pump) with the two ports connected with each other by a control valve. While the hydraulic excavator is traveling or being steered, the duplex pump operates as two pumps.

2.2.2 Features

(1) The duplex pump occupies a smaller space than does the tandem pump (Fig. 3).

As illustrated in Fig. 3, the overall length and space occupancy of the duplex pump are about 15% smaller than those of a tandem pump having the same discharge rate.

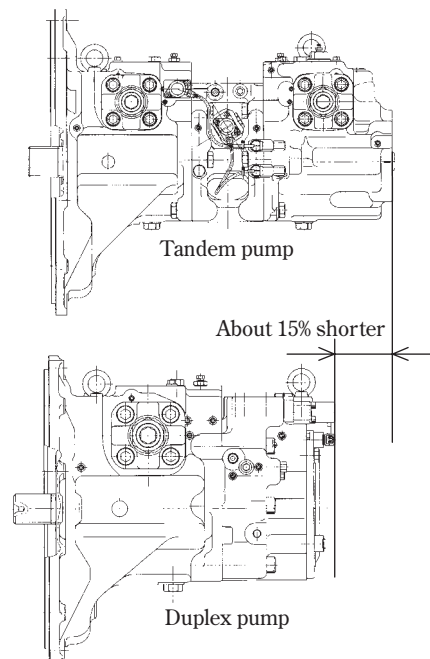


Fig. 3 Comparison of space occupancy between duplex pump and tandem pump (pumps of Komatsu make)

(2) The duplex pump offers better traveling/steering performance than does the single-pump CLSS system.

In the single-pump CLSS system, while the hydraulic excavator is traveling or being steered, the pump pressure at the driven side becomes the same as the pump pressure at the driving side as the pressure compensating valve inside the control valve is actuated. In this case, the flow rate of pump working fluid is decreased markedly to prevent the engine from stalling. In the duplex pump system, by contrast, the pump pressure at the driven side remains low, making it possible to reduce the decline in flow rate of working fluid to about 50% that in the single pump system. Therefore, it allows for more powerful traveling and steering.

2.3 Technologies Incorporated in HPD71+71

For a duplex pump, HPD71+71 has a large capacity (71+71 cm³/rev) and a high discharge pressure (max. 41.2MPa (420 kg/cm²)). Therefore, the following technologies accumulated in the process of development of the HPV series and the results of our R&D efforts are incorporated in this new pump.

(1) High self-priming performance

In order to prevent the occurrence of cavitations in any of the ports in the cylinder block which are the parts of the pump suction passage that have the smallest bore, the following three measures were taken to lower the flow velocity and prevent the pressure drop in the ports.

① Spherical structure of cylinder block and valve plate (Fig. 4)

To lower the flow velocity in the ports, a spherical structure was adopted for the cylinder block and valve plate. As a result, the flow velocity could be lowered by 13% (as compared with the conventional plane structure).

② Tapered cylinder block ports (Fig. 4)

The ports were gradually tapered to allow for a smooth flow of working fluid from the cocoon-shaped ports into the cylinders during suction of the fluid, thereby preventing the occurrence of local cavitations (patent of Komatsu).

③ Installation of impeller (Fig. 4)

A duplex pump has two systems of cocoon-shaped grooves (inner and outer grooves) in the cylinder block. Generally speaking, therefore, the cross-section area of cocoon-shaped grooves is smaller than that of a single pump. This means that the flow velocity of working fluid in the ports becomes higher. To prevent this, an impeller was installed and the port suction pressure was increased.

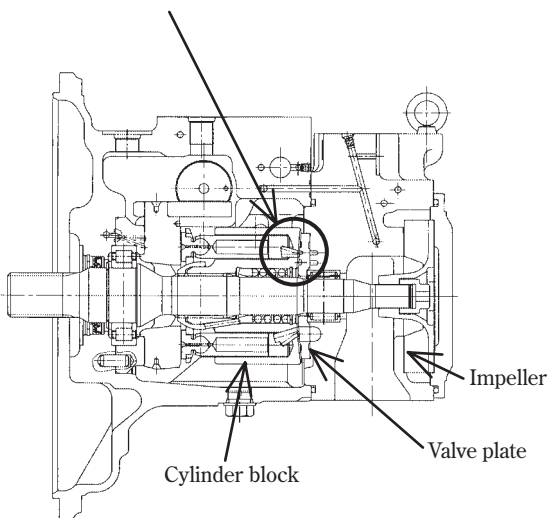
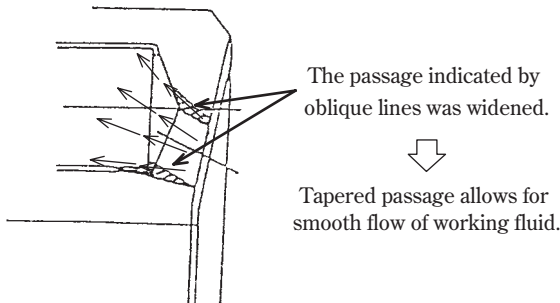


Fig. 4 Longitudinal cross section of HPD71+71

(2) Reduction of noise and vibration

The noise and vibration of a pump are ascribable largely to the pulsation of discharge pressure caused by a change in pressure of the working fluid in the cylinder bore – high pressure in the discharge stroke and low pressure in the suction stroke – with the rotation of the cylinder block. In order to smooth and disperse the pressure fluctuation, the following two measures were taken.

① Adoption of unequally-pitched ports in cylinder block (Fig. 5)

The variable pitch cylinder block of Komatsu is characteristic in that the cylinders are arranged at equal pitches, whereas the cocoon-shaped grooves of the same width are arranged at unequal pitches. By arranging the cocoon-shaped grooves at unequal pitches, it is possible to shift the timing of switching between the suction stroke and the discharge stroke for each of the piston cylinders (patent of Komatsu).

This arrangement permits dispersing the phase of noise frequency in each rotation of the pump. Namely, it is possible to make the pump noise less harsh than that of a pump with an equally-pitched cylinder block.

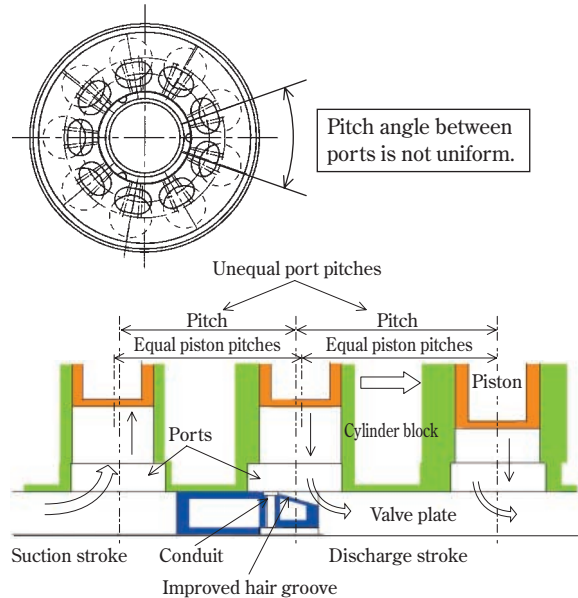


Fig. 5 Variable pitch cylinder block (expansion plan)

② Optimization of boost stroke-side port angle and hair groove profile of valve plate (Fig. 6)

In order to smoothly raise the pressure inside the bore when the suction stroke is switched to the discharge stroke, an optimum port open timing and an optimum hair groove profile obtained by a simulation were adopted for the new pump. As a result, the level of noise could be reduced.

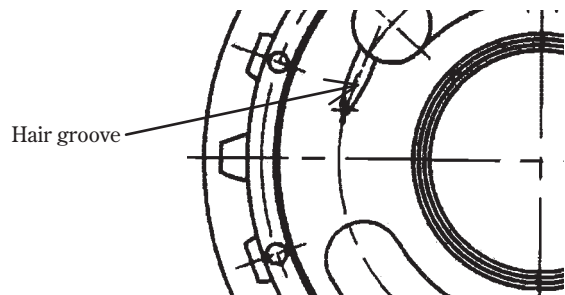


Fig. 6 Hair groove in valve plate

(3) Increased pressure

Increasing the pressure of a pump requires measures not only to increase the strength of individual parts, clamps of parts, and sliding surfaces of parts but also to stabilize the pump rotating body and prevent erosions caused by a high-pressure fluid. Therefore, the following three measures were taken to increase the pump pressure.

① FEM analysis of valve plate (Fig. 7)

In a duplex pump, the two rows of discharge ports (inner and outer grooves) are subject to an independent pressure. Therefore, the high-pressure endurance test (impulse test) for confirming the durability of the valve plate as a pressure holding component needs to be carried out in three different cases: pressure in only the inner groove is high; pressure in only the outer groove is high; and pressure in both grooves is high. In order to avoid any loss arising from re-testing or modification of forged parts, FEM was used to analyze the valve plate. As a result, we could come up with a port rib shape which is free from stress concentration and thereby secure a sufficient port area and sufficient valve plate strength.

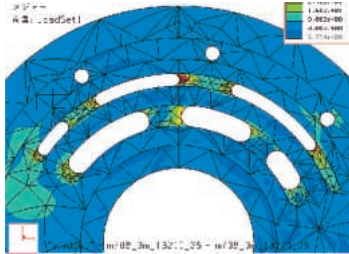


Fig. 7 FEM analysis of valve plate

② Optimization of diameter of spherical cylinder block and valve plate

Based on results of numerical calculations, the diameter of the spherical cylinder block and valve plate was optimized to minimize the moment of overturn of the cylinder block and reduce the swirling of the cylinder block, thereby improving the rotational stability of the internal parts.

By improving the rotational stability of the internal parts, it is possible to prevent the seizure and blowing of the sliding surfaces even under a high pressure and at a high speed of pump rotation and thereby improve the efficiency of pump operation.

③ Valve plate structure free from erosions (Fig. 8)

The pinhole in the front end of the hair groove not only allows for a smooth rise in pressure in the bore (as does the hair groove) but also disperses the oblique jet stream produced by the hair groove by a perpendicular jet stream from the pinhole and thereby prevents the cylinder block bore from being eroded (patent of Komatsu).

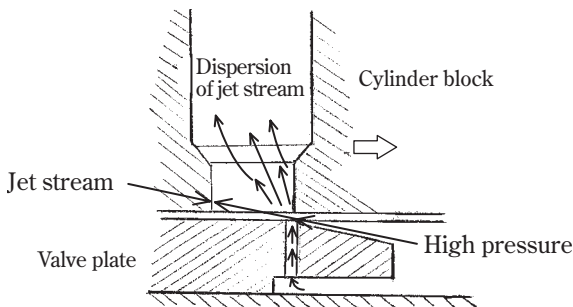
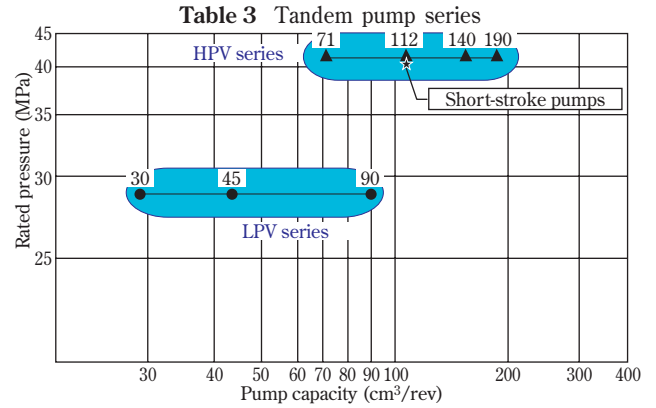


Fig. 8 Valve plate structure free from erosions

3. HPV112+112

3.1 Product Series and Specifications

As the tandem pumps that have been mass-produced by Komatsu, there are the medium-pressure LPV series and the high-pressure HPV series. The maximum rated pressure is 27.5 MPa (280 kg/cm²) for the LPV series and 41.2 MPa (420 kg/cm²) for the HPV series (Table 3).



The newly-developed, short-stroke pump, HPV112+112, is a variation (new series) of the existing HPV95+95 (112) tandem pump and has an overall length smaller than that of HPV95+95. It is the main pump for PC210N-7 of the PC200-7 series, the body width of which has been reduced to meet the transport regulations of the EU.

The principal specifications of HPV112+112 are shown in Table 4.

Table 4 Specifications of HPV112+112 (on board PC210N-7)

	Item	Unit	
(1)	Capacity	MAX	cm ³ /rev 112+112
(2)	Rotational speed	Rating	rpm 1950
(3)	Pressure	Rating	MPa {kg/cm ² } 37.3 {380}

3.2 Outline

The newly-developed, short-stroke tandem pump, HPV112+112, is 15% smaller in overall length than the existing tandem pump, HPV95+95 (Fig. 9).

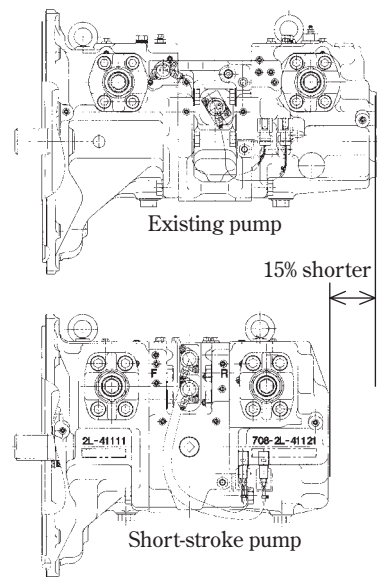


Fig. 9 Comparison between existing pump and short-stroke pump (pumps of Komatsu make)

(1) Structure (Fig. 10)

In order to reduce the pump overall length, the following measures were taken.

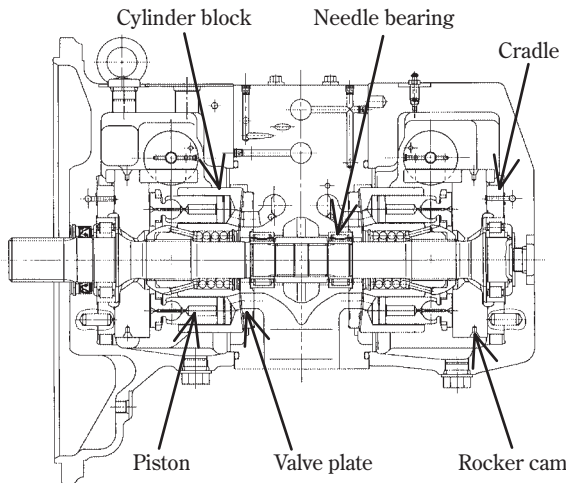


Fig. 10 Longitudinal cross section of HPV112+112

① Decreasing stroke

The piston diameter was increased by 15% and the stroke was decreased by 25%.

② Reducing pump casing length

The pump casing length was reduced by 22% by housing all the pump control valves in the end cap. In the existing pumps, they are distributed between the pump casing and the end cap.

③ Decreasing bearing width

The decrease in stroke reduced the distance between the two bearings that support the shaft, making it possible to reduce the main bearing size.

④ Adopting needle bearing with inner race

The increase in piston diameter increased P.C.D. of the suction and discharge ports in the valve plate and end cap. This made it possible to adopt a needle bearing with inner race. As a result, the length of the needle bearing part could be cut by overlaying the inner race in the machined part of the tandem coupling spline of the shaft.

⑤ Increasing number of cradle fitting bolts and decreasing bolt size

Since the piston P.C.D. increased, the P.C.D. of bolts for fitting the cradle that supports the rocker cam (swash plate) was increased, the number of fitting bolts was increased, the size of the bolts was decreased, and the parts at which the cradle is fitted was decreased by 15%.

3.3 Technologies incorporated in HPV112+112

(1) Improvement of volume efficiency

Generally speaking, the volume efficiency of a piston pump tends to decline in the region in which the swash plate angle is small. For the new short-stroke pump, the following measures were taken to attain high volume efficiency.

① Reducing clearance between piston and bore

Because of the reduced gouging force of the piston and the low piston sliding speed, it was possible to reduce the clearance between the piston and the bore.

② Reducing leak from static pressure bearing of cylindrical plane between cradle and rocker cam

The amount of leak was reduced by optimizing the throttle of the high-pressure fluid supply channel.

③ Reducing leak from surface of piston shoe pad

The amount of leak was reduced by improving the hydraulic balance at the pad surface (static pressure bearing) to suit a small swash plate angle and by optimizing the throttle dimensions.

④ Optimizing diameter of spherical cylinder block and valve plate

The same measure as described in 2.3(3)② was taken.

(2) Design of optimum stiffness by FEM analysis

① Strength of part from rocker cam to cradle

In order to reduce the pump overall length, an FEM analysis of stiffness of the part mentioned above was carried out.

② Strength of clamped part from pump casing to end cap (Fig. 11)

The piston thrust (reaction) has increased due to an increase in piston diameter. In addition, the positions of the discharge ports in the end cap and the bolt positions on the clamped part differ markedly from those of existing models. Since these facts make it difficult to adopt the same design method as used for the existing models, an FEM analysis was carried out to study the stiffness.

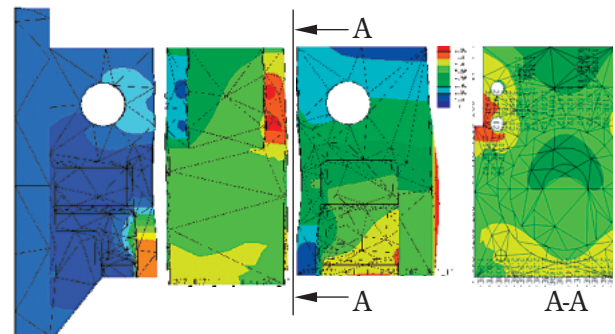


Fig. 11 FEM analysis of deformation of clamped part from pump casing to end cap

③ Strength of pressure holding part (end cap) (Fig. 12)

The end cap has discharge ports of complicated flow passage. At the very beginning of the present development, the internal stresses were analyzed by FEM and the analysis results were reflected in the drawings and prototype to confirm the durability of the pressure holding part.

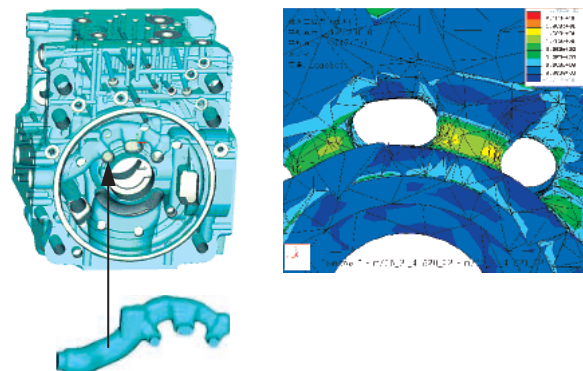


Fig. 12 FEM analysis of discharge passage of end cap

(3) Improving self-priming performance

The same measures as described in 2.3(1) ①, ②, and ④ were taken.

(4) Reducing noise and vibration

The same measures as described in 2.3(2) ① and ② were taken.

4. Conclusion

HPD71+71 and HPV112+112 are high-quality, high-reliability products which incorporate the advanced technologies and know-how accumulated in the process of development of Komatsu HPV series of high-pressure piston pumps

Introduction of the writer



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[A few words from the writer]

Most of the hydraulic piston pumps (hydraulic devices) of Komatsu are supplied from the Oyama plant to the company's construction equipment plants around the world. In the future, we intend to make improvements on our existing pumps in terms of performance, quality, and cost, and develop new products so that we will be able to struggle through the ever-intensifying competition in the world market.