

Low Noise Type Hydraulically Driven Engine Cooling Fan System

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Recently a hydraulically driven engine cooling fan is becoming a mainstream technology as one of the means to bring down the level of noises generated by construction equipment. However, the currently available system is no better than a mere combination of various general purpose-devices such as a hydraulic pump and motor, valves, etc. As a result, it requires large space for installation; the overall configuration necessarily becomes complex as each component device is connected with each other with piping, leading to difficulty in designing its installation on an actual machine; and all these drawbacks end up in an increased system production cost.

Prompted by the recognition of this reality, we set about a series of activities for improvements that included identifying problematical areas and working up a concept on an ideal hydraulically driven engine cooling fan system. In more concrete terms, we picked out a piston pump and motor for a base equipment that has a good and long track record in its application to the Komatsu's hydraulic excavators, then designed a new pump and motor exclusively for the cooling fan application, and put them together. A combination of the pump and motor has successfully made up a compact and unique Komatsu hydraulically driven engine cooling fan system of high performance and high reliability.

This paper discusses various characteristics of this new system.

Key Words: *Low Noise, Energy Saving, Engine Cooling Fan System, Fan, Pump Motor, Conformity with Noise Regulations*

1. Background of development of hydraulically driven engine cooling fan system

A hydraulically driven engine cooling fan system (simply the fan system hereafter) is gaining momentum in its application to construction equipment in general as the world puts an ever increasing emphasis on the environmental preservation. Even so, there are some around us who cast a question to us, asking "Why do you attach importance to the fan system now?" The following are our replies to the question.

(1) Stringent demand for an engine cooling fan of lower noise

A demand for lower noise in relation to construction equipment remained to be a local issue in a confined area like Europe up until a certain point of time in the past, and we coped with the issue by preparing for special equipment designed exclusively for that strict area. In the recent years, however, the demand level went still higher and far beyond the European borders, so much so that we can no longer handle the situation merely with the upgraded conventional technology. Low noise machines will become a de-facto standard for construction equipment on the worldwide scene in the current trend of protecting the global environment.

(2) Desire of wider latitude in component layout

The fan system tolerates a wide latitude and flexibility in the component layout. This characteristic should be particularly effective with the engine room of a short tail hydraulic excavator, which is very complex and crowded. There has been a latent aspiration among us to render the engine room even less complex and simpler. On the other hand, there has been increasingly a request for better machine maintainability, particularly easiness in cleaning, from renting companies of construction equipment, as the population of renting machines is on a constant rise in the Japan's domestic market.

(3) Following worldwide trend

As we often experience in various exhibitions of construction equipment of international scale, use of the fan system is currently a worldwide trend that extends over construction equipment as a whole, encompassing even mini size equipment. Its use is gradually regarded as a matter of course in designing construction equipment right now.

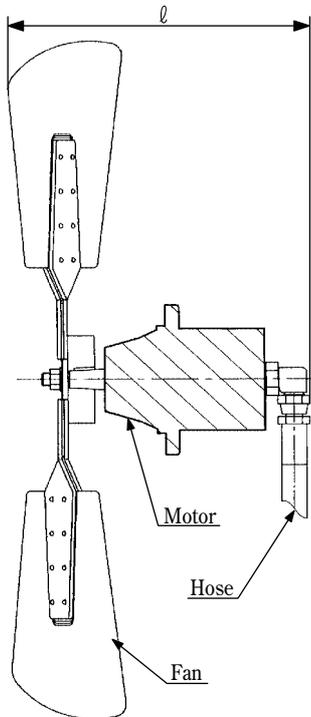
This paper mentions the problems inherent in the conventional fan system that came to the surface in the course of developing the new system, touches upon the features of the fan system and introduces its wide variation in a combination of pump and motor components.

2. Problems with conventional system

The first thing we have done in the development of a new engine cooling fan system was to identify the problems encountered with the conventional fan system.

(1) Large space the fan and motor occupies when installed

When installed, the fan and motor including the piping far stretch in the axial direction, requiring large space in the engine room. (See Fig. 1)

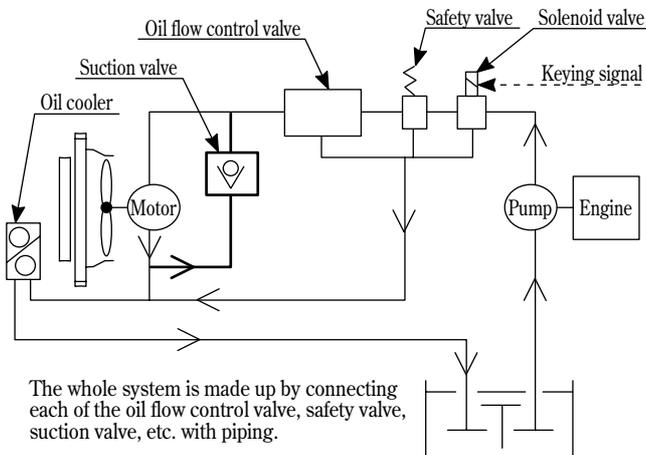


“*l*” dimension is so long that the fan system occupies large space when installed on an engine.

Fig. 1 Combination of conventional motor and fan

(2) Posing a problem in forming the whole system

Currently available tools and equipment that are required to control an engine cooling fan system are largely multi-purpose products. As such, we are obliged to connect each tool and equipment with a piping after it is installed. (See Fig. 2) But this sort of practice inevitably invites problems like an increase in the system cost, difficulties in laying out each tool and equipment, larger space being required, etc.



The whole system is made up by connecting each of the oil flow control valve, safety valve, suction valve, etc. with piping.

Fig. 2 Example of conventional engine cooling fan system

(3) Low efficiency as system

A gear pump and a motor are often employed in the conventional type of a hydraulically driven engine cooling fan system. Its working efficiency is rather low as a fan system (in other words, the loss is big).

(4) Difficult to have a wide variation in combination of fan and motor components

Generally an engine cooling fan system has to cope with each different specification of the mother engines. Meanwhile, as mentioned earlier, the current fan system is made up of a combination of various multi-purpose tools and equipment. And that necessitates to form a different combination all again from the beginning every time the specifications of a mother engine differ. To put it differently, it is impossible with this practice to apply a so called add-on method that an additional tool or equipment is added to the basic fan system according to individual engine specifications.

(5) Difficult to reverse fan rotation

Reversing fan rotation is one of the functions required of an engine cooling fan system. Aims of reversing the fan rotation are primarily cleaning the radiator fins and warming air inside the operator’s cabin in a cold weather. In the conventional method, a reversible fan has been long in use to achieve these purposes, whose fan blade inclination is reversed to change the direction of wind flow. But the trouble with this practice is that this type of fan is costly in the first place and that it is much time consuming for an operator to reverse the fan blade angle.

(6) Difficult to input multi monitoring temperatures in controller

The conventional type of hydraulically driven engine cooling fan system consists of dual systems, i.e. one for monitoring various temperatures (coolant temperature, hydraulic oil temperature, etc.) and the other for controlling the fan rotation, using a thermo relief valve. This cooling fan system will do in the case that there is only one temperature to be monitored. If, on the other hand, there are plural temperatures to be monitored and controlled, required circuits tend to be complex and difficult to be dealt with.

3. Characteristic of Komatsu's hydraulically driven engine cooling fan system

(Solutions to the problems)

(1) Structure of in-fan mounted motor (See Fig. 3)

A hydraulic motor is housed in the fan boss, thereby minimizing the protrusion of the motor at the rear.

(2) Built in control valve (See Fig. 4)

All the valves necessary for an engine cooling fan system are housed in the pump and motor. They are a safety valve, suction valve, oil flow control valve, reversible valve, solenoid proportional servo, etc.

- What is basically needed to make up the system are only an inlet and outlet piping as well as drain piping other than the fan and the in-fan mounted motor.
- Thanks to a built-in reversible valve, the fan rotation can easily be reversed.
- A solenoid proportional control system is employed for controlling the system. Thus various monitoring temperatures can easily be inputted, which in turn has realized various controls.

(3) High working efficiency (See Fig. 4)

We decided to adopt an axial piston type pump and motor which was remodeled based on a hydraulic pump used in Komatsu' line of hydraulic excavators, as it had had a good track record.

(4) A wide variation in combination of pump and motor components (See Fig. 5 and 6)

To cope with requests for a wide range of engine specifications, we came up with an add-on method that adds a required component to the base system. This system has enabled us to easily deal with various additional functions required of the system. (See Fig. 7)

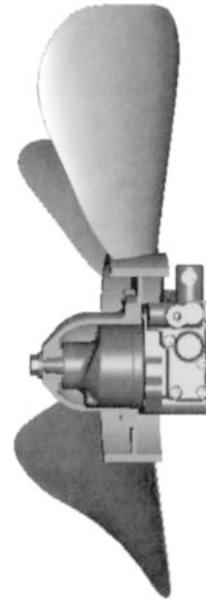


Fig. 3 Structure of in-fan mounted motor

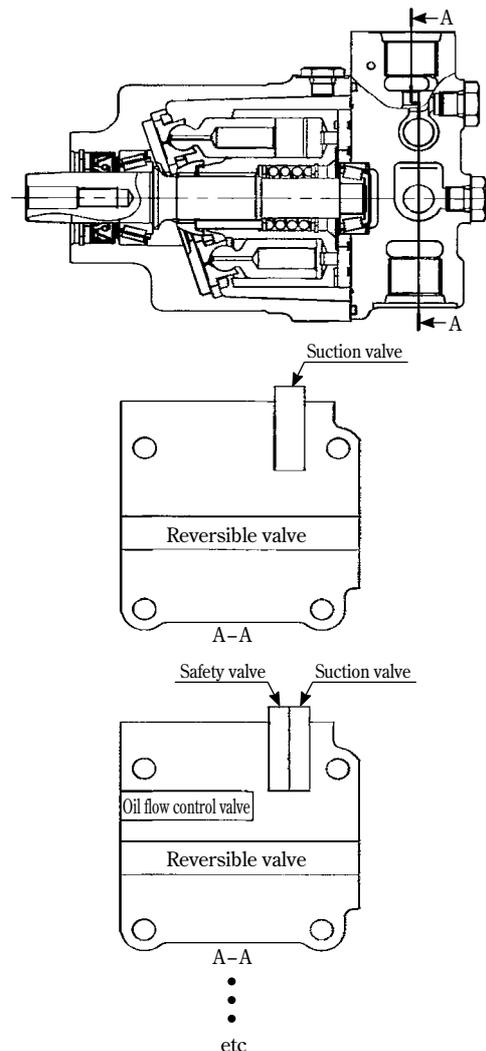


Fig. 4 Cross section of in-fan mounted motor

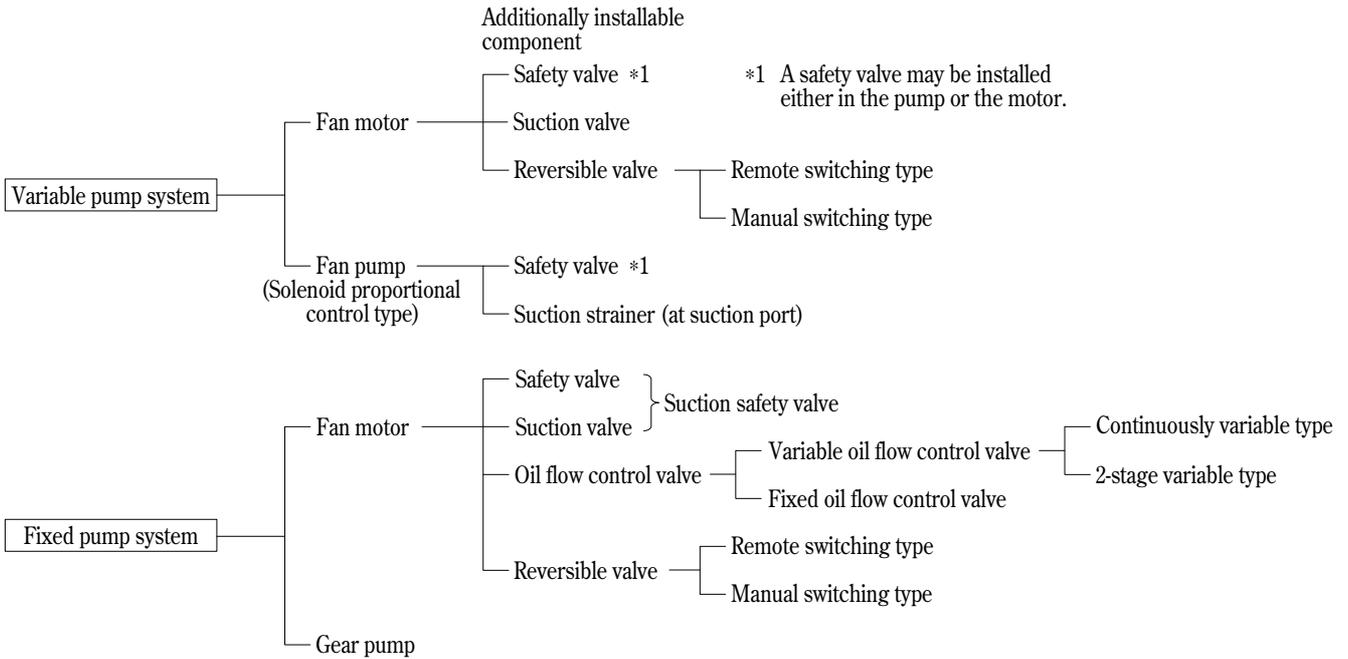


Fig. 5 Wide Variation in Combination of Components

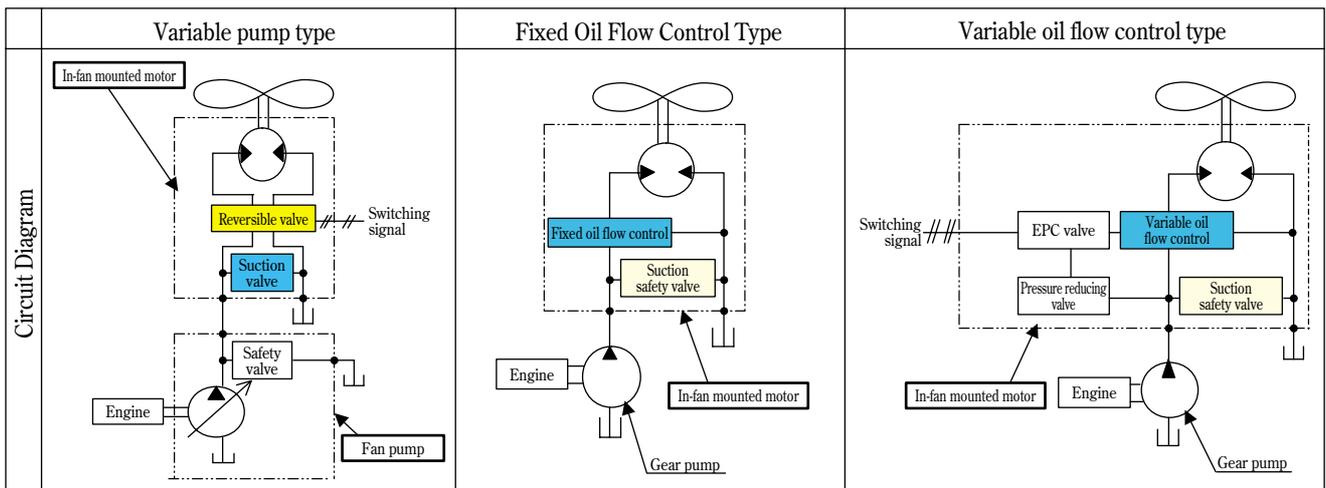


Fig. 6 Variation in system

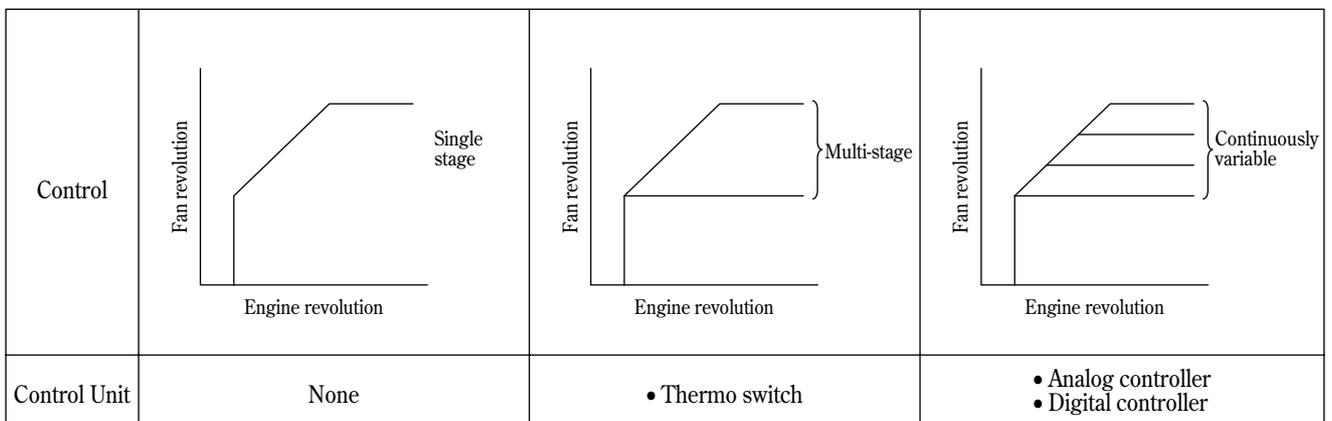


Fig. 7 Variation in control

4. Hydraulically driven engine cooling fan system

(1) Variable pump system

<Outline of system>

- The fan system employs a solenoid proportional control type pump for the fan pump. (See Fig. 8)
- In this type of pump, a swash plate reacts to a command current signal (EPC ampere) and changes the angle, whereby the command current signal and the pump delivery show characteristics as shown in Fig. 9.
- Monitoring temperatures like coolant temperature, hydraulic oil temperature, etc. are fed into the controller.
- A map of the monitoring temperatures and the required fan revolution is separately prepared, based on which a target fan revolution is to be set.
- Necessary pump delivery is calculated. At the same time, an engine rpm (pump revolution) is detected. Based on this rpm data, a necessary angle of the swash plate is calculated; then a command current signal is sent to the solenoid proportional control valve (EPC valve) to set the swash plate angle; and the required oil amount is delivered to the motor.
- Through this way of control, the fan revolution can be kept at a constant required speed as shown in Fig. 10 without any relation to the engine revolution.

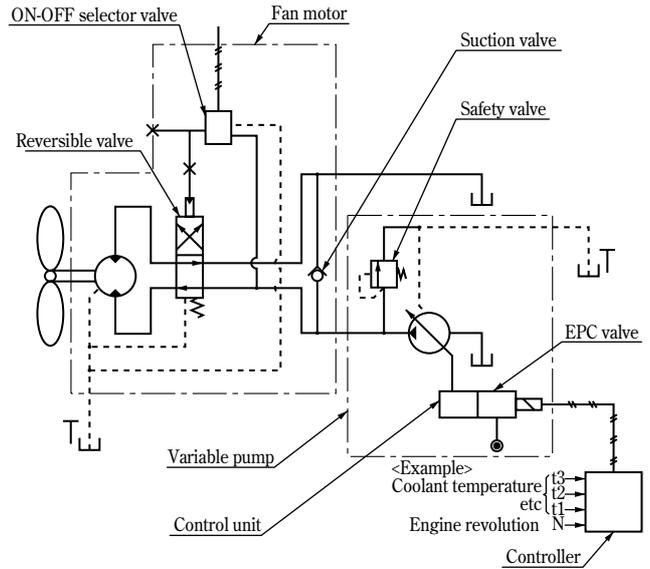


Fig. 8 Variable pump system circuit diagram

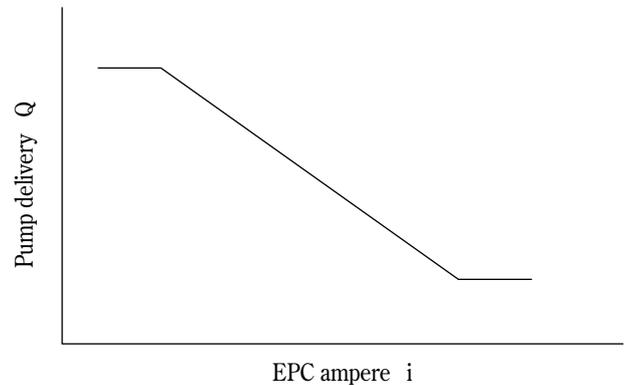


Fig. 9 Fan pump control characteristic

Conceptual graph of control system

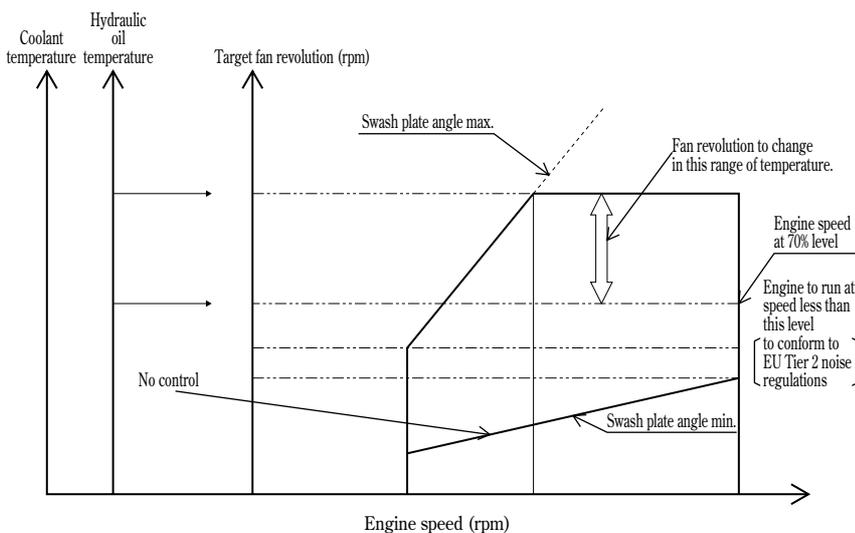
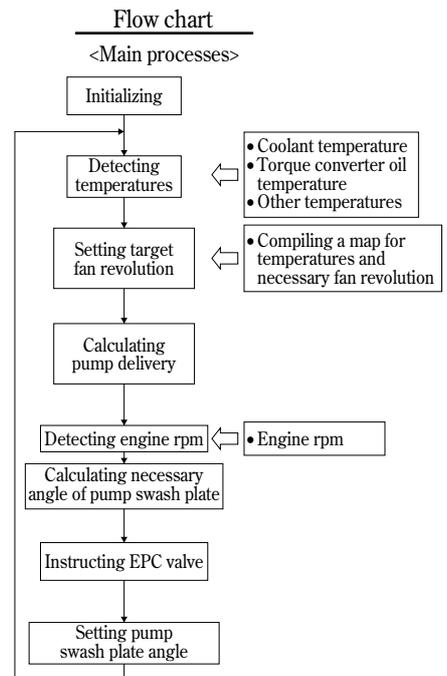


Fig. 10 Control system and flow chart of hydraulically driven engine cooling fan system



(2) Fixed pump system

<Outline of system>

- The fixed pump system employs a fixed pump (gear pump) for the fan pump. (See Fig. 11)
Pressurized oil is delivered from the fixed pump in the amount proportionate to the engine rpm.
- The motor revolution rises in proportion to oil influx amount Q as shown in Fig. 12 and the motor rotates at \textcircled{B} rpm with oil influx amount Q_1 .
In order to reduce the noise level and a functional loss, it becomes necessary to control the fan motor in way that its fan rotates at a required constant speed all the time without any relation to the engine rpm. Thus an oil flow control valve is needed to satisfy this requirement.
In other words, even if the influx oil amount increases from Q_0 to Q_1 , the motor revolution is preferably controlled to level off at an rpm level of \textcircled{A} and \textcircled{C} .
- An oil flow control valve serves to feed the fan motor with as much pressurized oil as necessary and return redundant oil to the tank. In Fig. 12, when influx oil amount exceeds the Q_0 level, the oil flow control valve is actuated (P and T ports open) and sends the redundant oil in the hatched area to T port through the valve, thereby keeping the motor revolution at the constant level of \textcircled{A} and \textcircled{C} .
- Here we show an example for oil control when installing a solenoid proportional variable oil flow control valve. As shown in Fig. 13, a flow control valve for this type is capable of changing the motor revolution continuously within the range between $\textcircled{A} - \textcircled{C}$ and $\textcircled{A}' - \textcircled{C}'$ levels by altering a command current signal to the EPC valve. It is possible, therefore, to freely set the motor revolution following the indicated monitoring temperature like coolant temperature, hydraulic oil temperature, etc.
- In the example cited above, we discussed a case of continuously variable control. Besides, a multi-stage control and a single stage control (fixed flow control type) are also possible.

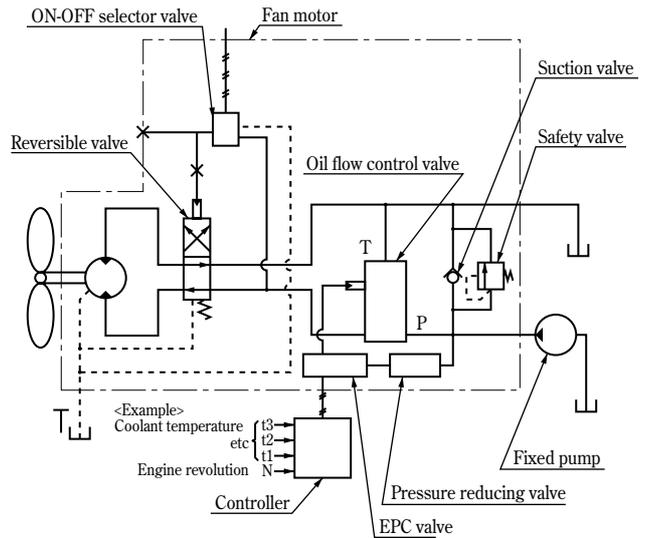


Fig. 11 Fixed pump system circuit diagram

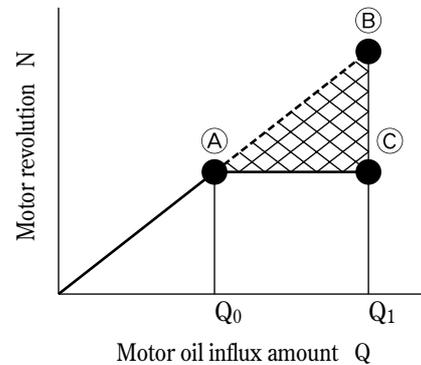


Fig. 12 Relation between oil influx amount and motor revolution

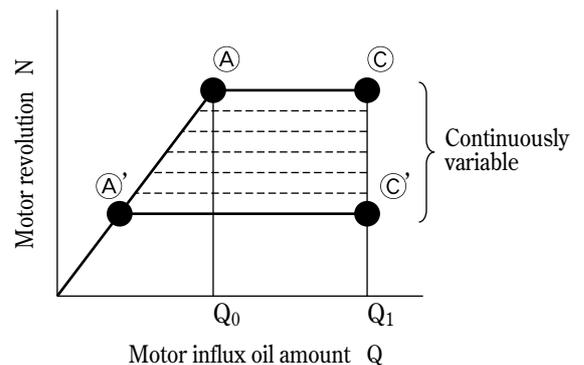


Fig. 13 Chart of continuously variable control

5. Conclusion

A hydraulically driven engine cooling fan system is becoming more and more essential for lowering noises generated by construction equipment. It seems the fan system will remain as effective as ever in the future, too, since people will further intensify attention to the issue of protecting the global environment.

The Komatsu-made fan system employs a variable pump system. It is currently installed on bulldozers and mobile crushers besides hydraulic excavators, and the application is still expanding to other models. With a fixed type system, on the other hand, start of its mass production is close at hand.

Our next target is to expand the product lineup and extend their application to other models.

Introduction of the writers



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[A few words from the writers]

On the face of it, a hydraulically driven engine cooling fan system may look a simple system that puts a pump and a motor together and turn a fan connected to the motor. In reality, however, it requires a lot of ideas and ingenuity to accommodate varied requests from users, and overcome restrictions to reflect them on an actual product. In this sense, we are satisfied that the new fan system is a product of high marketability particularly in respect to the function and variation in a combination of fan and motor components.

The next step is to work up a concept for a fan system in the next generation that should become far more advanced one. To that goal, we are refreshing our resolve now.