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ENERGY SAVING MEANS AND EFFECT OF OIL HYDRAULIC UNIT FOR PRODUCTION MACHINE

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ABSTRACT

Environmental problems of global warming are common topics that relate to all people on the earth now. The effort of conservation of energy is already an obligation. The purpose is to reduce the amount of the CO_2 exhaust that occupies most of the heat-trapping gas that causes global warming. As for the oil hydraulic unit used for the production machine in the factory, the one of energy conservation or more is strongly requested.

In this paper, it proposes our two kinds of conservation of energy oil hydraulic units. After the problem for a current oil hydraulic unit is clarified, the applied technological means and the effect are shown with the application case such as machine tools and the press machines.

KEY WORDS

hydraulic power unit, electric power consumption, efficiency, trade-off

NOMENCLATURE

W	: Electric power consumption [W]
N	: Rotation speed [min-1]
T	: Torque [Nm]
q	: Displacement of Pump [cm^3/rev]
P	: Pressure [MPa]
Q	: Flow rate [l/min]
η_M	: Motor efficiency
η_m	: Mechanical efficiency of Pump
η_v	: Volumetric efficiency of Pump

INTRODUCTION

Some of the chief merits of oil hydraulic system are it can output big power with compact system and easy force control - more precisely pressure control - . This grace enables a lot of hydraulic actuators to be widely used for the clamping device in machine tools.

Furthermore, a lot of hydraulic systems are used as driving system of the press machine that needs bigger power.

Now efforts to reduce the emission of the CO_2 which affects on global warming are made in the production machines of the factory. Therefore, the hydraulic equipment that decreases the consumption energy is needed in the production machine.

We have been working on developing and improving its hydraulic equipment that aims at Energy Saving, Safety, Compactness and High Quality. As for the hydraulic power unit, we take different energy saving means to each one, because all the required functions

differ depending on its usage. It is also because each acceptable cost is different according to how to use it.

This paper is organized as follows. In Section 2, power consumption of the hydraulic power unit is explained. In Section 3, a feature of usage in machine tools, past issues and best fit means to solve these issues are explained. Moreover, results which proved by actual applications are shown. In Section 4, same topics of the hydraulic power unit which mainly adopted by Press Machine are mentioned. Conclusions are summarized in Section 5.

Electric power consumption of the hydraulic power unit

Hydraulic power unit is constructed by Pump, Motor which drives the Pump and Tank. Now let's look at the electric power that the hydraulic power unit consumes.

Electric power consumption of Motor is below.

$$W = 2\pi \times N \times T / 60 / \eta_M \quad (1)$$

And, the Torque needed for Pump is

$$T = q \times P / 2\pi / \eta_m \quad (2)$$

Re-organizing equations (1) and (2), then electrical power consumed by the hydraulic power unit becomes equation (3).

$$W = N \times q \times P / (\eta_M \cdot \eta_m) \quad (3)$$

On the other hand, flow rate discharged from the Pump is equation (4).

$$Q = q \times N / 1000 / \eta_v \quad (4)$$

The role of hydraulic power unit is to supply the needed pressure (P) and flow rate (Q) according to the machine's movement.

What should be noted here is that the efficiency mentioned in equation (3) and (4) is not constant but is variable according to load condition and driving conditions.

It is difficult as a real problem, though it is an ideal to decrease the loss in all the areas to raising efficiency. Therefore, we paid attention to an actual way to use, and aimed at the efficiency improvement of the corresponding area. As a result, the consumption energy can be decreased while used actual.

Hydraulic power unit for machine tool

In the machine tool, the electric motor such as AC servo motor is used for the spindle and the table drive. These are axes that influence the processing accuracy directly. On the other hand, the hydraulic equipment is used for the part that supports work processing such as clamping and chucking. And, during the work processing, hydraulic unit is used in pressure keeping mode for a long time which doesn't require almost any flow rate Q.

Hydraulic power unit which equipped variable displacement pump is now generally used on machine tool. The pump is driven with an induction motor that turns in a constant rotation. However, the pump can reduce flow rate Q by reducing displacement q of the pump in equation (4).

Here, the problem and the improvement method are described about each of the pump and the electric motor that composes the hydraulic power unit. And, the operating method of the hydraulic power unit is similarly described.

Pumps

Volumetric efficiency η_v of the pump decreases by rising of pressure. This is because the amount of the leakage from internal sliding area increases.

In the variable displacement pump, displacement q becomes small when pressure is keeping. However, it is necessary to enlarge displacement q in equation (4) to keep pressure when the amount of an internal leakage is large. As a result, the electric power of equation (3) increases, too. Therefore, reducing the leakage contributes to the power consumption decrease.

On the other hand, it is understood that the mechanical friction increases when the leakage is decreased and mechanical efficiency η_m worsens.

Then, we did the design that took the trade-off of η_v and η_m so that the torque T of equation (2) might become small with pressure keeping mode.

Electric motors

A general electric motor is designed so that efficiency η_M at the load factor 100% may rise, and when the load factor lowers, becomes inefficient. The torque T is small in the variable displacement pump, while keeping pressure. So it will be used for a long time in the point where the electric motor efficiency is in a word low.

Then, even if some efficiency at the ratings load was sacrificed, the electric motor that improved efficiency in the point where the load factor was low was adopted.

Driving method

It is understood to be able to reduce power consumption by even reducing rotational speed N

from equation (3). In the variable displacement pump on keeping pressure, the pump axis input lowers as shown in Figure 1, when the rotational speed is lowered.

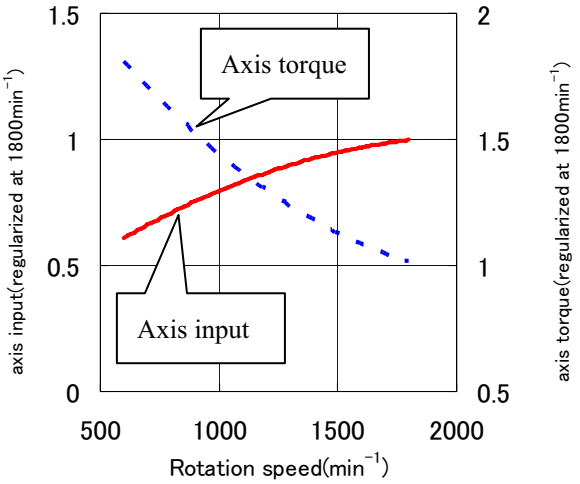

Figure 1 Pump axis input and torque

On the other hand, the efficiency η_M of the electric motor (driven by inverter) decreases oppositely when the rotational speed is lowered as shown in Figure 2, and efficiency changes in the same rotational speed according to the load torque.

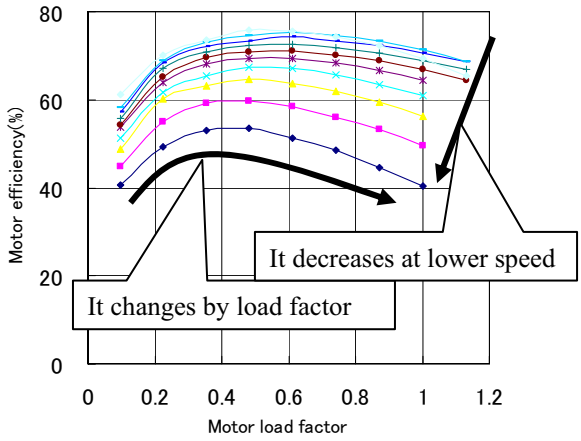

Figure 2 Motor efficiency

Although the user adds the inverter to an existing hydraulic power unit for saving energy, to lower the rotational speed, it is understood it is necessary not only to lower the rotational speed to do the best conservation of energy driving but also to make it to efficiency of the electric motor and the best rotational speed corresponding to the state of the load.

In the hydraulic power unit driven by inverter of Figure 3, the built-in controller calculates the load from the pressure sensor signal. And, it drives in the condition with better the entire efficiency.

The hydraulic power unit works by driving the variable displacement pump in a constant rotational speed. Or, the hydraulic power unit works by driving of changing the rotational speed the fixed displacement type pump by the inverter.

On the other hand, the hydraulic power unit of Figure 3 has two control degree of freedom of variable displacement of the pump and a changeable rotational speed. And, the control moved to an efficient operation point is done by using this one tedious degree of freedom.

Figure 3 Hydraulic power units driven by inverter

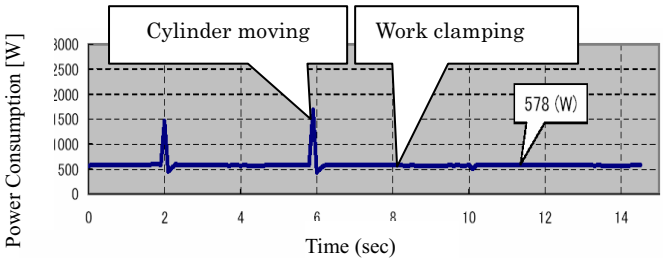

Figure 4 Power consumption of hydraulic unit (Conventional.)

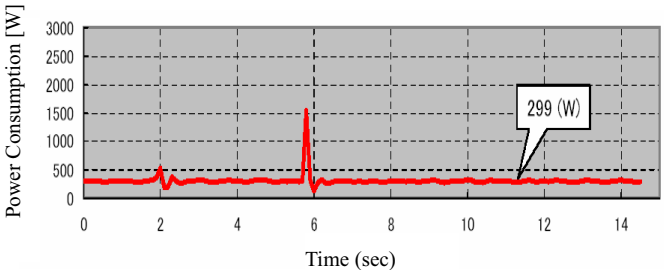

Figure 5 Power consumption of hydraulic unit (Driven by inverter)

Application and effect

The result of measuring the power consumption of the hydraulic power unit is shown in Figure 4 and Figure 5, in the machining centre where the hydraulic power unit

of conventional type and Figure 3 was installed.

The hydraulic power unit is used for clamping work, which electric motors are 2.2kW, flow rate at a no load is set to 28L/min, and the highest pressure is set to 6.0MPa. It is understood that most time is clamping work from the measurement result. The power consumption at this time is 578W in Figure 4, 299W in Figure 5, and it is decreased by about 48%.

Hydraulic power unit for press machine

The movement performance of the hydraulic actuator is related to the performance of the machine as it is in the press machine. Because it influences the processing accuracy of work, the hydraulic system with good control performance is requested. Moreover, a big difference with how with the machine tool to use it is that the hydraulic actuator works frequently.

Generally, the hydraulic power unit to which the variable displacement piston pump is driven with the induction motors is used. The movement direction switch and the speed control of the actuator are done with the valve. In this system, the pressure loss in the control valve is large. Within the range of the control, it is not good at control of a narrow, especially low side from about 1/10. Moreover, the electric motor keeps rotating when standing by, and the energy loss at this time is also large.

To solve these problems, the hydraulic system that drives both rotation piston pump with the AC servo motor has been commercialized. It is a system that does all the controls of pressure, the speed, and the position by only rotating the motor. And it can decrease the energy consumption that the pump operates only as for a necessary amount when it is necessary.

A fixed pump is used to avoid the complexity of the control without using the variable displacement pump.

The servo motor used with this system has the following feature. Efficiency is high from low speed to the high speed revolution. A torque that is even about 0 rotations bigger can be generated. Acceleration and the deceleration are made a high response, too. Thus, there are depend on the ability of the servo motor a lot of performances of this system.

On the other hand, the pump improved volumetric efficiency η_v when low-speed rotating. This is an important point to suppress pump rotational speed N low while keeping pressure.

In the vending machine of Figure 7[2], the positioning accuracy of each micron and a brilliant movement has been both achieved by combining the prefill circuit with this system. The comparison of power consumption with a past system is shown in Figure 8. Power consumption is decreased to about 1/4.

Figure 7 Vending machine

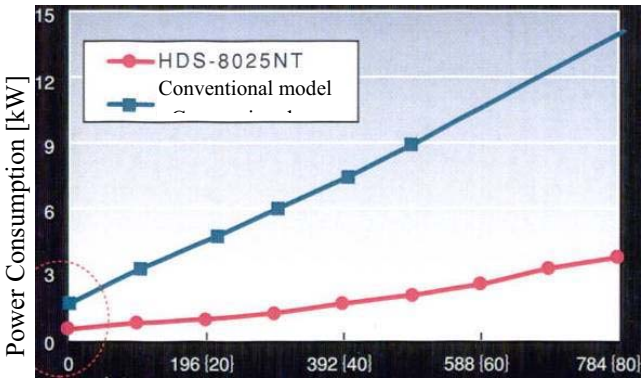

Figure 8 comparison of power consumption

CONCLUSION

We introduced two hydraulic power units for the machine tool and for the press machine that attempted conservation of energy. As for the system that uses the servo motor, the energy-saving effect is large though it costs. It is thought that application will increase in the future. Of course, this system is not a hydraulic system of almighty in the point of conservation of energy. It is necessary to be going to do the approach of the loss decrease of each equipment in the future, to ascertain an actual way to use, and to continue the approach that attempts conservation of energy in the effect.

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