Fluid Coupling for Boiler Feed Pump
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Abstract
At the time when global warming is becoming a serious issue requiring our efforts to reduce CO₂ emission, various industrial plants are confronted with a challenge of how they can reduce operation power consumption of turbo machinery. Since reduction in the operation power cost itself is an important issue from the viewpoint of corporate management, those plants are required to improve the operation efficiency. As one solution to these issues, control of rotating speed of turbo machinery became popular, and now, many plants use fluid couplings. In this paper we explain operation principles of fluid couplings and the structure and features of the fluid coupling for electric motor driven boiler feed pumps as an example of large capacity, high speed fluid couplings used for high pressure pumps.

Keywords: Fluid coupling, Boiler feed pump, High pressure pump, Carbon dioxide emission reduction, Rotating speed control, Impeller, Runner, Scoop tube, Electro-hydraulic servo mechanism

1. Introduction
With the rises in fuel costs triggered by the oil crisis of the 1970s, businesses have been required to improve the operational efficiency at their plants, which is now one of the important challenges they must address. As a solution to this challenge, increasingly more plants have started to control the rotating speeds of turbo machinery, resulting in increased use of fluid couplings. In addition, recent years have seen global efforts against global warming, requiring businesses to reduce CO₂ emissions. Under the circumstances, businesses in many fields are starting to adopt fluid couplings into turbo machinery.

This paper describes operation principles of fluid couplings as well as, as an example of a large capacity, high speed fluid coupling used for high pressure pumps, and the structure and features of fluid couplings for motor-driven boiler feed pumps.

2. Overview of fluid couplings
A fluid coupling is a rotating speed controller that is placed between the driver (such as a motor) and driven machine (such as a turbo machine) to vary the output rotating speed while keeping the input rotating speed constant.

The major features of fluid couplings are that they are capable of:

(1) Reducing the power consumption by controlling the output rotating speed according to the plant load;
(2) Absorbing shocks to the driver and driven machine because they transmit power through oil; and
(3) No need for special driver design or electric equipment even for a turbo machine with a large inertial moment, because they allow the driven machine to be started with almost no load applied to it.

2.1 Basic structure
A fluid coupling basically consists of two components: an impeller and a runner. The impeller is coupled to the drive shaft and is also called the pump vane. The runner is coupled to the driven shaft and is also called the turbine vane.

As Figure 1 shows, the impeller and runner are wheels that have radially-arranged straight blades, face...
each other, and provide an impeller casing to contain oil inside.

2.2 Operation principles
A fluid coupling converts power from the drive shaft into velocity energy of oil, and uses this energy to transmit the power to the driven shaft; as Figure 2 shows, it may be considered to be a combination of a pump and a turbine efficiently housed in a casing. When the drive shaft turns, the impeller functions as a pump, giving centrifugal force to the oil inside it. With this velocity energy, the oil flows into the runner acting as a turbine, transmitting rotary power to the runner. The oil flow from the impeller into the runner requires a difference in rotating speed (slip) between the impeller and runner. For this reason, the output rotating speed must be slightly lower than the input rotating speed.

2.3 Speed variation principles
As described above, a fluid coupling uses velocity energy of oil to transmit power. With an increase in the amount of oil flow from the impeller to the runner, the power to be transmitted increases, resulting in a higher output rotating speed. On the other hand, with a decrease in the amount of oil flow, the power to be transmitted decreases, resulting in a lower output rotating speed. The amount of oil flow from the impeller to the runner is determined by the amount of oil filled inside the coupling. As Figure 3 shows, a fluid coupling, which operates at a given output rotating speed, controls the output rotating speed by scooping a certain amount of oil inside the coupling using a scoop tube to regulate the oil amount.

When the scoop tube is at the position nearest to the rotor shaft center, output rotating speed is maximized and as the tube moves toward the rim, the speed decreases.

3. Fluid coupling for motor-driven boiler feed pump

3.1 Structure
Figures 4 and 5 show the structure and an appearance photograph, respectively, of the large-capacity, high-speed fluid coupling (model GCH) used to drive motor-driven boiler feed pumps in thermal power plants.
[1] Speed increasing gear
The boiler feed pump requires faster rotation speed than the motor, so a speed increasing gear is housed inside the casing. With a carburized and finely grinding tooth surface, the gear wheel is designed to provide a sufficient load capacity and durability. For a large-capacity application, a double-helical gear is adopted.

[2] Impeller and runner
The impeller and runner, power transmitting parts, are placed on the side of the high-speed shaft so that they can be smaller and lighter. Since they are used at high rotating speed and transmit large power, they are made of forged steel for higher reliability.

[3] Bearings
A fluid coupling uses forced-lubricated hydrodynamic bearings because they receive a load caused by reaction force of gear meshing and a thrust load produced by the impeller and runner as well as the coupling operates at a high rotating speed.

[4] Scoop tube
Operating at stepless output rotating speed, the fluid coupling for motor-driven boiler feed pump is provided with a scoop tube.

Since the scoop tube is used to scoop oil circulating at a high speed, the tube tip is made of a special alloy for higher erosion resistance.

[5] Oil pumps
This fluid coupling is provided with three oil pumps: main and auxiliary oil pumps for lubricating the bearings and working oil pump for supplying oil to the coupling. The main and working oil pumps are interlocked with the drive shaft and the auxiliary oil pump is driven by a small motor. They are all gear pumps, which provide stable oil supply.

3.2 Scoop tube operation mechanism
As a mechanism for operating the scoop tube, an electro-hydraulic servo mechanism, which is our proprietary technology, is used to achieve a compact and highly reliable system.

Operation principles of the electro-hydraulic servo mechanism are described below.

3.2.1 Speed reducing mechanism (Figure 6)
When the actuator rotates in the X direction, the compression chambers A and D become connected with each other through the groove C cut on the rotary pilot, increasing the pressure in the chamber D. Since the
internal piston in the chamber D has a pressure receiving area approximately two times that in the chamber A, the piston moves leftward in the figure. With this piston movement, the scoop tube coupled to the piston moves toward the rim of the rotor (see Fig. 3 (b)), reducing the output rotating speed.

### 3.2.2 Speed increasing mechanism (Figure 7)
When the actuator rotates in the Y direction, the chamber D becomes connected with the drain port through the groove E cut by the rotary pilot, decreasing the pressure in the chamber D.

Since the chamber A is constantly pressurized, the piston moves rightward in the figure; the scoop tube, coupled to the piston, moves toward the shaft center (see Fig. 3 (a)), increasing the output rotating speed.

### 3.3 Working oil system
The oil to the coupling is supplied by the working oil pump, which is interlocked with the drive shaft. As Figure 8 shows, the working oil system forms a closed circulation system, downsizing the oil tank as well as improving speed-increase responsiveness. In addition, the oil regulating valve regulates the working oil supply to the coupling according to the scoop tube position, achieving improved operation efficiency as well as stable control of rotating speed.

### 3.4 Lubricating oil system
As Figure 9 shows, the main pump, which is interlocked with the drive shaft, lubricates the bearings. During start-up, shut-down and emergencies, the motor-driven auxiliary oil pump lubricates the bearings. This lubricating oil system also lubricates the bearings of the boiler feed pump and the main motor, eliminating the need for installing a separate lubricating oil system.

### 4. Trends of fluid couplings for boiler feed pumps
Figure 10 shows changes in rated transmitted power of fluid couplings for motor-driven boiler feed pumps. With the increase of capacity and pressure of boiler feed pumps, the rated transmitted power has increased year by year, and this trend is expected to continue.

At the same time, the increase in construction of power plants for independent power producers (IPP) has created a demand for smaller-capacity fluid couplings.
5. Conclusion

This paper covered fluid couplings for motor-driven boiler feed pumps used for thermal power generation. Besides this, fluid couplings are used in many plants to control the rotating speed of turbo machinery, helping the plants improve operation efficiency. In the future, further improvements and extension of the application range will be required to help reduce environmental load and improve productivity.