Development of Micro Pump and Micro-HST for Hydraulics

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Recently, an energy-saving drive system which combines a small displacement pump with an AC servo motor or inverter motor can be frequently seen. Therefore, our company has developed small axial piston pump/motor series with a spherical valve plate using our original design and the precision processing technology. Furthermore, we have developed a compact HST as well in order to contribute to the low birthrate and longevity issue. In this report, I briefly explain the efficiency and application example of the micro pump and HST with a spherical valve plate.

Keywords: Hydraulics, Design, Pump, Motor

1. Introduction

The demand for hydraulic pumps and motors is escalating in recent years. While larger capacity and higher pressure pumps and motors are required, those of more compact and lighter weight are also needed in increasing numbers.

The reason is a pump with small capacity can satisfy a large variety of specifications using a hybrid drive system that is a combination of the merit of hydraulic and that of AC servo motor and inverter motor that is easy to control, and shows significant energy-saving effects in the many industrial areas. Moreover, in this aging society where working population is less, people demand convenience and affluence in their daily life, which leads to the large demand for compact and easy-handing vehicles and work machines. In order to make these compact vehicles, the development of essential parts are also required.

With the above as background, we want to make the best use of our original design and precision process capability for the development of micro axial piston pumps, motors and HST to meet the demand from the society and industry.

This paper explains briefly the basic technology which realized the developments, features of micro pumps using our essential parts and application examples.

2. Adoption of Spherical Valve Plate

Spherical valve plate has the features shown in the reference 1). Spherical valve plate is the first and foremost important aspect for developing a micro pump and HST that meet the above mentioned purposes. It has been employed in a pump and motor design requiring large capacity and higher pressure. There were no established designing theories, therefore sliding surface such as spherical diameter was designed by trial and error and it would take many hours. However, together we established the method of calculation to decide the related dimension with concept of moment balance shown in Fig.1. With this calculation, no trial and error development was needed in every type of rotary group mentioned in this report.

On the manufacturing side, we made best use of Takako’s precision manufacturing technique that we acquired from Takako’s long time experience and therefore produced the rotary components easily with lower cost.

Fig.1   Moment balance of spherical valve plate
In short, we preceded development in parallel simultaneously and shortened drastically the period until realization.

The following characteristics of spherical valve plate are realized with this development.
- Stable performance even at high-speed and high-pressure
- Tolerant of high inlet vacuum
- More tolerant of system contamination
- Torque efficiency is high, thus reduce the energy loss
- The increase in temperature is less and degradation of fluid oil is less.
- High efficiency can be maintained in a wide range of rotation speed.

3. Composition and Merit of Micro Pump

Figure 2 shows the latest micro pump series and Table 1 shows related specifications. The displacement referred in the table follows to JIS 8383 from our initial intention of exporting overseas and thus conforms to the International Standardization Organization (ISO 3662).

![Fig.2 Appearances and rotary parts of micro pump series](image)

![Table 1 Specifications of micro pump series](image)

<table>
<thead>
<tr>
<th>Displacement(cm³)</th>
<th>Pressure (MPa)</th>
<th>Speed (min⁻¹)</th>
<th>Weight (g)</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4</td>
<td>14</td>
<td>2000</td>
<td>295</td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
<td>21</td>
<td>3000</td>
<td>457</td>
</tr>
<tr>
<td>3</td>
<td>1.6</td>
<td>21</td>
<td>3000</td>
<td>755</td>
</tr>
<tr>
<td>4</td>
<td>3.15</td>
<td>21</td>
<td>3000</td>
<td>1980</td>
</tr>
<tr>
<td>5</td>
<td>6.3</td>
<td>21</td>
<td>3000</td>
<td>2000</td>
</tr>
</tbody>
</table>

Prof. Tanaka et al. studied the characteristics of many hydraulic and electric actuators, and made Fig. 3 which shows comparative chart between rotating parts inertia and rated torque.

We put ● marks at the inertia and torque of Takako’s micro pumps in Fig. 3.

As you can observe, other hydraulic manufactures have rarely produced pumps that covers such a wide range, which means that we have developed a new product region.

These newly developed micro pumps are the result of our unrestricted and accurate designing technology of rotary groups including the spherical valve plate as above-mentioned, together with production technology that made it possible to manufacture them as quality products at lower cost.

4. Micro Pump’s Representative Characteristics

The efficiency for the displacement of 0.4 cm³ and 1.35 cm³ are shown in Fig.4 and Fig.5 respectively.

![Fig.4 0.4 cm³ performance curve (fixed speed)](image)

These data were recorded when the pressure were changed at a fixed rotational speed and a constant temperature. Due to its small displacement, the 0.4 cm³ pump’s efficiency is a little bit low at this pressure region, however, the 3.15 cm³
pump demonstrates more than 85% efficiency even at 7 MPa (1000 psi).

On the other hand, Fig.6 shows how the efficiency changed when rotational speed is increased with 1.6 cm³ displacement at a fixed pressure. The efficiency reached to 80% at 250 min⁻¹ and exceeds 90% at 2000 min⁻¹. At higher speeds the efficiency becomes slightly lower due to turbulent resistance.

Figure 7 shows the micro pump demonstrates much higher efficiencies compared to gear pump. There is a significant improvement in the efficiency, especially at high pressure and slow speeds. The main reason is that the sliding-in phenomenon of spherical valve plate configuration prevents the inclined opening of sliding surface and reduces the leakage from the clearance between cylinder block and valve plate.

5. Major Application Example of Micro Pump

About 10 applications integrating this series of micro pumps have already tested, passed and prepared for mass production by our customers. Since they are not officially announced yet, let us introduce only one example here.

**Contamination measurement device**

Figure 8 shows a photo of device that is a cleanliness monitor of hydraulic fluids in which the 0.4 cm³ pump used.

Figure 9 shows the installation of the 0.4 cm³ micro pump inside the test device.
Originally a gear pump was used for pumping the hydraulic fluid, however, the generation of bubble prevents the unit from measuring correctly. By changing the gear pump to a piston pump, the bubble problem was completely eliminated.

The device makes it possible to automatically get real-time cleanliness data in NAS and/or ISO grade on the monitor while making the fluids flow into it without collecting on the filter and counting by particle size as is the conventional technique. The customer is now studying ways to increase the number of varieties of fluid oil to be measured and items to be measured. Because the test unit is compact, it doesn’t require a lot of space and with a monitoring function, wide variety of usage possible.

6. Micro-HST Series for Vehicles

Basic displacement series for the HST’s are for 2.5 cm³ and 5.0 cm³. Figure 10 shows structure of typical rotary group and Fig.11 shows its the outside appearance.

As Fig.12 shows, compared to a HST with a flat valve plate that has similar displacement, a HST that has a spherical valve plate displays overwhelmingly improved performance.

This HST at present is used for agricultural rotary tillers and snow blowers. Figure 13 shows an agricultural rotary tiller. In the future wide varieties of applications, including lawn mower and small farm carts, are expected.

7. Conclusion

Our micro pump are not only penetrating into to markets but also becoming high value-added products that take back people’s understanding about the advantage of hydraulics as a countermeasure to the various problems that were happening from electro-driven equipment that had once replaced hydraulic-driven equipment.

Also in the future, we would like to contribute to society by producing products that meet market requirement and are environmentally friendly.
This paper has been firstly presented in the 2\textsuperscript{nd} Japan-China Joint Workshop on Fluid Power 2012 in Tokyo, May 23, 2012.

References
