Product Introduction

# Development of Vane Pump for Medium Passenger Vehicle CVT

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## 1 Introduction

This report introduces a vane pump for medium passenger vehicle CVT Note 1). This vane pump will be mounted, as a hydraulic power source, to the transmission mechanism for medium passenger vehicles developed by JATCO Ltd. as the successor of existing CVT unit that has already been in mass production and rolled out globally.

Production of this product was started at KYB Kanayama in October 2020.

Note 1) An acronym for Continuously Variable Transmission.

## 2 Newly Developed CVT Unit

Compared with the existing type, the new CVT unit that has just been developed by JATCO Ltd. has the following features:

① Lower fuel consumption due to lower friction
② Superior operation feeling
③ Lower NVH Note 2)

The new CVT unit has been developed on the assumption that it will mainly be combined with an environmentally friendly downsized turbo engine.

The product is backed up by a global supply chain with production sites including Japan, China, and Mexico.

Note 2) An acronym for Noise, Vibration, and Harshness.

**Photo 1** Appearance of new CVT unit (Extracted from JATCO Ltd.'s website)

## 3 Newly Developed Vane Pump

Partly because it was to be mounted as the successor of the existing CVT, the new vane pump needed to be rolled out globally including Japan, China, and Mexico in the same manner as for the existing vane pump. So, it was mandatory to achieve a sophisticated design quality during the development stage.

Based on the existing vane pump, we promoted the development of a new model with a focus on the discharge performance and durability being equivalent to or superior to that of the existing model as well as lower friction. As a trade-off for lower friction with equivalent discharge performance, a vane pump will inevitably be less durable. Still, we obtained an optimal design satisfying the specification requirements.

Furthermore, we strove to reduce the pump weight for environmental conservation and lower the production cost that was also demanded by end-users.

Photo 2 shows the appearance of the newly developed vane pump. Table 1 shows the detailed specifications and Table 2 the major improvements.

**Photo 2** Appearance of new vane pump

**Table 1** Specifications of new vane pump

| | |
|---|---|
| Type | Balanced vane pump |
| Basic discharge | 11.3 $cm^3$/rev |
| Pump revolutions | Up to 7300 rpm |
| Discharge pressure | Up to 6 MPa |
| Oil temperature | -40°C - 140°C |
| Production site | Japan, China, Mexico |

**Table 2** Performance improvements

| | |
|---|---|
| Improvements | ・A notch in the cam ring<br>・Aluminum cover instead of iron cover<br>・Ports of an optimal shape |

## 4 Performance Improvements

### 4.1 Optimally Designed Cam Ring Notch

To ensure that the CVT unit can deliver lower friction for lower fuel consumption, the driving torque of the vane pump must be reduced.

The driving torque equation for vane pumps can be expressed as (Basic discharge × Pressure) / 2π. Since there is no change in service pressure between the existing and new models, the basic discharge was reduced for lower driving torque. However, a precondition was that the new model must meet the performance specifications equivalent to those of the existing one.

The new vane pump is of a type with an integral flow control valve (spool). It should be designed to internally maintain a flow rate that can well cover the required discharge characteristics according to the pump speed.

A vane pump with an internal flow control valve can make use of the power of any excessive internal circulating flow to enhance the suction capability (Fig. 1).

In designing the new pump, the basic discharge was reduced, resulting in about 10% lower internal circulating flow. This led to lower suction capability, making the pump likely to suffer cavitation (Fig. 2).

Cavitation is a phenomenon in which the air dissolved in the hydraulic fluid forms bubbles. Repetitive formation and collapse of such bubbles wears and damages the pump components. This is because we expected the new vane pump to be unable to satisfy the requirements for durability testing merely by reducing the basic discharge while keeping the other specification items unchanged from the existing ones.

Several countermeasures could be considered. From the viewpoint of cost-effectiveness, we introduced a "notch" in the suction part of the cam ring that serves as a suction oil path. The notch expanded the suction oil path to reduce the pressure loss, raising the suction capability (Fig. 3).

In response to the introduction of the notch, the surface pressure on the cam ring applied by the sliding vanes increased, resulting in a higher PV factor Note 3). This resulted in various durability disadvantages including abnormal wear of the cam ring.

Then, in order to determine the balance between the notch depth and the PV factor, in other words, the point at which performance and durability can go hand in hand, the new vane pump was subjected to a durability test to identify the critical point. We finally determined the optimal size of the notch (Fig. 4).

Through these development efforts, the new vane pump satisfied both the durability and performance requirements, achieving the lower driving torque as aimed for.

Note 3) PV factor = P (surface pressure) × V (velocity); One of the wear factors

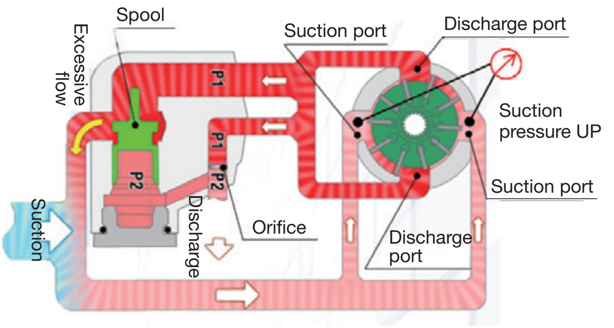


**Fig. 1** Oil circulation in vane pump

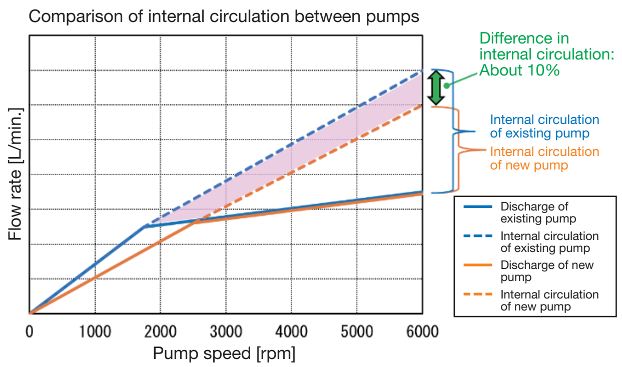


**Fig. 2** Comparison of internal circulation between pumps

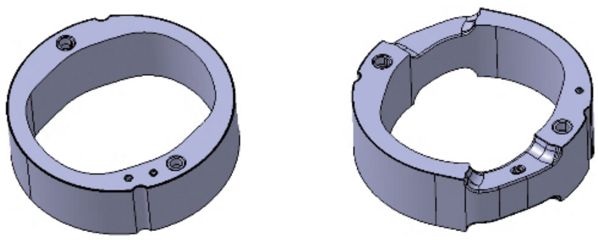


**Fig. 3** Comparison of cam ring specifications

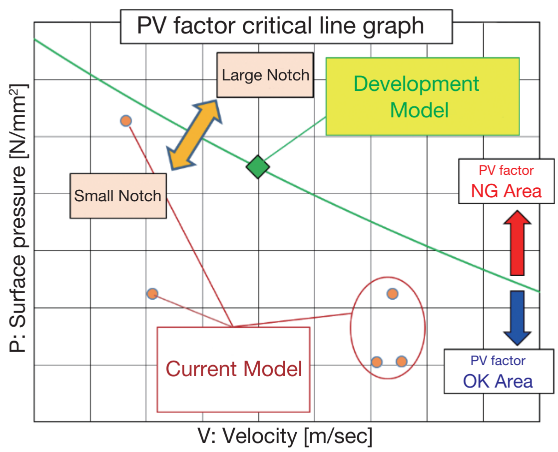


**Fig. 4** PV factor critical line graph

### 4.2 Aluminum Cover Instead of Iron Cover (Weight and Cost Reduction)

The existing vane pump for medium passenger vehicle CVT used a core oil path cover made of cast iron (Figs. 5 and 6). The new product has been designed to have an aluminum diecast cover. With this design, the weight of the cover alone has been reduced by 350 g, which is an approximately 30% reduction in the total weight of the vane pump, contributing to substantial weight reduction, and consequently lower fuel consumption.

Furthermore, the manufacturing method has been changed from the cast iron system to an aluminum diecast system. This has helped improve the productivity and reduce the manufacturing cost.

Along with the introduction of the aluminum diecast cover, however, the geometry of the oil path inside the cover changed in such a manner that the oil was unlikely to flow smoothly. We noticed that the new oil path geometry worsened the pump's NVH (Figs. 7 and 8).

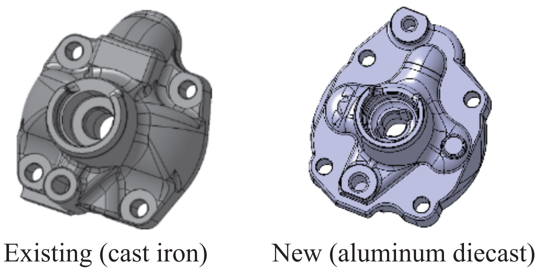


**Fig. 5** Comparison of appearance of cover

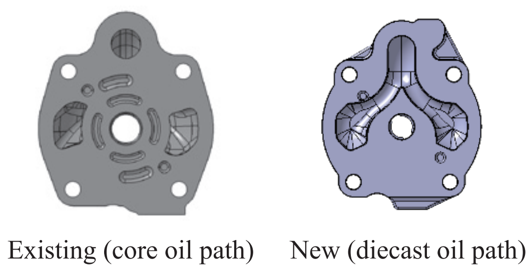


**Fig. 6** Comparison of oil path

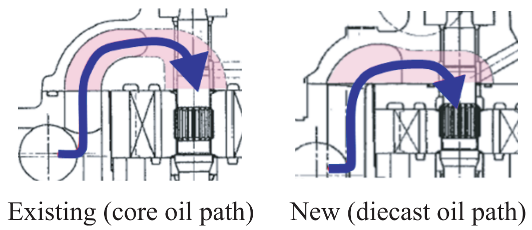


**Fig. 7** Comparison of flow in oil path

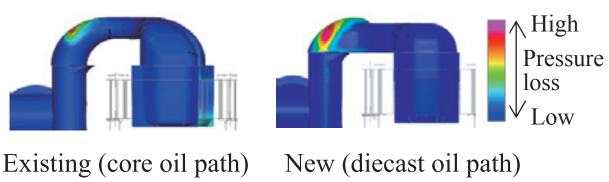


**Fig. 8** Visual comparison of pressure loss in oil path

### 4.3 Ports of Optimal Shape

It was mandatory to improve the pump's NVH in order to satisfy the requirement that the NVH of the new pump be equivalent or superior to that of the existing model. However, the oil path of the new cover, which was a factor that deteriorated NVH, could not be improved from the viewpoint of manufacturing method. It was impossible to design an oil path for the diecast cover that is similar to that of the cast iron cover.

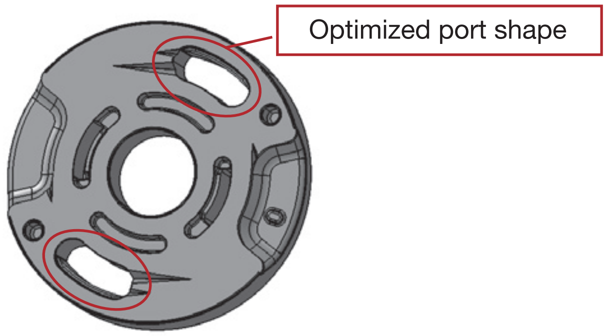


**Fig. 9** Ports of side plate

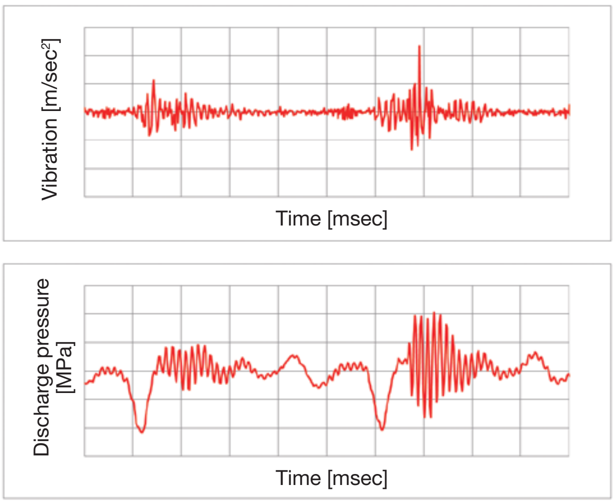


**Fig. 10** Pump discharge pressure and vibration before improvement

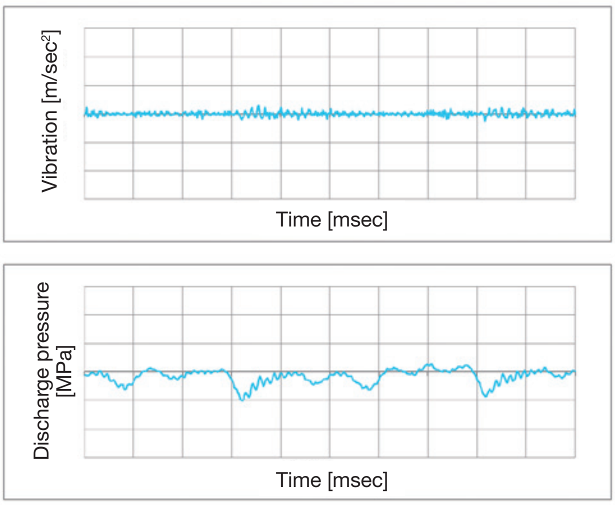


**Fig. 11** Pump discharge pressure and vibration after improvement

Then, we decided to pursue an optimal shape of the ports of the side plate for the aluminum cover. With the optimal port design, the discharge pulsation was reduced to suppress the vibration, satisfying the NVH requirement (Figs. 9, 10 and 11).

## 5 Evaluation

This development project was highly rated by JATCO Ltd. and won the FY2020 JATCO QCDS Best Performance Award.

This prize is awarded only to the one company globally rated as overall No.1 in development, quality, cost and delivery. We were only able to win this prize with the cooperation from those concerned not only in Development but also in other departments. We would like to take this opportunity to deeply thank all those concerned.

As a quality-specific prize, we also won the JATCO Regional Special Award at the same time.

Furthermore, KIMZ (KYB Industrial Machinery (Zhenjiang)), which launched production in March 2021 after KYB Kanayama was established, won the QCDS A-rank Award. KYB has been highly evaluated both at home and abroad.


**Photo 3** QCDS Best Performance Award (right), Regional Special Award (left)


**Photo 4** QCDS A-rank Award (China)

## 6 Conclusions

Compared with the existing model, this newly developed product has achieved the following:

① About 10% lower pump driving torque
② About 30% lighter pump
③ Simultaneous achievement of durability and low driving torque
④ Lower noise
⑤ Lower cost

The considerations discussed in this development project are shown in the inclined developed views of the existing and new products (Fig. 12).

## 7 In Closing

We sincerely appreciate the cooperation of all those engaged in program development from JATCO Ltd. and all other partner companies and all those concerned in relevant KYB departments.

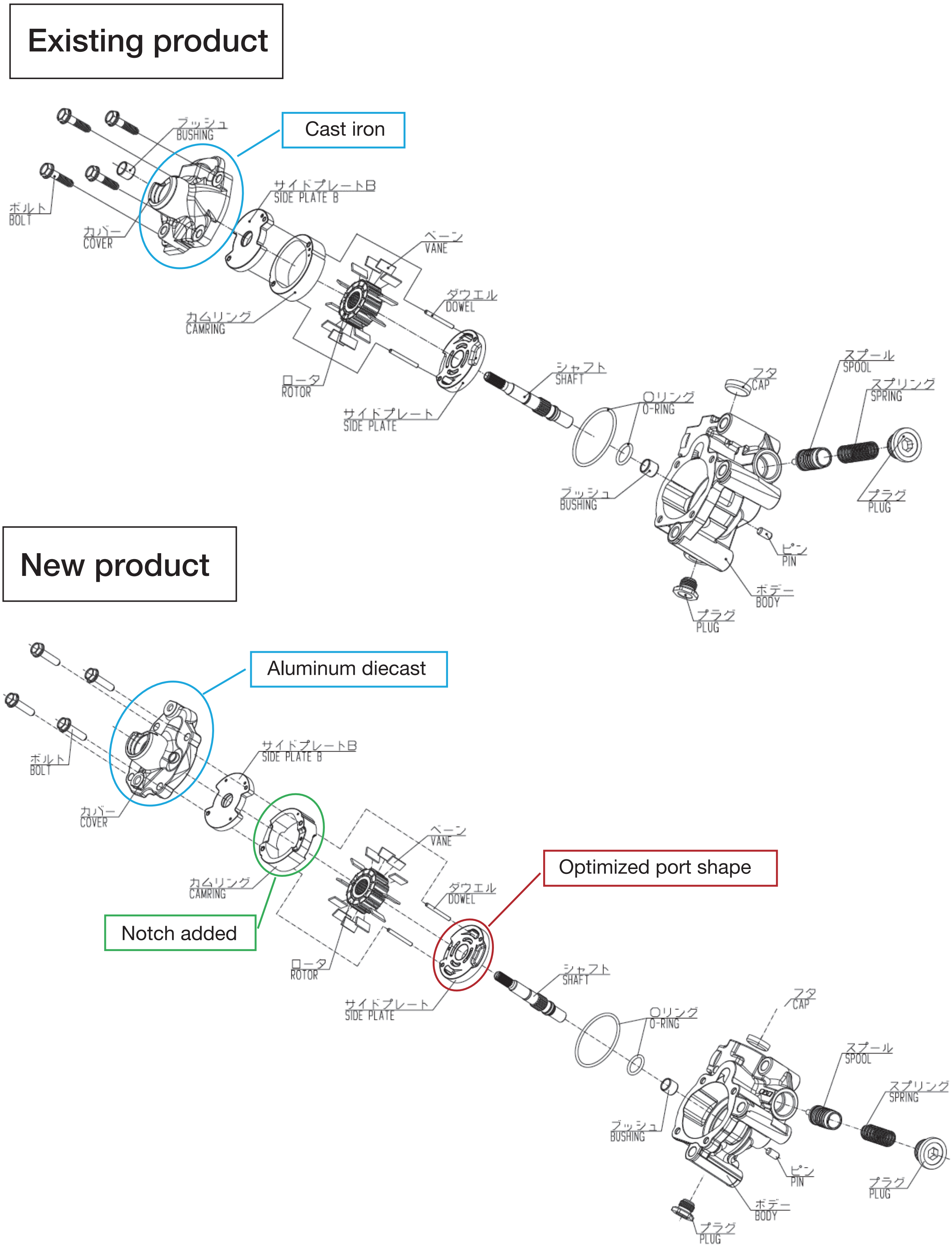


**Fig. 12** Inclined developed views of existing and new products

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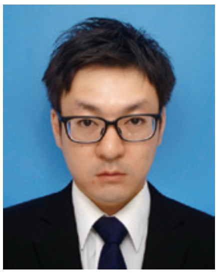

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