Product Introduction

Development of Vane Pump for AT

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1 Introduction

The vane pump for AT [Note 1)] introduced in this paper is to be used as a hydraulic source of the new AT mounted on the new SUV [Note 2)] that has been developed by Mazda Motor Corporation. Manufacturing of this product was launched in December 2021.

Note 1) Automatic Transmission.

Note 2) Sport Utility Vehicle.

2 About AT Unit

The AT unit (Photo 1) on which the newly developed vane pump will be mounted is a step-type automatic transmission (hereinafter “the AT"). The AT uses a power transmission system that is different from that used in CVT [Note 3)] for which KYB has developed and produced vane pumps so far. The pump used for the AT is required to deliver a discharge pressure different from that of the pump used for CVT. KYB is preparing its first vane pump product lineup for the AT. Table 1 compares the specifications of these two types of transmission.

Note 3) Continuously Variable Transmission.

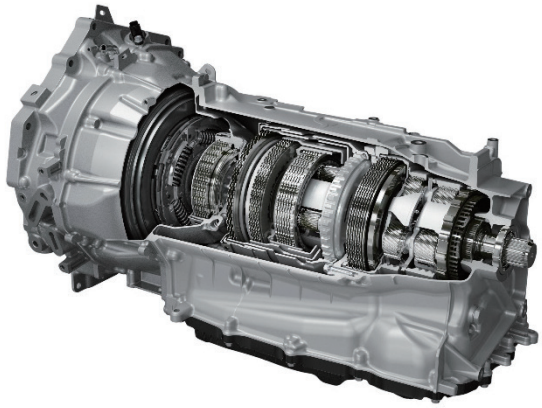

Photo 1 Appearance of transmission unit *

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Table 1 Comparison of specifications of AT and CVT

Type	AT	CVT
Speed change by	Gearset	Belt
Hydraulic pressure requirement	Up to 2.1 MPa	Up to 6.0 MPa

3 Newly Developed Vane Pump

The newly developed vane pump is based on the existing product for CVT. Since the pump specifications for the AT are different from those for CVT as described above, we reviewed all the specifications of the existing vane pump for CVT to set up optimal specifications for the AT during the development stage.

The first point to be considered in the development stage was that the vane pump for the AT is only required to deliver a low discharge pressure. Then, we reduced the friction of the existing product as far as possible while maintaining the required durability, contributing to improved fuel efficiency of the vehicle.

We also improved NVH [Note 4)] which is essential for the pump start-up characteristics and the vehicle ride comfort, achieving an optimal design to satisfy the required specifications.

Photo 2 and Table 2 show the appearance and detailed specifications of the new vane pump respectively.

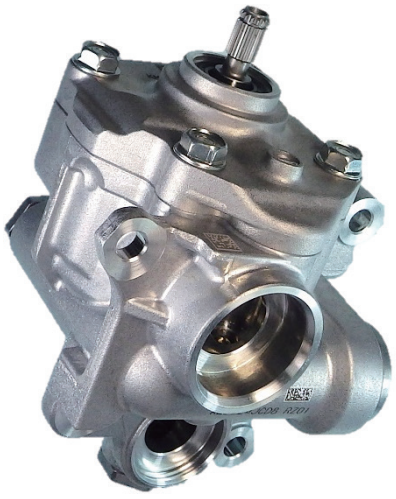

Photo 2 Appearance of new vane pump

Table 2 Specifications of new vane pump

Type	Balanced vane pump
Basic discharge	15.9cm^3/rev
Pump revolutions	Max. 7,420 rpm
Discharge pressure	Max. 2.1 MPa
Oil temperature range	-40˚C to 165˚C
Production site	Japan

Note 4) Noise, Vibration, and Harshness.

4 Performance Improvements

4. 1 Improvement of Volume Efficiency

In the newly developed vane pump, the clearances of the sliding parts have been optimized, specifically reduced, to match the discharge pressure. The smaller clearances lead to less leakage or lower flow loss in the pump, resulting in higher volume efficiency but lower durability, such as seizure of the sliding parts, is unavoidable. Still, a deformation study through FEM analysis (Fig. 1) and a critical durability test helped us set an optimal clearance. As a result, the volume efficiency has been improved while the required durability is maintained.

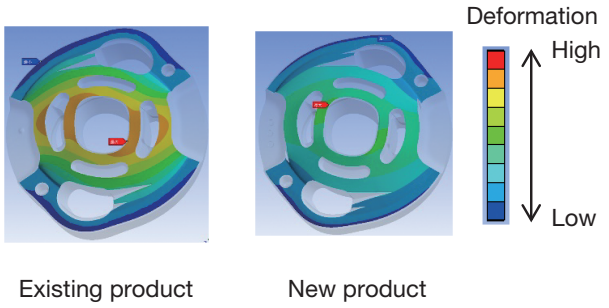

Fig. 1 Example of FEM analysis

4. 2 Improvement of Mechanical Efficiency

The driving torque of a vane pump is the sum of the theoretical torque and the loss torque (friction). To improve the mechanical efficiency, it is primarily necessary to reduce the loss torque. Major components of the loss torque include the torque consumed for pressure loss in operating the flow control valve [Note 5)] and the sliding torque for the vanes to maintain contact with the walls of the cam ring. To reduce these two kinds of loss torque, the following improvements were made.

Note 5) When the pump has an integrated flow control valve.

[1] Lowering the working pressure of the flow control valve
[2] Using a thinner cam ring
[3] Using thinner vanes

For item [1], lowering the working pressure of the flow control valve can reduce the loss torque due to pressure loss. This causes the flow control valve to internally circulate excess flow, thereby enabling the pump to leverage the flow to improve the suction capability (Fig. 2). However, the reduced working pressure naturally lowers the hydraulic pressure in the internal circuit, resulting in the disadvantage of lower resistance to cavitation. Cavitation is a phenomenon in which the air dissolved in the hydraulic fluid is released as air bubbles. Repeated release and dissipation of such air bubbles causes wear or damage to the pump components.

To resolve the problem, the suction part of the cam ring was machined to have notches, expanding the suction oil path. This reduced the pressure loss to improve the suction capability (Fig. 3).

For item [2], the cam ring bore, which decides the basic discharge, has been enlarged in some parts from that of the existing product. With this design change, the width of the cam ring has been reduced by 24% (Fig. 4). This reduced the area of vanes to which pressure is applied, resulting in a lower sliding torque.

For item [3], KYB introduced its thinnest vanes (29% thinner than the existing vanes) for the first time to further reduce the area to which pressure is applied and the sliding area (Fig. 5).

These improvements reduced the loss torque by about 20% from the existing product that performs equivalent work, successfully improving the mechanical efficiency.

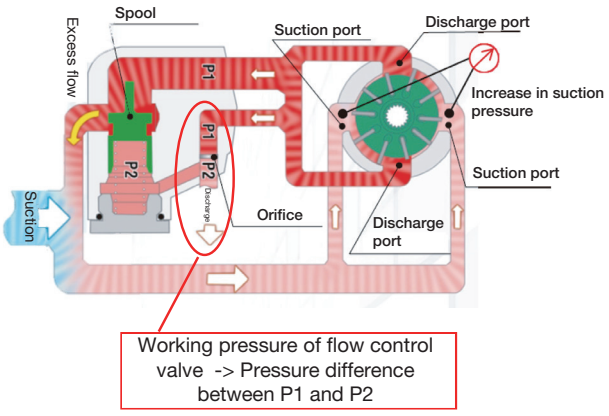

Fig. 2 Oil circuit in vane pump

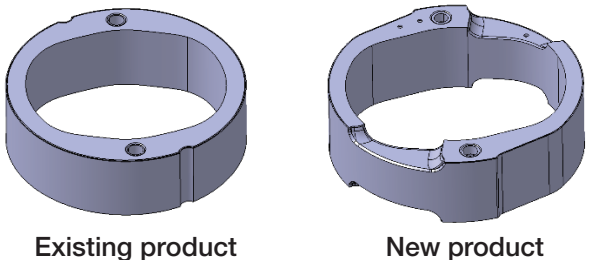

Fig. 3 Comparison of cam ring specifications

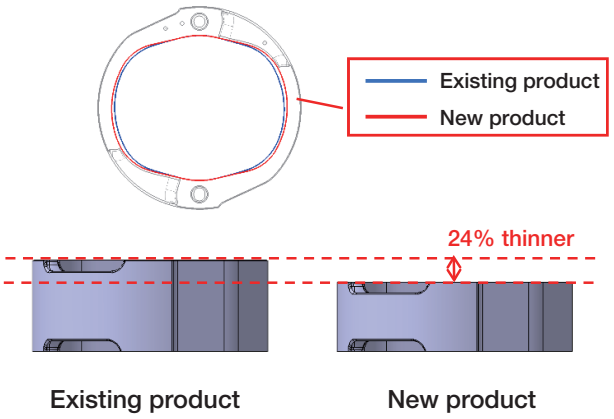

Fig. 4 Illustration of thinning of cam ring

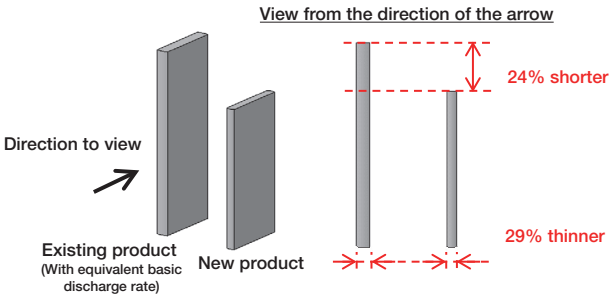

Fig. 5 Thinning of vanes

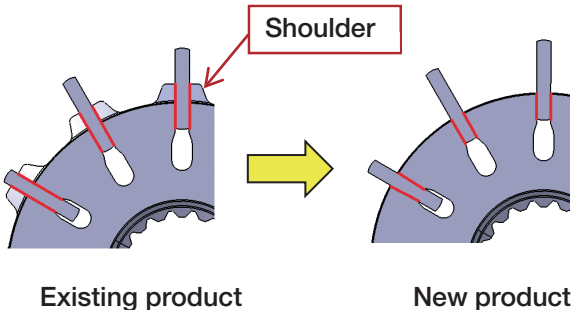

Fig. 6 Rotor geometry

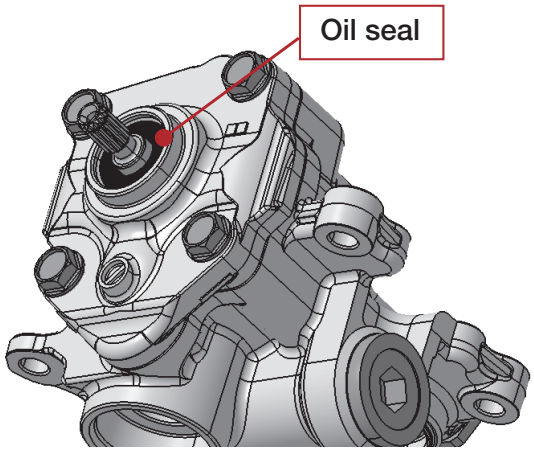

Fig. 7 Oil seal

4. 3 Improvement of Start-up Characteristics

As described above, reduction of the loss torque was achieved by thinning the vanes to deliver a lower contact pressure against the walls. The trade-off was lower start-up capability. As the transmission pump has recently been required to deliver rapid start-up from the viewpoint of improvement of automobile functionality, the start-up characteristics needed to be improved.

Then, we changed the rotor design to eliminate the "shoulders", reducing the sliding resistance of the sticking-out vanes (Fig. 6). We also optimized the back pressure for pushing the vanes out and the clearance of the sliding parts of the vanes to improve the start-up capability at low temperatures, successfully achieving start-up characteristics that were superior to those of the existing product. Furthermore, the pump cover has been fitted with an oil seal to attain improved airtightness, preventing oil release from the pump during halts and reducing the time needed to suck the fluid again during restart. These measures contribute to further improved start-up characteristics (Fig. 7).

4. 4 Improvement of NVH

As automobiles have recently become quieter year after year, the demand for quieter transmissions has been rising. It is also a must for pumps to have improved NVH characteristics.

In the newly developed vane pump, the port profile in the side plate was optimized to suit the environment where the transmission unit is used (Fig. 8). The optimized port helped reduce the discharge pulsation, suppressing vibration. The notches in the side plate, which connect the vane chamber with the port and help build a pressure in the vane chamber, were tuned through simulation (Fig. 9). This improved the quietness of the pump during both normal and high-speed rotations.

While the existing product had these notches only in side plate A, the new product has the notches in both side plates A and B. This design change increased the supply of high-pressure fluid to the vane chambers to alleviate the delay in pressure rise during high-speed rotation or during the use of fluid with much entrained air, serving as measures for cavitation (Fig. 10).

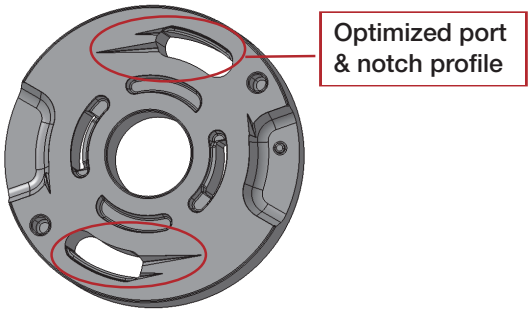

Fig. 8 Ports and notches of side plate

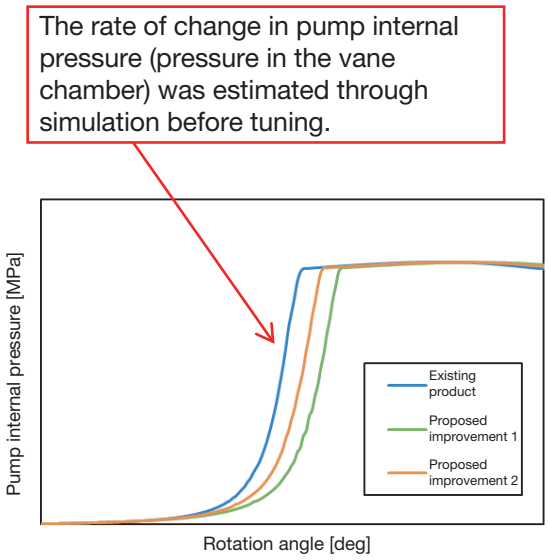

Fig. 9 Example of simulation of pressure in vane chambers

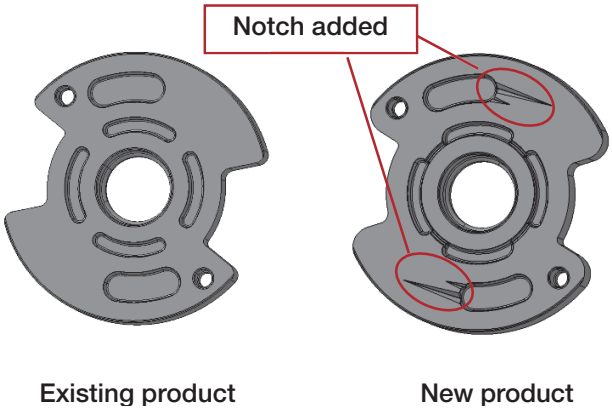

Fig. 10 Notches added

5 Conclusions

We have developed KYB's first vane pump for the AT and achieved the following:

[1] Development of a vane pump optimized for the AT
[2] About 20% lower loss torque than existing product
[3] Achievement of both durability and low driving torque
[4] Improved start-up characteristics
[5] Lower noise

The improvements discussed in this development project are shown in the inclined development views of the existing and new products (Fig. 11).

6 In Closing

The vane pump for the AT was developed according to specifications that KYB has never experienced in its product development history. Mass production of the vane pump has been achieved through great cooperation of all those who were involved in the development project.

I would like to take this opportunity to deeply thank all partners including those involved in the program from Mazda Motor Corporation as well as all personnel in the related functions of KYB.

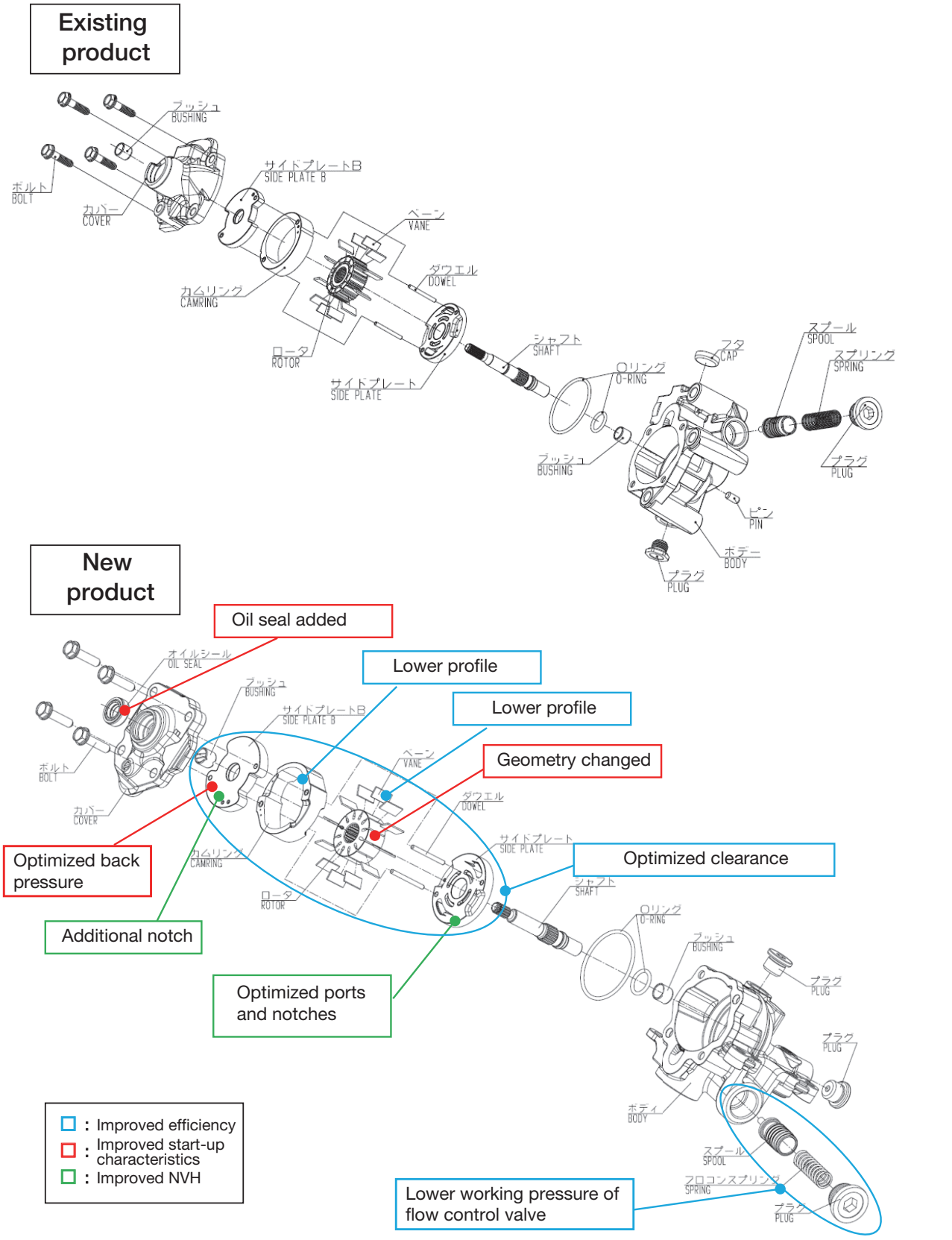

Fig. 11 Inclined development views of existing and new products

Author

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Joined the company in 2012.Pump Engineering Dept., Steering Business Dept., Automotive Components Operations Engaged in design of vane pumps.