Product Introduction

Development of Cartridge Type Vane Pump for Electric Pumps

KUBO Kohei

1 Introduction

KYB began producing vane pumps for hydraulic power steering in 1955. Today, it develops and supplies vane pump products as hydraulic sources of CVT or AT to meet market needs.

This paper introduces a cartridge type[Note 2)] vane pump for electric pumps[Note 1)] to be used as the hydraulic source of a new AT[Note 3)] or CVT[Note 4)] that contributes to higher fuel efficiency of the vehicle.

Production of this product was started in October 2022.

Note 1) An oil pump driven by an electric motor.

Note 2) A mounting system in which the pump housing is provided on the main machine to form an assembly when mounted.

Note 3) An acronym for Automatic Transmission.

Note 4) An acronym for Continuously Variable Transmission.

2 About Electric Pumps

First of all, let me explain what an electric pump is.

An electric pump is a pump driven by a motor that can be controlled by itself by receiving a signal from the vehicle (main machine) (Fig. 1). Its main feature is the ability to deliver any required flow rate at any required time, drastically reducing waste.

With the recent electrification of vehicles, electric pumps are being used in various applications with higher demands. Examples of these applications include cooling/lubricating electric drive motors or batteries, and hydraulic sources of AT or CVT for hybrid cars.

Note that vane pumps for CVT/AT traditionally mass-produced by KYB are driven by engines and are called mechanical pumps.

Mechanical pumps have been improved many times to achieve very good performance, but the following challenges remain.

[1] They must have a large displacement volume to provide the required flow rate even at low speeds, requiring a high theoretical pump torque.

[2] They inevitably discharge a larger flow than necessary at high speeds, resulting in a lot of waste.

[3] They require an electric pump for pressure retention to be able to discharge when idling.

These challenges of mechanical pumps can be solved by electric pumps if their speed is controlled in a manner appropriate to the application. This can lead to an improved mileage of the vehicle.

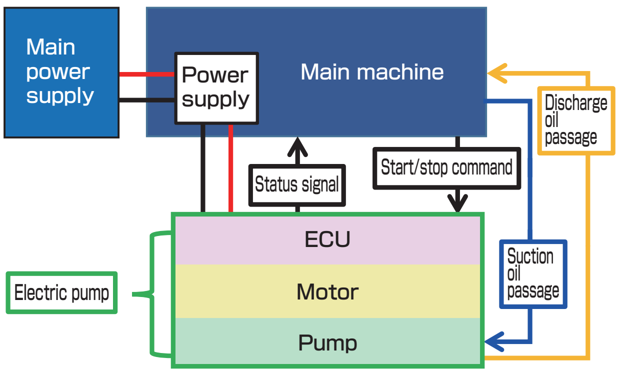


Fig. 1 Electric pump

3 Development Details

Figs. 2 and 3 and Table 1 show the appearance, a diagrammatic development view, and detailed specifications of the cartridge type vane pump developed in this project, respectively.

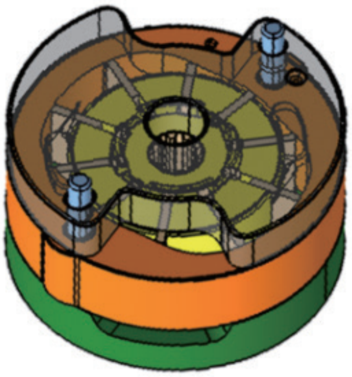


Fig. 2 Appearance of the electric vane pump

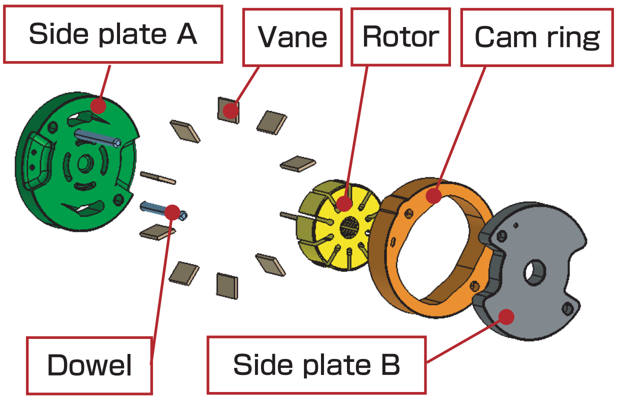


Fig. 3 Diagrammatic development view

Table 1 Specifications of the developed pump

Type	Balanced vane pump
Displacement volume	～4 ㎤/rev
Maximum rotation speed	3,300rpm
Maximum pressure	4.0MPa
Operating temperature	−40～165℃

3. 1 Development Concept

For an electric pump to be adopted in a vehicle equipped with a traditional mechanical pump system, it must provide superior cost performance in terms of space saving, energy saving, low noise, and low cost.

We then reviewed the design of the traditional mechanical pump for the following issues in order to develop an optimized motor-driven pump.

3. 1. 1 Downsizing and Torque Loss Reduction

In order to have a higher degree of freedom in vehicle mounting, the electric pump must be compact.

In addition, the drive torque of the pump is directly related to the power consumption because the motor has the sole function of driving the pump. Therefore, we worked to develop a downsized pump with lower torque as a top priority.

The drive torque of a vane pump is the sum of the theoretical torque and the torque loss (friction). To improve mechanical efficiency, it is necessary to reduce both theoretical torque and friction.

We then decided to downsize the vane pump to the limit, taking productivity into account, to reduce the sliding area of the parts, as shown below, thereby reducing friction:

[1] Thinner cam ring
[2] Smaller rotor
[3] Use of thinner vanes (1 mm thick)

Finally, we downsized the pump to the manufacturing limit that would allow durability and mass production, resulting in a cam ring 46% narrower (Fig. 4) and a rotor 32% smaller in outer diameter (Fig. 5) than the traditional mechanical pump.

We used thin-walled vanes, the second case at KYB, to reduce the pressure-receiving area and the sliding area (Fig. 6).

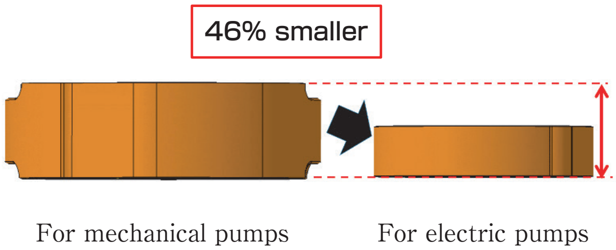


Fig. 4 Conceptual drawing of cam ring thinning

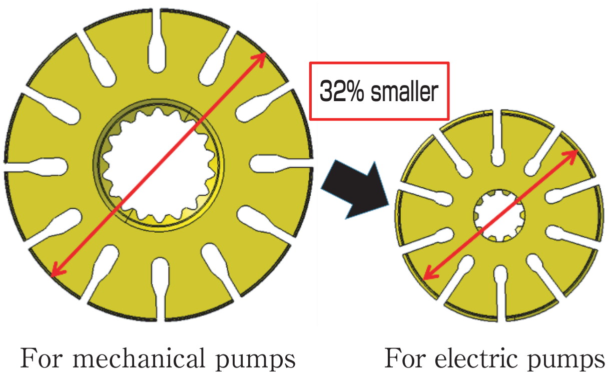


Fig. 5 Conceptual drawing of rotor outer diameter reduction

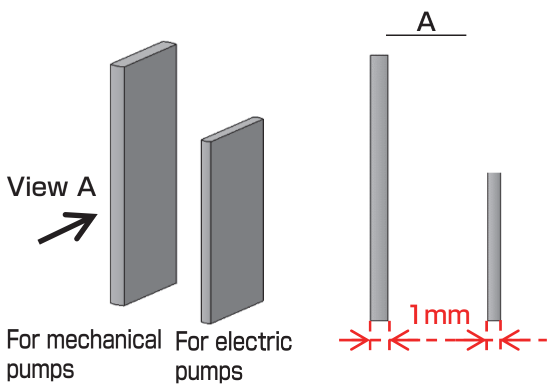
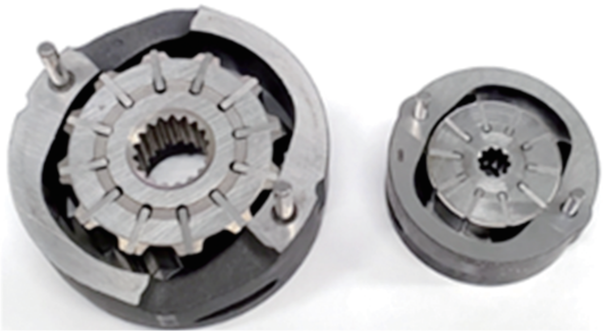


Fig. 6 Vane pump thinning

The resulting pump had excellent mountability, high efficiency, and low cost, achieving a torque loss reduction of approximately 52% over the existing product performing the same work.

Photo 1 compares the size of the vane pump for electric pumps to the size of the vane pump for mechanical pumps that KYB has traditionally mass-produced.

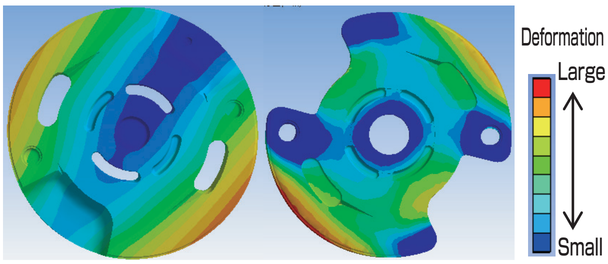


For mechanical pumps For electric pumps

Photo 1 Cartridge size comparison

3. 1. 2 Improving Volume Efficiency

In the vane pump developed in this project, we optimized the clearance of each sliding part according to the operating conditions. Reducing the clearance will reduce the internal leakage of the pump, that is, the flow loss, which will improve the volume efficiency. On the other hand, the durability of the pump will be worsened, with potential issues such as seizure in the sliding parts. Nevertheless, the pump was subjected to analysis and durability testing to find the optimal clearances while improving the volumetric efficiency. As an example, Fig. 7 shows the results of FEM analysis of the side plate.



Side plate A Side plate B

Fig. 7 FEM analysis results

3. 1. 3 Use of Ten Vanes

The quietness of automobiles has been improving year by year. With the electrification of vehicles, the demand for quietness is increasing. Electric pumps are no exception, so it is essential to develop a low-noise pump. We then focused on reducing the vibration of electric pumps. The frequency of vane pump noise is greatly affected by the number of vanes. Unlike the traditional mechanical pump for CVT/AT, which is designed to be quiet by using 12 vanes, we decided to redesign the vane pump developed in this project to have ten vanes so as to avoid resonance with the motor, which has a number of poles (multiples of two) and a number of slots (multiples of three).

We optimized the timing position of the pump suction and discharge ports for ten vanes to prevent resonance with the motor, successfully achieving the quietness required for electric pumps.

Reducing the number of vanes by two also contributed to cost reduction.

3. 1. 4 Use of the Cartridge Design

The mechanical pump currently manufactured by KYB is assembled into a housing (the "pump assembly") prior to delivery to the customer (Fig. 8).

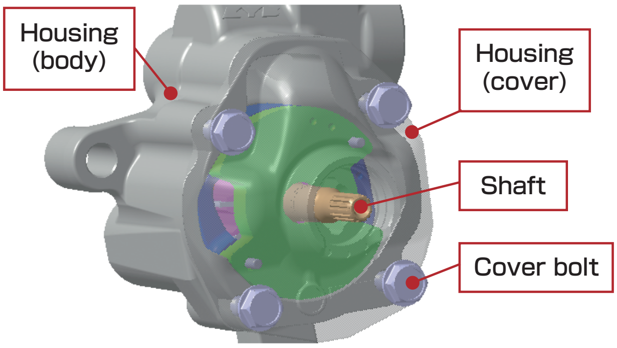


Fig. 8 Appearance of the pump assembly

In this project as well, we initially designed the pump assuming that it would be delivered to the customer as a pump assembly. However, we decided to supply the pump only as a cartridge design, which was a first for KYB pumps, because supplying only functional parts of the pump would reduce the number of parts to reduce costs.

Then we had to face the following new challenges:

[1] Ensure handling in mass production
[2] Avoid dents during transportation
[3] Clarify the scope of functional warranty

For [1], side plates A and B were incorporated into the cartridge to allow easy carrying during manual handling and to prevent the ingress of contaminants. This addition of parts achieved the minimum configuration of the pump that could ensure the required pump performance.

Regarding [2], the pump developed in this project was designed so that the motor shaft, which transmits the power to the pump, is installed on the motor side. This means that the pump cartridge alone cannot fix the position of its components using the shaft, allowing the rotor to move freely. As a result, the rotor can be moved by vibration during transportation or other occasions and come into contact with other parts, causing dents (Fig. 9).

We then developed and patented an easily removable tray specifically designed for the cartridge, which positions the rotor and prevents the cartridge from rotating (Fig. 10).

For [3], we decided to have the cartridge pump performance tested at KYB, so that we could deliver the cartridge pump to the customer as a functional component under warranty, in addition to the dimensional warranty.

As a result, we were able to guarantee the performance of the cartridge pump with a minimum number of components. The reduced weight and size improved transportation efficiency to achieve both product marketability and cost effectiveness. This led to the implementation of need-based product development.

3. 1. 5 Use of New Materials

The operating conditions of the electric pump that we aimed to develop in this project involve lower pressures and speeds than those of the conventional mass-produced mechanical pump.

Therefore, we wanted to use materials that were commercially available and which considered the productivity of downsized pumps. By evaluating durability many times from the early stage of development, we were able to select materials that contribute to durability.

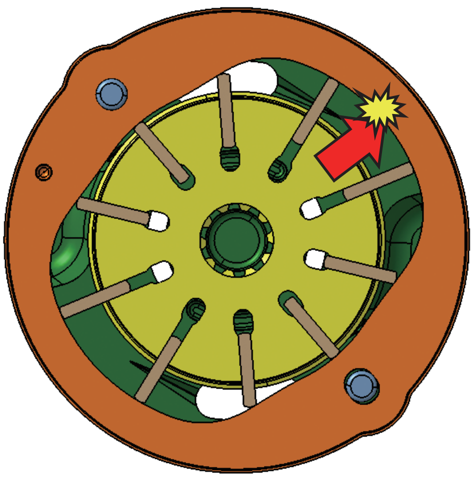


Fig. 9 Contact by moving rotor

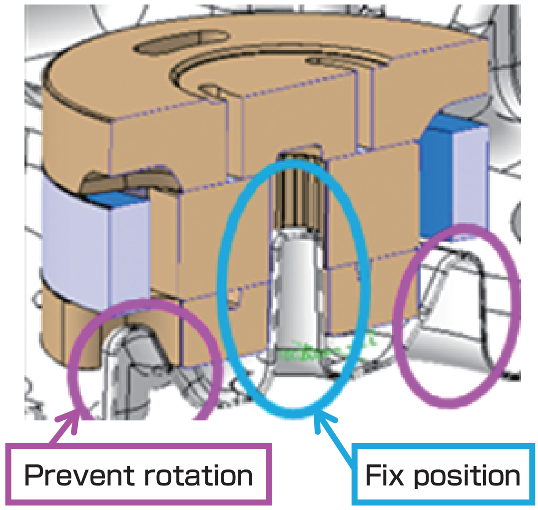


Fig. 10 Shape of tray

4 Conclusions

In this project, we developed a vane pump for electric pumps for the first time in KYB to achieve the following:

[1] Developed KYB's smallest vane pump optimized for use as an electric pump.
[2] Developed KYB's first cartridge-type vane pump.
[3] Adopted new materials.
[4] Established optimal pump specifications for motor characteristics.

5 In Closing

Thanks to the great cooperation of those involved in this development project, we have been able to develop and mass-produce the vane pump for electric pumps in spite of specifications that have never been seen in products previously developed by KYB. We would like to take this opportunity to express our deep gratitude to the partner companies and all those in the internal related departments for their cooperation in this development project.

Author

KUBO Kohei

Joined the company in 2009.
Pump Design Sect., Engineering Div., Mobility Devices Headquarters, Automotive Components Operations.
Engaged in design of vane pumps.