Analytical Study of Volumetric Scroll Pump for the Cold Moderator System

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The volumetric scroll pump has been designed and analyzed numerically. The suction process flow analysis was carried out with the Low-Reynolds number k-e turbulence model. The results could verify the feasibility of the application of the pump to a cold moderator system of a MW-class spallation neutron source. The analytical results show that the scroll pump has good characteristics. The following advantages could be expected: (1) The pump could be gas, liquid, and mixture; (2) The minimum pulsation, applied with which provides less vibration; (3) The fluid flow rate could be estimated in design process.

Key Words: Volumetric scroll pump, Analysis, Suction process, Cold Moderator

1. Introduction

The volumetric scroll pump has been studied for a cold moderator system of a MW-class spallation neutron source at the Japan Atomic Energy Research Institute (JAERI). An appropriate and safety operation could be expected in its application with the cold moderator system due to the volumetric pump features.

The processes inside the scroll pump are as shown in Fig.1. The purpose of the study is to understand the fluid flow behavior inside the scroll pump. In the previous study, the results of the suction process under water conditions shown that the scroll pump has small negative relative pressure, and preferable volumetric intake profile [1].

Fig.1 Process inside a scroll pump

In the present study, the analytical model has been reconstructed for predicting flow patterns and pressure distributions in the suction process under liquid hydrogen conditions.

2. Analytical Model

The scroll pump configuration is as shown in Fig.2. Adjustment of suction coefficient, \( \alpha \), would change the pump size while adjustment of discrepancy of starting rolls angle, \( \beta \), would change the thickness of scroll wraps.

Fig.2 Scroll pump configuration

The relationship between intake volume and scroll coefficient, \( \alpha \), is shown in Fig.3. In the study, the scroll coefficient, height, and the discrepancy of starting rolls angle are set to 5 mm, 50 mm and 0.5\( \pi \) radian, respectively.

The three-dimensional fluid cells model of the scroll pump is generated by using multi-block grid generation approach. The meshes were generated inside the blocks repeatedly at each step for 72 time steps of 5 degree. The active cells are 97220 cells at the first step then activate 800 cells into the cell set at each step resulting of 154000 cells at the last step.
The analysis was carried out under liquid hydrogen flow conditions. The heat transfer effect is neglected to simplify the problem. The flow is assumed to be turbulent and induced by the motion of the orbiting scroll wrap. The Low-Reynolds number k-ε turbulence model was applied to determine the Reynolds stress and turbulent scalar fluxes. The suction inlet boundary pressures are held constant at atmospheric pressure throughout the computation. The velocity magnitude of the orbiting scroll equals to 1.645 m/s according to the shaft speed of 2000 rpm.

3. Results and Discussions

The approximate intake volume of one cycle (360 degree) is 174 cm³. This value could be estimated from Fig.3, which has the intake volume equals to 34.7 cm³ per cm of scroll height. This would give the volume flow rate of 5.8 l/s at 2000 rpm or 1.0 l/s at 345 rpm. In this case, adjusting the crank speed could control the fluid flow rate of the system.

The results of velocity magnitude and total pressure on the center surface, z = 25 mm, are plotted at 0, 90, 180, and 270 degree in Fig.4 to Fig.5, respectively. The pressures are relative pressures, which indicate the pressures difference against the inlet pressure.

Fig.4 Velocity contour at several orbiting angles

The velocity result in Fig.4 shows how the orbiting scroll induces velocity fields. In the figure, the orbiting wrap drives the surrounding fluid and induces the high velocity fields nearby the wrap in its moving direction. It can be seen that the recirculation flows occur in the regions where the high velocity fluids flow against the stationary wall. The impaction of the high velocity fluids build up the other high velocity regions near the stationary wall.

Fig.5 Pressure distribution at several orbiting angles

In Fig.5, the high-pressure regions are the regions that the velocity and the static pressure are high, i.e. the regions surrounding the orbiting wrap and the regions that the recirculation flows occur. The maximum and minimum values of total pressure are plotted with the corresponding angle in Fig.6.

Fig.6 Relative pressure plot at several angles

In Fig.6, the maximum and minimum pressures increases and decreases significantly at the end of suction process. This phenomenon might damage scroll pump components if the high-pressure side is too high and/or the low-pressure side is too low until the cavitations occur.

4. Concluding Remarks

In ideal case, as in the study, when the pocket closes and separates fluid inside from suction chamber, it also opens fluid inside to discharge chamber at same time. In real case, to prevent extremely high pressure and cavitations, the pocket should open to the discharge chamber before it closes and separates from the suction chamber.

References