A REVIEW ON MICRO IMPELLERS USED IN MICRO PUMPS

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Abstract – *Micro-impellers are, in essence, down-sized impellers with the same functions as conventional impellers(macro-impellers) in that they are the rotating component in a pump that uses the energy from the motor to accelerate fluid flow. In this paper, designs and manufacturing methods suggested, effects of various alterations to impellers on pump performance, techniques employed to evaluate impeller parameters and applications of micro-impellers in varied fields are reviewed*

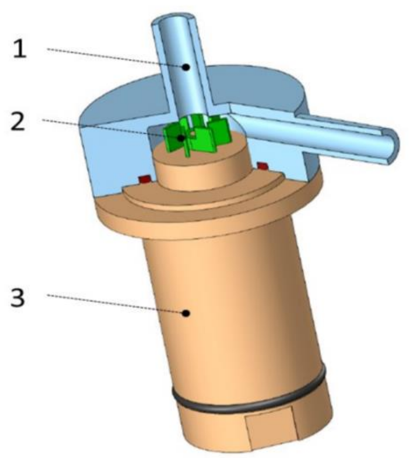
Key Words: Micro-impellers, Impellers, Micro-pumps, Centrifugal pumps, Cavitation.

1. INTRODUCTION

Micro-impellers, as discussed in the abstract, are essentially impellers in micro scale i.e., with diameters ranging from 25mm to 30mm. In spite of that fact micro impellers cannot be manufactured in manners similar to conventional impellers. There exist a multitude of processes for manufacturing micro impellers either through machining or more recent means such as 3D-printing. These methods have been discussed below along with techniques to improve performance as well as the applications of micro impellers.

1.1 General idea for manufacturing

The hydrodynamic components are designed based on partial emission pump. Meanwhile, the geometric profiles of both impeller and volute are specifically simplified for ease of manufacturing.



The impeller does not set up front and back shrouds. Straight blade profile is adopted without curve or three-dimensional twist. Meanwhile, the blade axial projection is a rectangle, which means the blade height is uniform along the radial direction.

The volute consists of suction channel, pressurized-water chamber and outlet channel. The suction and outlet channels are simplified to straight pipes, and the pressurized-water chamber design adopts rectangular section and circular casing.

The impeller can be manufactured by applying wire-cutting and EDM (Electric Discharge Machining) forming. After that, the blade surface could be polished appropriately to reduce the surface roughness which could affect hydrodynamic performance.

Fabricated Volute and Motor (micro)

The volute part could be manufactured using a Computer Numerical Control (CNC) machine .The three parts of the volute which are the suction channel, pressurized-water chamber and outlet channel are integrally milled to avoid the misalignment of the internal joint surfaces. Before assembling, all the hydraulic parts are cleaned by the ultrasonic cleaning machine with absolute ethyl alcohol.

Micro pump assembly

1.2 Methods of Evaluation

In numerical analysis, the commercial software ANSYS-CFX is used. Water is assumed to be incompressible and isothermal and the mass flow conservation and Reynolds Averaged Navier-Stokes equations are solved by the finite volume method.

The flow rate is found through the magnetic flow meter installed far downstream of the pump and torque is measured by a torque meter. Then, the shaft power could be calculated using the torque and the rotational speed measured by a rotational speed sensor. The shaft power is evaluated by the eliminating mechanical loss and disc friction loss using a disc without the impeller. The hydraulic efficiency of the pump could be calculated as the ratio of the water power to the shaft power.

2. Literature Review

Toru Shigemitsu et al [1] studied the effect of splitter blades on the performance of mini centrifugal pumps having a diameter smaller than 100mm which are employed in many fields. Mini centrifugal pumps with simple structure were investigated by this research. Splitter blades were adopted in this research to improve the performance and the internal flow condition of mini centrifugal pump which had large blade outlet angle. The original impeller without the splitter blades and the impeller with the splitter blades were prepared for an experiment. The performance tests are conducted with these rotors in order to investigate the effect of the splitter blades on performance and internal flow condition of mini centrifugal pump. On the other hand, a three dimensional steady numerical flow analysis is conducted with the commercial code (ANSYS-CFX) to investigate the internal flow condition in detail. It is clarified from experimental results that the performance of the mini centrifugal pump is improved by the effect of the splitter blades.

Sayed Ahmed Imran Bellary et al [2] optimized centrifugal impeller blade shape through numerical modeling using surrogate model based shape optimization methodology to enhance performance of a centrifugal pump. Design variables, such as blade number and blade angles defining the pump impeller blade shape were selected and three-level full factorial design approach was followed for efficiency enhancement. A three dimensional simulation using Reynolds-averaged Navier Stokes equations for the performance analysis was carried out after designing the geometries of the impellers at the design points. Standard k-ε turbulence model was used for steady incompressible flow simulations. It was inferred that the optimized impeller incurred lower losses by shifting the trailing edge towards the impeller pressure side.

S. Pennathur et al [3] elaborated on the impact of cavitation on MEMS fluid machinery. Cavitation in 900-micron-chord cascades characteristic of micro centrifugal pump was investigated through analysis and experimentation for working fluids of water and ethanol. The primary finding was that these micro devices exhibited static and dynamic behavior similar to that of large scale flows. Conventional cavitation models coupled to 2D and 3D CFD simulations matched micro scale data well in predicting the onset of cavitation and the length of cavitation zones. No mechanical damage from cavitation was found.

Bin Duan et al [4] proposed a design and fabricated a micro pump which is able to provide a 1.4L/min flow rate and a 75KPa pressure head at 24000 rpm with an oversize of 46mm wide and 69mm long. The hydrodynamic components were designed based on partial emission pump. Meanwhile, the geometric profiles of both impeller and volute were simplified for manufacturing. A computational fluid dynamics (CFD) analysis was performed to predict the effects of blade inlet angle and vane number on hydraulic performance. Experiments were conducted at 4 different rotational speeds to validate the numerical results. The results showed that the numerical simulation has a high accuracy to predict the micro pump flow field with the overall average deviation less than 3%. As expected, the micro pump prototype performed obvious partial emission pump features. In terms of the external characteristic, the pressure head at a given rotational speed decreased little with flow rate increasing.

Hilman Syaeful Alam et al [5] evaluated the integrity of micro impeller using fluid structure coupled simulation with three loading conditions. The loads were centrifugal force, hydraulic pressure, and combination loads. The hydraulic pressure was imported from the flow calculation using gas-liquid two-phase flow simulation and the centrifugal force was applied to model due to a high rotational speed of the impeller. Based on the simulation results, the maximum stress due to the combination of centrifugal force and hydraulic pressure was found to be 8.205 MPa and it was secure with enough strength because it was less than the allowable design stress of 280 MPa. Furthermore, the maximum axial and radial deformations of the impeller were 0.0001 mm and 0.0027 mm respectively. However, they didn't affect the normal working of the micro pump and the stiffness of impeller also met the requirements.

Pranit M. Patil et al [6] studied the effect of geometric changes to impeller on performance of centrifugal pump. Various techniques developed for improvement of pump performance which were discussed include impeller trimming, varying blade angles, addition of diffuser, tip clearance and splitter blades. It was found that every method could be used to improve performance although the relations between factors affecting performance and the actual performance itself vary among the techniques.

Mitsuo Uno et al [7] focus on non-contact driving method and performance of a newly developed shaft-less floating pump with centrifugal impeller. The drive principle of the floating impeller pump uses the magnet induction method similar to the levitation theory of the linear motor. In order to reduce the axial thrust due to the pressure difference between shroud and disk side, the balance hole and the aileron blade were installed in the floating impeller. Moreover, the performance curves of the developed pump are in agreement with those of a general centrifugal pump, and the dimension-less characteristic curve also agrees under the different rotational speed due to no mechanical friction of the rotational part.

S H Kim et al [8] discussed centrifugal force based magnetic micro-pump driven by rotating magnetic fields which could be used a wireless and battery-free blood pump. The proposed pump is controlled by external rotating magnetic fields with a synchronized impeller. Synchronization occurs because the rotor is divided into multi-stage impeller parts and NdFeB permanent magnet. Finally, liquid is discharged by the centrifugal force of multi-stage impeller. The proposed pump length is 30 mm long and 19 mm in diameter which much smaller than currently pumps; however, its pumping ability satisfies the requirement for a blood pump. The maximum pressure is 120 mmHg and the maximum flow rate is 5000ml/min at 100 Hz. The advantage of the proposed pump is that the general mechanical problems of a normal blood pump are eliminated by the proposed driving mechanism.

3. CONCLUSIONS

- Micro pumps utilizing micro impellers are a need of the day which are seeing more and more improvements to existing designs frequently.
- Their characteristics can be analyzed using evaluating techniques similar to those used for conventional pumps and impellers.
- They can be manufactured easily enough that meeting the demand wouldn't pose a problem.
- They have found wide applications the field of biomedical engineering as blood pumps and drug delivery devices.

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