

## Fluid Engineering Laboratory in Faculty of Engineering at Hosei University

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### 1. Introduction

The fluid engineering laboratory at Hosei University is composed of one professor, one associated professor and one research assistant with two doctor course and twelve master course students. Moreover, about forty bachelor course students belong to the laboratory.

The research subjects are classified into the experimental and the computational ones, and emphasized on the internal flow and the performance characteristics of turbomachine. The recent research projects are related to the following subjects.

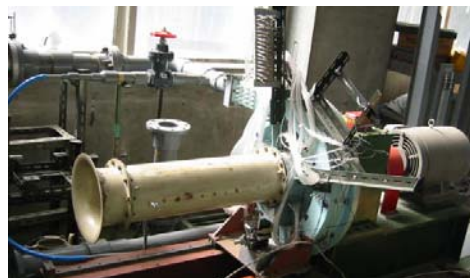
- (1) Internal flow and performance of ultra-micro centrifugal compressor
- (2) Experimental study of high rotational bearing including air-bearing
- (3) Internal flow within ultra-highly loaded turbine cascade(UHLTC) and bowed blade
- (4) Control of surge and rotating stall of centrifugal compressor at low flow rate
- (5) Loss generation mechanisms of flow in turbomachinery by using curved duct
- (6) PIV measurement of flow around leaned cylinder

The projects concerning the ultra-micro centrifugal compressor are a part of the research project on ultra-micro gas turbine organized by the committee in Gas Turbine Society of Japan(GTSJ) and performed in cooperation with Prof. Yoshioka and Prof. Ohta laboratories in Waseda University. These results have been published in the Journal of GTSJ<sup>(1)</sup> and presented at several domestic<sup>(2)</sup> and international<sup>(3)</sup> conferences. The experiments for the subject (3) are the cooperative research with Dr. Yamamoto in Japan Aerospace Exploration Agency (JAXA). The numerical investigations for the UHLTC are made by the CFD code developed in the present laboratory.

The last year, the numerical investigation of transpiration cooling for a turbine blade<sup>(4)</sup> was carried out as the cooperative research with Prof. Bohn in the Steam and Gas Turbine Institute of Aachen University of Technology. Moreover, the visualization study using PIV in a cylindrical tank with and without vortex suppressor, which is the cooperative research with Prof. Gowda in Indian Institute of Technology Madras, was published<sup>(5)</sup>.

### 2. Experimental Investigations

Figure 1 shows the experimental apparatus used in the investigation for the rotating stall and the surge in the centrifugal compressor at the low flow rate. The compressor is constructed by the backward centrifugal impeller, the vaneless diffuser and the collector. The impeller is driven at 5,000 rpm by the electric motor. Before start the investigation for



**Fig. 1 Experimental Apparatus for Stall and Surge**



**Fig. 2 Gas Turbine**



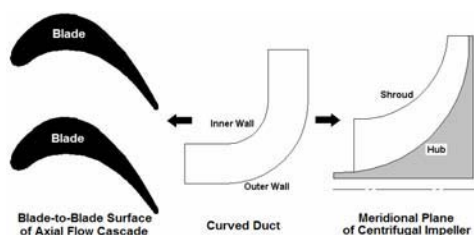
**Fig. 3 Plastic Impellers**



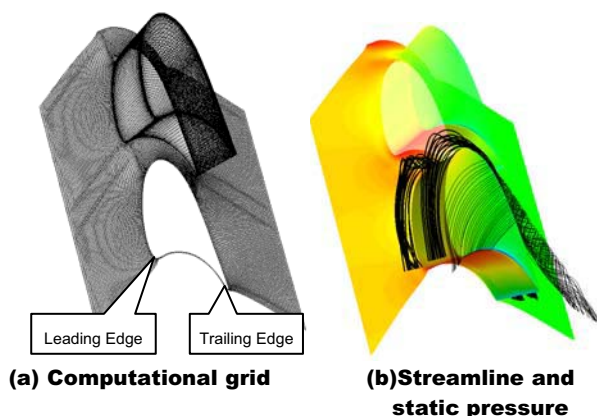
**Fig. 4 Aluminum Impeller**



**Fig. 5 Micro Gas Turbine**



**Fig. 6 Axial Cascade and Curved Duct**



**Fig. 7 Ultra Highly Loaded Turbine Cascade**

the ultra-micro gas turbine, the gas turbine(Fig.2) was made by installing the combustion chamber in an automotive turbo-charger under the support by Dr. Hayashi in JAXA. This gas turbine has been driven successfully. The ultra-micro centrifugal impellers are now in the production process. Figures 3 and 4 show the plastic impellers manufactured by using a micro stereolithography method and the aluminum one by using a 5-axis milling machine. The ultra-micro turbine shown in Fig.5 was tried to be driven at 350,000 rpm with the ball bearing.

### 3. Numerical Investigations

In the secondary flows in a turbomachinery, the passage vortex generates the major part of the losses

in the flow channels. The curved ducts are considered to be fundamental models for the generation of the passage vortex. The objective of this study is to numerically analyze the effects of the passage vortex on the loss generation by comparing the passage vortices within the curved duct with those in the cascade of turbomachinery. The bend of curved duct is related to the blade-to-blade surface of an axial flow cascade or to the meridional plane of a centrifugal impeller(Fig.6). By taking the inlet boundary layer thickness and the inlet velocity distortion as an aerodynamic parameter and the aspect ratio of the cross-section as a geometrical parameter, the effects of these parameters on the formation of passage vortex and the loss generation were clarified<sup>(6)(7)</sup>.

Another numerical investigation is made for the development of the UHLTC. By increasing the blade loading, it becomes possible to reduce the number of blades and stages. As a result, the reduction of both the weights and the costs for manufacturing and maintenance will be accomplished. However, in such highly loaded turbine cascade with the high turning angle, the secondary flow becomes strong due to the steep pressure gradient within the blade channel and deteriorates the performance characteristics enormously. In this study, the numerical analysis were performed for the flows within the linear UHLTC with the turning angle of 160 degree in order to achieve the increased blade loading without the decrease of the performance of blade. The computed results within the UHLTC with the tip clearance are shown in Fig.7.

### References

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