Research on the Gas Turbine at the Institute of Industrial Science, The University of Tokyo

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1. Introduction

Our research facilities relocated to the "Komaba Research Campus" from the "Roppongi Campus" in 2001. A panoramic view of the building is shown in Fig. 1. The new building consists of shared rooms and rooms that belong to each laboratory. The former rooms are located on the first basement level and the first floor, and latter rooms are located above the second floor.

The gas turbine facilities, which emeritus professor Haruo Yoshiki held, are attached to the Chisachi Kato laboratory to which the author belongs. In this paper, the outline of the research on the gas turbines at the Institute of Industrial Science, The University of Tokyo is described.

2. Experimental apparatus

2.1 Cold air test bench

In order to evaluate the aerodynamic performance of the test turbine, cold air tests are carried out with varying pressure ratios and rotational speeds of the turbine. The schematic view of the experimental apparatus is shown in Fig. 2. The pressurized air from the air source drives a turbocharger. The turbocharger is installed to increase the inlet gas temperature of the test turbine. It supplies compressed air to the test turbine through the bypass valve, which controls the pressure ratio of the test turbine. Outflows from the turbine are discharged into the atmosphere through the mixing chamber. The chamber is installed in order to homogenize the exhaust gas temperature distributions while keeping the total temperature constant with heat insulating materials surrounding it.

On the other hand, the compressor connected directly to the turbine with a single shaft absorbs the work output of the test turbine. Outflow from the compressor is cooled in an in-line intercooler and returned to the inlet condition through the regulating valve. By forming a compressor air loop, a wide range can be achieved for the velocity ratio of the test turbine.

2.2 Hot air test bench

We have a hot air test bench to develop the palm-top gas turbine. The bench has a liquefied petroleum gas feed system and ventilation ducts. We are measuring the characteristic of the test combustor and the operation characteristic of the palm-top gas turbine using these apparatus.

Fig. 1 Panoramic view of Institute of Industrial Science, The University of Tokyo

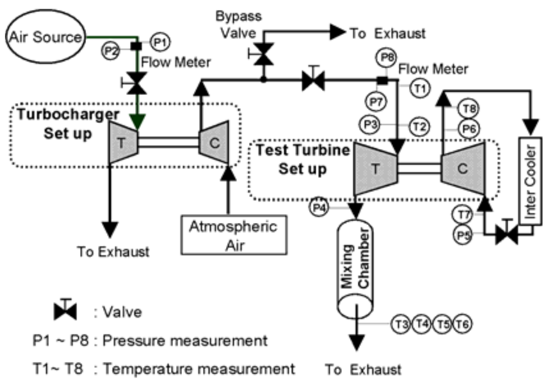

Fig. 2 Schematic view of experimental apparatus

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3. Outline of the research

First, by trial, the key hardware components of a gas turbine system of 10-times enlarged size than that required for the final target product are designed and manufactured. These manufactured components are tested in terms of their aerodynamic performance. The palm-top gas turbine has an impeller with a tip diameter of 40 mm and is expected to generate a net output of 2-3 kW. The primary details of research are introduced hereafter.

3.1 Two-dimensional turbines

Various shaped two-dimensional radial turbines are designed, manufactured by trial, and their performance is measured with cold air tests, and the results are compared with those obtained from numerical simulations. The relation between the velocity ratio and adiabatic efficiency is shown in Fig. 3.

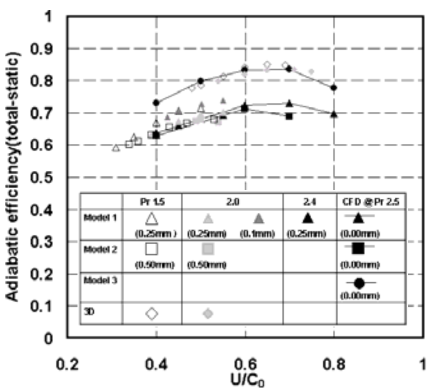

Fig. 3 Measured total-to-static adiabatic efficiency of test turbines

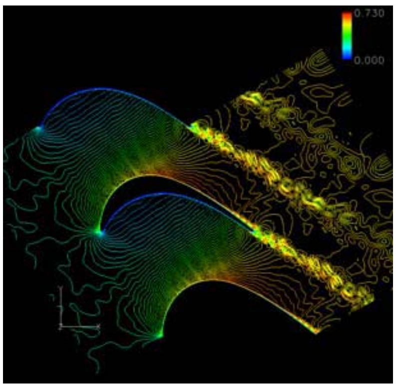

Fig. 4 Contour of Mach number around the turbine blade

3.2 Palm-top gas turbines

The third-generation palm-top gas turbine with a regenerative heat exchanger is designed and manufactured by trial. By optimizing the entire design, this system is equipped with dynamic-pressure air bearings and annular combustion chambers.

3.3 Numerical simulations

In order to estimate the performance of the designed turbines and to discuss the methodology for design improvement, steady numerical simulation based on three-dimensional compressible Navier-Stokes equations with thin layer approximation and Baldwin-Lomax turbulence model is performed. Furthermore, since the Reynolds number in a turbine rotor blade is approximately 100 000, large-eddy simulation has been attempted in consideration of a compressible transitional flow. An example of the result is shown in Fig. 4.

4. Future work

The work for further improvement in adiabatic efficiency of the two-dimensional turbine is currently in progress. With regard to component development for the finger-top gas turbine, we designed and manufactured an aerodynamic test apparatus with an impeller's tip diameter of 8 mm and expected the maximum rotational speed to be 1 million rpm. The finger-top gas turbine is expected to generate 80-100 W. The trial production turbines are shown in Fig. 5.

5. Acknowledgement

This research has been supported by New Energy and Industrial Technology Development Organization (NEDO) and Research Grant (Tenkai Kenkyu) of the Institute of Industrial Science, The University of Tokyo.

Fig. 5 Prototype of radial turbines (ϕ8 mm)