Research on Small Gas Turbines and Turbochargers at Mitsubishi Heavy Industries, Ltd. Nagasaki R&D Center

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1. Introduction

At Mitsubishi Heavy Industries, Ltd. Nagasaki R&D Center, small high-speed radial-flow turbo-machines including turbochargers for marine diesel engines, turbochargers for passenger-cars, and small gas turbines for aircraft have been researched and developed over the past 50 years.

Turbo-machine development relies on aero -dynamics for centrifugal compressors and radial turbines, as well as other leading-edge technologies in the areas of material strength, vibration, and tribology. Here, recent advances in research on aerodynamic performance and new materials are presented.

2. Research and Development on Centrifugal Compressors

Specific speeds and pressure ratios for compressors differ substantially among small turbochargers for passenger-cars and trucks, large turbochargers for marine engines, and small gas turbines. Thus, the various flow issues that require attention also differ.

Fig.1 shows a small turbocharger and LDV measurement results for a large-scale model of an actual turbocharger impeller. Because of the development requirements for small turbochargers used in cars and trucks, various prototypes with different specifications and impeller shapes are subjected to performance testing on an almost daily basis. Research is also conducted for actual flow measurement and verification of CFD. Small turbocharger impellers are characterized by smaller numbers of blades. Accordingly, the flow within impeller is three-dimensional. In order to reduce losses, secondary flow control design has been developed.

In the case of large marine turbochargers, requirements are for the pressure ratio to be increased to 4~5, as well as for higher capacity. This means that impeller inlet tip flow velocity is supersonic. Flow in the transonic impeller is complicated by the occurrence of shock waves and three-dimensional flows. Fig.2 shows a pressure distribution measurement for the evaluation of shock wave generation.

Pressure ratios are even higher in small gas turbines, reaching a maximum of 11. In such cases, the Mach number at the impeller inlet reaches approximately 1.5, and aerodynamic design must take

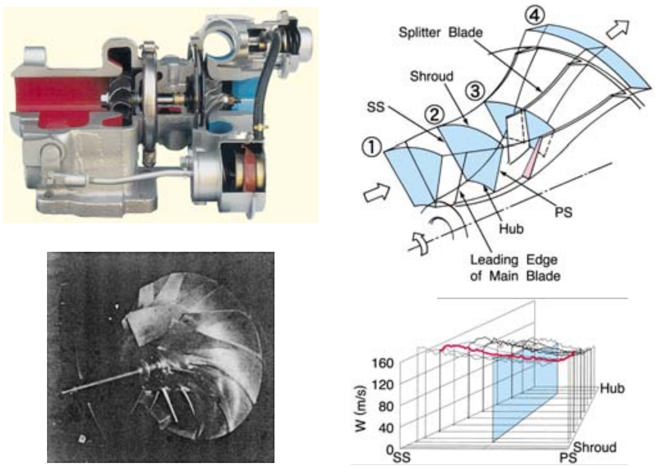
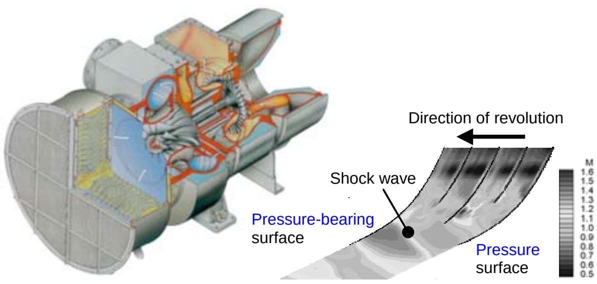


Fig. 1 Passenger car turbocharger, and LDV measurement for a large scale model of an actual impeller



Equivalent entropy mach number for shroud wall

Fig. 2 Marine diesel engine turbocharger, and pressure measurement for shock wave generation

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into account the interaction between the shock wave and the boundary layer. Fig.3 shows gas turbine compressor test facility, capable of high output, high velocity revolution. Fig.4 presents a high pressure ratio centrifugal compressor together with a result for shock wave measurement.

As described above, in order to achieve higher efficiency for centrifugal compressors, various impeller flow measurements and CFD evaluations covering the range from subsonic to super-sonic are being conducted using actual and model impellers.

Fig. 3 Gas turbine compressor test facility

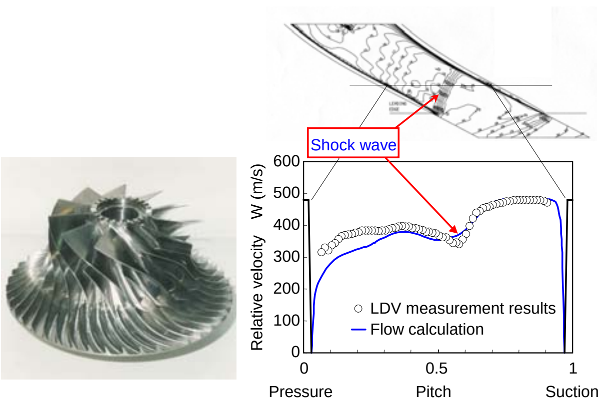

Fig. 4 High pressure ratio impeller and shock wave measurement

3. Research and Development on Radial Turbines

Issues relating to radial turbines include not only aerodynamic performance, but also the development and evaluation of lightweight materials with high-temperature endurance.

3.1 Aerodynamic performance

Because turbochargers and gas turbines are used at high temperatures of 700~1000℃, there can only be a small number of blades in a radial arrangement. The flow in a rotor is complex three- dimensional flow characterized by a large incidence angle and a large turning angle. Fig.5 shows a flow measurement using a pressure transducer.

3.2 Development of materials

As turbochargers for passenger cars suffer from turbo-lag, rotors with low inertia are effective. A titanium aluminide rotor has been developed with improved anti-oxidation properties. In addition, so as to further improve gas turbine efficiency, efforts are being made to develop ceramic turbines. Rotational burst testing is conducted under conditions of approximately 1350℃and approximately 900m/s. Fig.6 shows a titanium aluminide turbine and the high-temperature high-velocity rotational test facility.

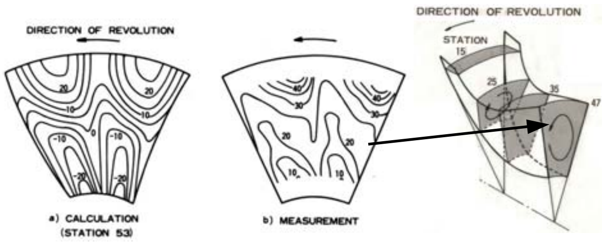

Fig. 5 Radial turbine flow measurement

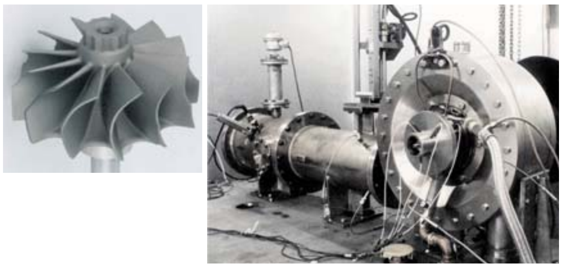

Fig. 6 Titanium aluminide turbine, and high temperature, high-velocity rotational testing equipment for turbines

4. Conclusion

The Nagasaki R&D Center is conducting research in areas ranging from aerodynamic technology to materials, as well as developing turbo-machines for small gas turbines and turbochargers. These proprietary technologies support products of Mitsubishi Heavy Industries, characterized by world-class performance.

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