Turbochargers

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1. Introduction

In recent years, turbochargers have increased in importance and have become indispensable to environmental protection and improved output, accompanied by further tightening of emissions standards. For this reason, the worldwide turbocharger market has expanded.

This report presents new technologies and turbocharger products for passenger cars, trucks and buses, and marine and industrial uses in Japan in response to this market trend.

2. Items required for turbochargers

The requirements for turbochargers in passenger cars are:

- Small size and light weight
- Wide operating range
- High performance
- High response

In addition to the above a "high pressure ratio", is required for turbochargers in trucks and buses, and an even higher pressure ratio is essential for turbochargers used in marine and industrial applications.

Some of these new technologies and products are described in the sections below.

3. New technologies and products

3.1 Variable geometry turbocharger

Variable geometry turbochargers (VG turbos) continue to be developed by various companies for a wide operating range to meet engine requirements. VG turbo development is in progress for passenger cars, trucks and buses, as well as marine and industrial services. Fig.1 shows a VG turbo for passenger cars [1]. Flow analysis is being conducted, as indicated in the figure, and improvements are being made in terms of shape.

The VG turbo can raise boost pressure by throttling the VG nozzle in response to decreased exhaust emissions at low engine speed and can be effective for the improvement of low speed engine torque.

Furthermore, during high speed running, the VG turbo can improve the fuel efficiency of the engine by opening the VG nozzle to decrease the exhaust gas pressure.

Also, the negative pressure type pneumatic actuator has conventionally been the main type of actuator for driving VG nozzles, whereas the positive pressure type actuator with a position sensor and an electrical motor-driven actuator have recently been employed for improved controllability.

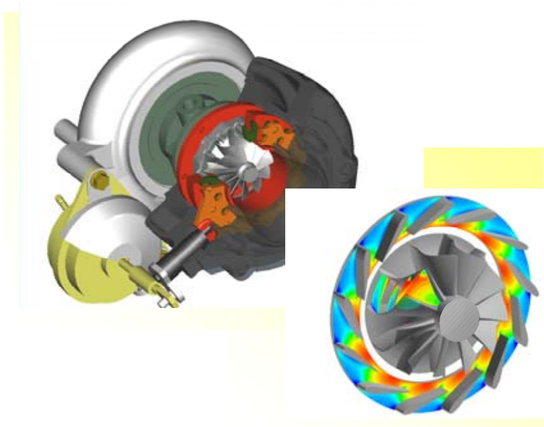

Fig.1 VG Turbo for passenger cars

3.2 High efficiency radial turbine

Understanding the internal flows through the turbine wheel is important for high efficiency design. For this purpose, research has been conducted to ascertain internal flows in radial turbines and to elucidate the arising loss mechanism[2].

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It has been reported that internal flows from the inlet to the outlet of the radial turbine wheel were measured with good agreement to the results of CFD (computational fluid dynamics) used for comparison. Fig. 2 shows the comparison results.

Using CFD with good agreement with the measurement results, the arising loss mechanism within the turbine blades is also being considered. Fig. 3 presents the turbine blade flow analysis results. The loss accumulation mechanism is clarified on the suction surface of the blade outlet on the shroud side.

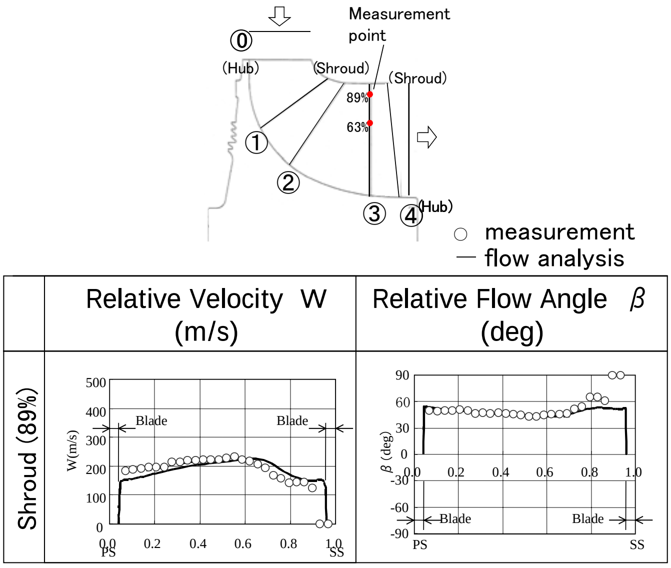

Fig.2 Comparison between measurement and flow analysis (radial turbine)

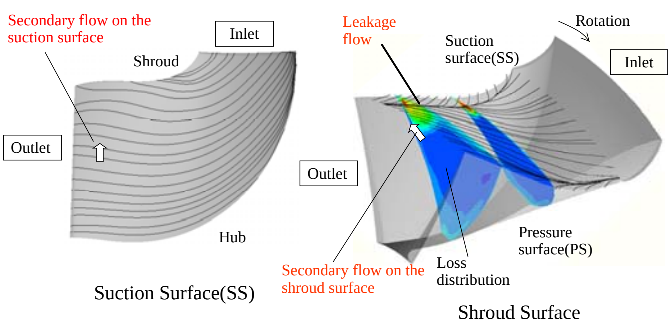

Fig.3 Arising loss mechanism in turbine blades (CFD result)

3.3 Wide operating range compressor

During recent years, in conjunction with the application of VG turbochargers, compressors with increasingly wide operating ranges have been required. Improvement in turbocharger performance is particularly needed in low engine speed regions, necessitating the expansion of compressor surge limitations on the low flow side.

Accordingly, research has been conducted on methods of improving compressor impeller internal flows, and limiting surge(3). Fig. 4 shows the results of compressor flow analysis in the surge vicinity. Consideration is given to the limitation of the occurrence of reverse flow and surge.

In addition, tests and flow analysis are being undertaken with respect to research on the optimization of casing treatment for compressors. Vanes are positioned in the casing treatment, and surge limitations are expanded on the low flow side. Fig. 5 shows casing treatment with vanes.

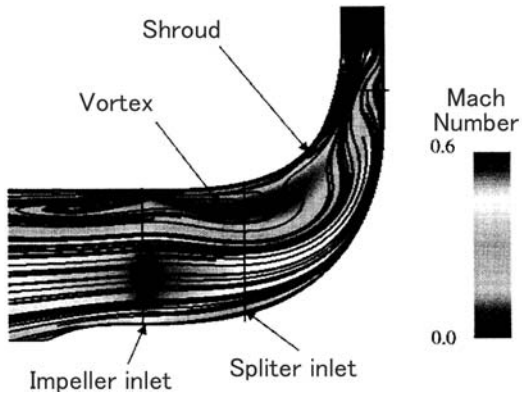

Fig.4 Surge vicinity flow analysis results for compressor impeller

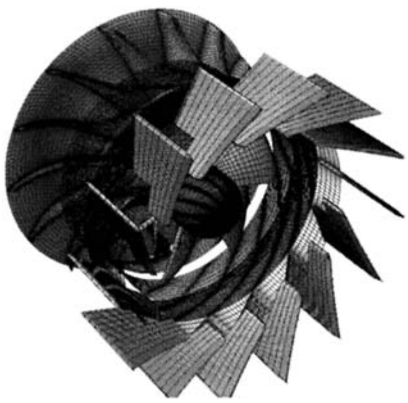

Fig.5 Casing treatment with vanes

3.4 Transonic Centrifugal compressor

Due to the high engine output ratio, a pressure ratio of 4 or more is required for marine and industrial turbochargers.

Although the use of a two-staged compressor can achieve the high pressure ratio as required, this would increase the volume of the turbocharger and complicate the system. Thus, high pressure ratio design using a single-stage compressor has become a common trend.

With the implementation of higher pressure ratios, a supersonic region occurs partially at the compressor inlet. Research is being conducted to ascertain internal flows in this type of transonic compressor impeller[5]. Fig. 6 presents measurement results for the internal flows in a transonic compressor impeller. Comparison of the measurement results and the flow analysis results shows that the internal flows are characterized by a complex flow field due to interference between the shock wave and the tip leakage vortex.

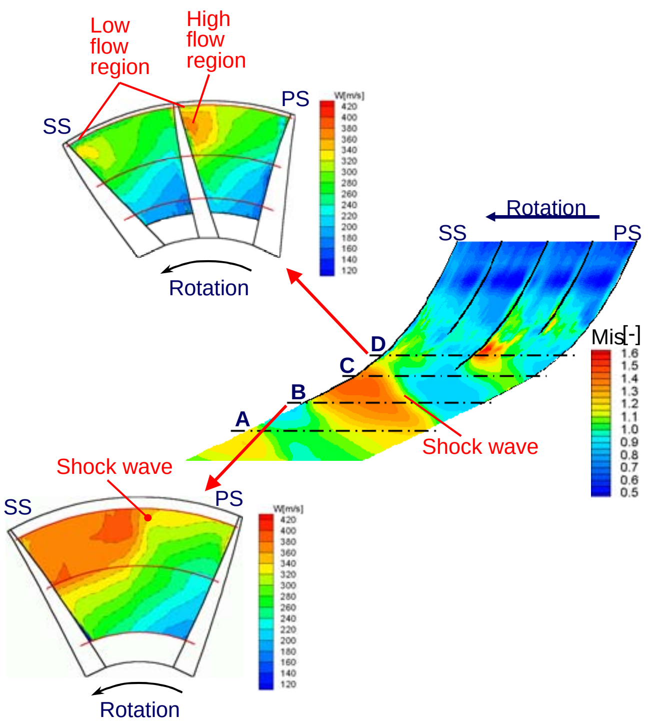

Fig.6 Measurement results of transonic compressor impeller

4. Summary

A further requirement for even higher performance of turbochargers will be continued and wide-spread expectations with respect to turbochargers, which are being enhanced due to the recent trend of more stringent emissions standards.

Development of new turbocharger technologies and products will need to be further advanced in order to deal with exhaust emission controls, as they become even tighter in the future.

References

(1) Mitsubishi Heavy Industries, Ltd., "Variable Geometry turbocharger for passenger cars", Proc. of the Turbomachinery Society of Japan (2003).

(2) Osako K, et al.,"Study on the internal flow of radial turbine rotating blades for automotive turbochargers", 2002 SAE World Congress.

(3) UCHIDA H, "Development of turbocharger technology at Toyota Central Research Institute", Journal of the Gas Turbine Society of Japan Vol.30 No.3 2002.

(4) YAMAGUCHI S, et al., "The development of effective casing treatment for turbocharger compressors", Turbochargers and turbocharging, I Mech E, 2002.

(5) IBARAKI S, et al., "Aerodynamics of a transonic centrifugal compressor impeller", International Gas Turbine Congress of ASME 2002.