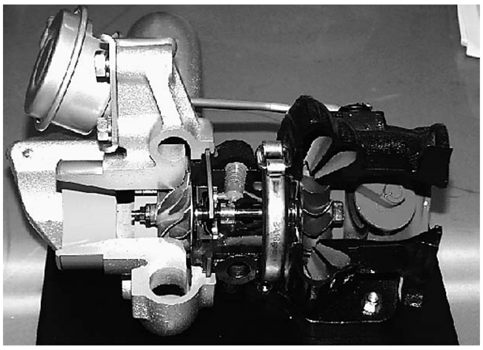

Mitsubishi Turbocharger for Lower Pollution Cars

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1. Introduction

Turbochargers have a long history of being used as components that contribute toward increasing the combustion efficiency and output of internal combustion engines, especially diesel engines. Mitsubishi Heavy Industries, Ltd. (MHI) also has produced various types of turbochargers mainly for marine and automobile engines.

The turbochargers produced by MHI have been highly regarded because of their high level of performance and quality, ever since MHI started to produce them in 1962 at its Ohi Plant that the company had at that time. In countries overseas, MHI has delivered turbochargers to VOLVO, SAAB, and BMW through Mitsubishi Equipment Europe B.V. (MEE) in the Netherlands, as the company's base organization in Europe. It has also delivered them to DaimlerChrysler through Mitsubishi Engine North America (MENA) in North America, and to Hyundai Motor through Key Yang Precision Co., which is the licensee of MHI in Korea. In the domestic market in Japan, MHI has sold turbochargers to many Japanese automobile manufacturers such as the Mitsubishi Motors Corp., the Mitsubishi Fuso Truck & Bus Corp., Fuji Heavy Industries Ltd., and Isuzu Motors Limited. Consequently, the total production of turbochargers each year has reached some 1.7 million, and the accumulated total of all turbochargers produced exceeded 10 million units in 2001.

Initially, the turbochargers have been installed on engines in order to increase the output of the engines. In recent years, however, they have also come to be recognized for their ability to improve specific fuel consumption and to keep the exhaust gas clean. Recently, there has been a growing trend worldwide toward strengthening emission regulations for trucks and buses. Accordingly, the European Community intends to enforce a new emission regulation, Europ IV, in 2005, and the Japanese government intends to introduce a new short term regulation for diesel engines in 2004 and a long term one in 2006. In addition, other countries such as China, Korea, etc. where such regulations are not applied directly at present will need to satisfy those requirements, when they export their products to countries where such regulations are in force. As a result, as it becomes an essential condition for diesel engines to be equipped with turbochargers, the rate of installation of turbochargers on engines is expected to increase even further in the future.

However, conventional technologies may not be able to cope with regulatory requirements as they become progressively strict each year with respect to fuel consumption and emission regulations. In order to satisfy such market requirement, MHI has striven to develop various advanced technologies applicable to turbochargers. This report introduces the three technologies: (1) variable geometry turbocharger, (2) technology for improving transient response, and (3) technology for handling high-temperature exhaust gas.

2. VG (Variable Geometry) turbocharger

The VG turbocharger has a mechanism for controlling the compressor charging pressure optimally by opening and closing of the nozzle vanes attached to the turbine side, and its installation rate for diesel engines is increasing steeply at present.

Fig. 1 shows the structure of a VG turbocharger. When an engine equipped with a VG turbocharger operates at a low engine speed, the nozzle vanes are closed, and when it operates at a high engine speed, the nozzle vanes are opened. By the motion of the nozzle vanes, the required charging pressure can be produced throughout the entire operating range of the engine.

As a result, the torque and fuel consumption of the engine can be improved and the amount of particulate matter (PM) can be reduced. By using the VG turbocharger, the required charging pressure can be produced at the required time, and the pressure of the exhaust gas can also be controlled. EGR (Exhaust Gas Recirculation) system reduces the combustion temperature by returning the exhaust gas to the intake air to reduce the amount of NOx. The optimization of the exhaust pressure by the VG turbocharger is effective for optimizing the amount of EGR (**Fig. 2**). Our VG turbochargers are highly regarded by customers because of their high performance and high durability.

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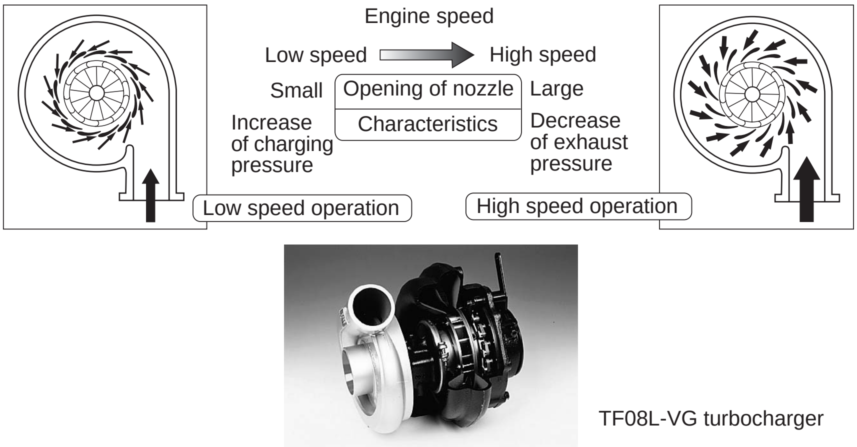


Fig. 1 Mechanism of VG turbocharger The charging pressure is kept optimum by closing the nozzle vanes at a low engine speed and opening them at a high engine speed.

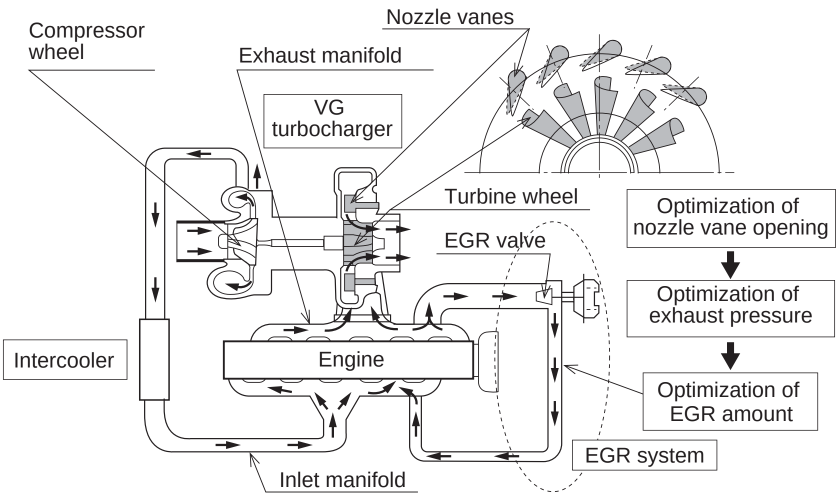


Fig. 2 VG turbocharger and EGR
The amount of EGR can be controlled properly since the exhaust pressure is adjustable by opening and closing the nozzle vanes.

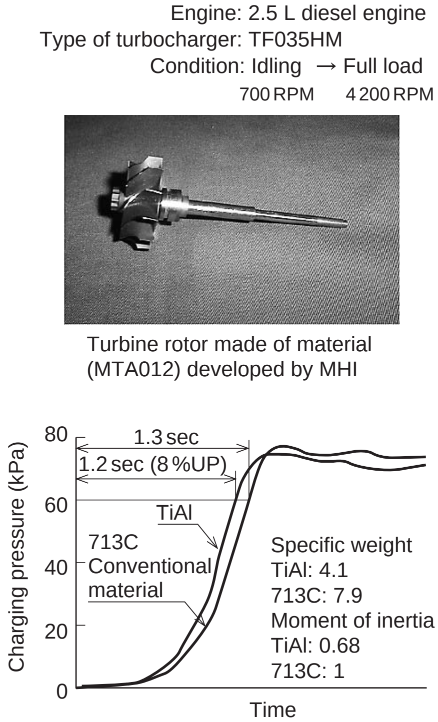


Fig. 3 Improvement of transient response by TiAl turbine rotor
The adoption of a TiAl turbine rotor shortens the time needed to build-up the charging pressure.

3. Technology for transient response

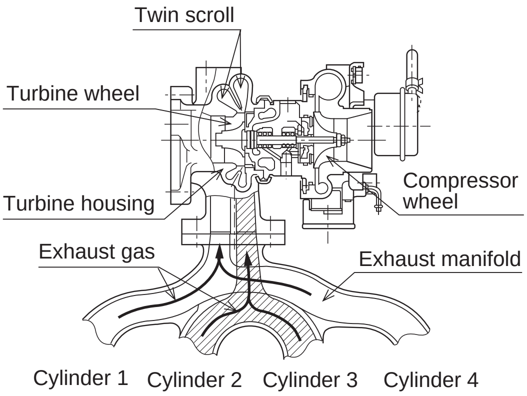
The improvement of the transient response is one of the technical issues in turbocharger development. The charging pressure is not build up immediately after the accelerator is stepped on. (There is a little bit of time lag.) Thus, in case of diesel engines, during the transient period, the amount of air available falls short and the production of PM increases. In other words, if the moment of inertia of the turbine rotor can be reduced, the charging pressure can build up in a short time and the amount of PM produced during the transient period can be controlled (i.e. reduced). At the same time, the time taken to build up torque can be shortened to improve drivability. The moment of inertia of the turbine rotor can be reduced by 30%, using titanium-aluminum alloy (hereafter abbreviated as TiAl) for the material of the turbine rotor. As a result, the time required for the charging pressure to build up can be reduced (**Fig. 3**). MHI is the first company in the world to succeed in mass production of TiAl turbine rotors.

In order to improve transient response, it is effective to adopt a twin-scroll turbine housing. In the twin scroll mechanism, the exhaust manifolds connected to the cylinders (whose ignition order is not sequential to each other) are collected, the interference of the exhaust gas is moderated by introducing exhaust gas to two turbine scrolls which is divided by a separating plate, and increase the output of the turbine.

As a result, both charging pressure and torque, especially at a low speed, are increased and acceleration performance during start up is improved, compared with a conventional single scroll (**Fig. 4**). The MHI twin scroll turbochargers for gasoline engines have an extensive track record and highly evaluated by customers.

4. Technology for handling high-temperature exhaust gas

In a gasoline engine, as shown in **Fig. 5**, the output and fuel consumption under high load and high speed are improved by increasing the temperature of the exhaust gas. Consequently, exhaust gas temperature tends



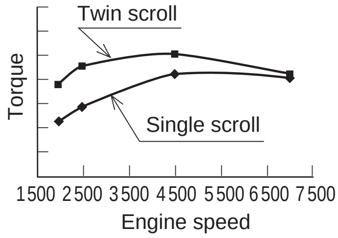
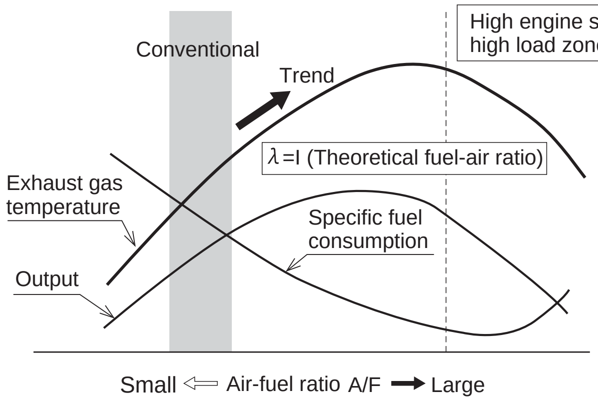


Fig. 4 Structure of twin scroll turbine housing
Charging pressure during low speed operation is increased by reducing interference of the exhaust gas.



High exhaust gas temperature proof turbocharger for gasoline engine

Fig. 5 Relation between exhaust gas temperature and engine performance
In gasoline engines, fuel consumption is improved by increasing the temperature of exhaust gas under high load and high speed operation. (The figure shows a conceptual illustration of this relation.)

to increase each year. Recently, exhaust gas temperature as high as 1 050°C may be required, with the result that material with excellent heat resistance qualities is required for the turbine housings and wheels. In response, MHI has adopted thin wall austenitic stainless steel casting (with an average thickness of 2.5 mm) for turbine housings and TiAl for turbine wheels, as material that is capable of withstanding high-temperature exhaust gas. In addition, making the turbine housing thin is not only an effective way of lightening turbochargers, but the reduction in heat capacity due to lightening of the turbochargers can also shorten the time required for the catalytic converter to reach its activation temperature. The reputation of MHI high-temperature resistance technology is very good, and the production of MHI turbochargers for gasoline engines has reached the top level in the world.

5. Conclusion

In order to meet increasingly strict emission regulations, the control of engines tends to be more complicated in the future. There has also been a growing need in turbochargers for technology in which a required charging pressure can be produced at a required time by controlling various variable mechanisms precisely through electrical actuators. In addition, it is thought that motor-driven compressors will become a subject of greater study in the future.

As described above, turbochargers are becoming essential components for making low-emission automobile engines. Furthermore, there seems to be no limits to the requirements for limiting pollution, with the result that all turbocharger manufacturers are keenly competing with each other to develop and introduce new technologies. In such circumstance, the production of MHI turbochargers has been expanding steady. In the future, MHI will continue efforts to improve the competitive strength of its turbochargers even further, doing its best to meet customer requirements quickly and precisely, while maintaining a good rate of development of new technologies.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