Turbochargers

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1. Trend

Expansion of the market share of diesel passenger vehicles in Europe countries continues. About 40 percents of new passenger vehicles install diesel engine. In 2003, over 6 million diesel engines were made at this area. It is so that a user merit that the mileage is good agrees with a merit of carmakers, which want to reduce the CO_2 emission for the ACEA commitment. The big torque characteristics of diesel engine can bring the easy operation and good response from middle speed, are also the reason. The common rail fuel injection system, which can inject the fuel with high pressure and control-ability, and turbocharging which can increase power density and reduce the exhaust gas emissions, support it strongly. Variable geometry turbochargers, which have moving vanes around turbine wheel, are widely used for the good fuel consumption and reduction of exhaust gas emissions.

Exhaust gas regulation in Japan is also strengthened, and turbocharger penetration in commercial vehicles progresses. It was thought that turbocharged engine does not suit to a dump truck use for its poor torque at low engine speed than that of large swept volume engine. But recently, many turbocharged engines with variable geometry turbocharger are applied to this category.

2. Variable geometry turbocharger

Figure one is a cross section of typical variable geometry turbocharger for commercial vehicles. A unit mechanism of moving vanes is adopted for the control of clearance between nozzles and side walls, and good handling at assembling. This mechanism contributes to the long life durability for commercial vehicles. For the recent tightened exhaust gas regulation, turbochargers were designed to allow higher rotational speed limit for generating higher boost pressure. The compressor impeller material and bearing system were modified to keep the reliability. And turbocharger speed sensor was adopted to monitor the unexpected failure of some devices. The continuous control of nozzle position with an electric motor actuator is expected to get more precise control of EGR system for severer future regulation.

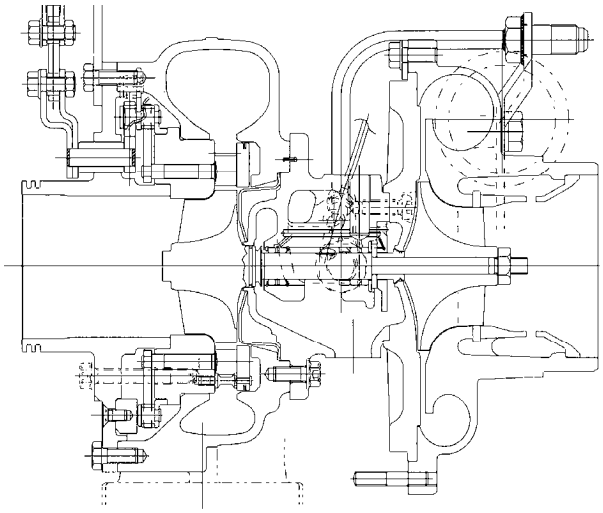

Fig.1 Cross section of typical variable geometry turbocharger for commercial vehicles

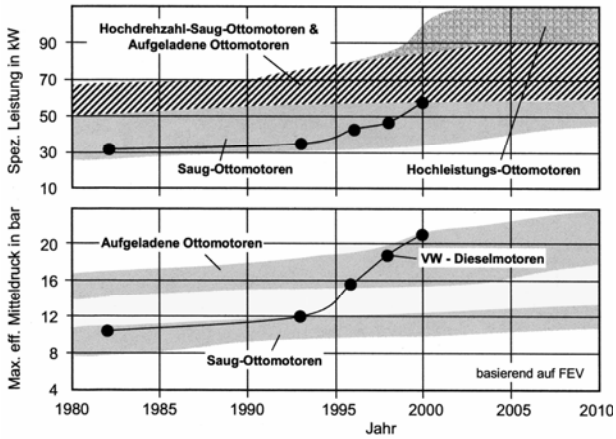

Fig.2 Diesel engine power density and mean effective pressure trend [2]
(up: power density, low: mean effective pressure)

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3. Turbocharger for high power density

Figure two shows power density and mean effective pressure trend in Europe. Power density of turbocharged diesel engines increases year by year from 1995. It has gotten the power density of turbocharged gasoline engine and mean effective pressure became dominant. It is expected that power density will reach at over 65 kW/L in near future. This trend is based on the increase of injection pressure and compressor pressure ratio. Therefore turbocharger rotational speed has a tendency to increase for high-pressure ratio. Impeller stress and rotor dynamics become more important than conventional design.

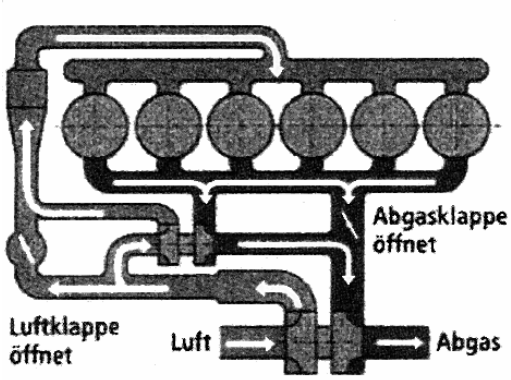

Fig.3 Example of 2-stage turbocharging system for passenger vehicle [4]

BMW applied a 2-stage turbocharging system to 3-liter diesel engine for passenger vehicle as shown in fig. three. In this case, it works as a 2-stage turbocharging system at low engine speed. But at high engine speed, it works as a single stage turbocharging system. High-pressure stage turbocharger doesn't work at that time. This system can get wide operating range without variable geometry turbine. Caterpillar applied a normal 2-stage turbocharging system to their heavy-duty diesel engines for commercial vehicles. It is expected that the similar system will be applied also in Japan.

In the field of passenger vehicles, high-pressure turbocharging progresses for the power density increase. But in the field of commercial vehicles, it is used also for the reduction of exhaust gas emission. The reason of this is that the EGR is used at full load condition. To keep the output power of engine, higher boost pressure is needed under higher EGR rate condition.

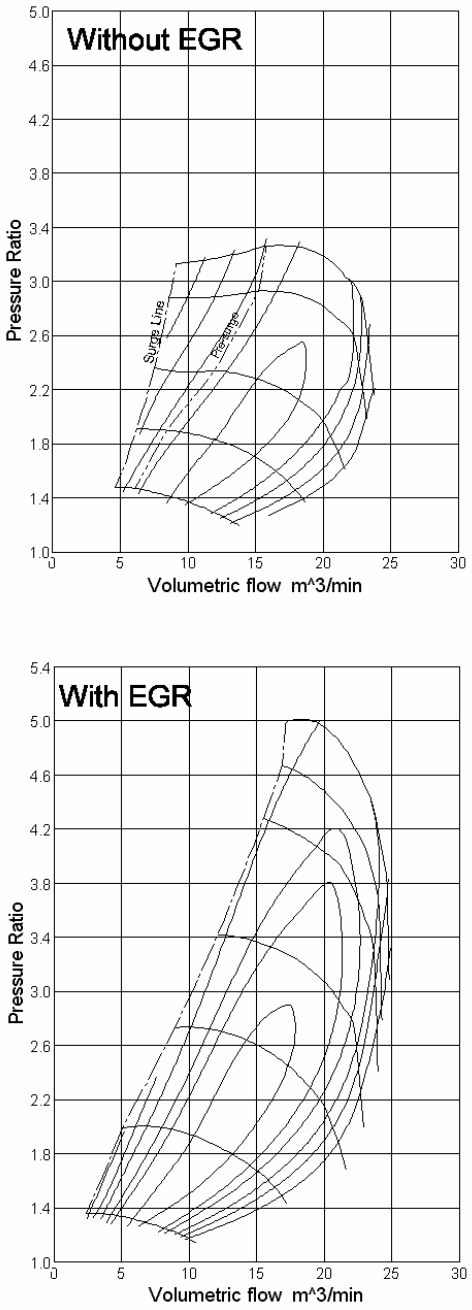

Fig.4 Compressor map comparison of super clean diesel engine project [6]

Ministry of Land, Infrastructure and Transport of Japan is progressing the project of development of the next generation low pollution commercial vehicles from 2002. One of the programs, super clean diesel engine, uses the very high-pressure ratio turbocharger for their high EGR rate and high air fuel ratio combustion concept. The pressure ratio of the turbo-

charger is over 4.0. Figure four shows the compressor performance map comparison between this turbocharger's and conventional performance map without EGR. At such high-pressure ratio condition, turbocharger total efficiency affects engine specific fuel consumption strongly. Therefore higher efficiency of turbocharger is required. And in order to generate high-pressure ratio, turbocharger rotational speed must be high. New compressor and turbine impeller designs are required to oppose to the stress by centrifugal force. Further it is also very important to expand the flow range of compressor at high-pressure ratio. In this way there are some problems that must be overcome to turbochargers. But this concept attracts attention as a technology to be compatible with the high output power with low exhaust gas emissions. It is expected that this concept will become the one of future turbocharging technologies for commercial vehicles.

4. Turbocharger for gasoline engine

Air fuel ratio of gasoline engine at wide open throttle is becoming leaner from fuel rich condition to stoichiometric condition. This is for improvement of fuel consumption and CO_2 reduction. Exhaust gas temperature is also increasing by air fuel ratio trend. This trend is not only for European makers but also for Japanese makers. Commonly the maximum temperature at turbine inlet was about 930 degrees. But now, it becomes over 950 degrees and will reach at 1000 degrees in near future. Development of the new material for such high temperature condition is also proceeding.

5. Summary

By expansion of diesel engine market, the number of turbocharger production is increasing significantly. Many diesel engines use variable geometry type turbochargers for reduction of exhaust gas emission and fuel consumption. In addition, the pressure ratio of compressor has a tendency towards increase by rise of power density. Especially in the commercial vehicles field, it is expected that pressure ratio will increase by EGR.

In the field of gasoline engine, temperature at turbine inlet is increasing for the fuel economy and CO_2 reduction. In near future, 1000 degrees is expected.

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