

The Research on Supercharger for the Diesel Engines

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Abstract: This paper introduces the diesel engine supercharger technology which is used most commonly. Turbocharger system can effectively improve power and torque of diesel engine, but the turbo hysteresis exists. Mechanical supercharging system can boost at low speed, but the efficiency is lower. Electric supercharger can effectively improve the intake air at early stage of accelerated working conditions, however electric supercharger will consume the engine power.

Introduction

The diesel engines are widely used in agriculture and engineering fields by its significant power, economy and emissions targets. The power of diesel engines is come into being by combustion of the fuel in the cylinder, which is restricted by the amount of fuel and the air sucked into the cylinder. The application of supercharger technology has greatly improved the performance of diesel engines. The air entering into the cylinder is increased by the supercharger technology that can not only improve the power of diesel engines but also ameliorate the economy of diesel engines by reducing the fuel consumption.

Air in the diesel engine air intake system is compressed into the cylinder for greater density so as to contain more oxygen molecules per unit volume requiring more fuel injected in accordance with the theoretical air-fuel mixing, so that greater density and quality of the combustible mixture will be obtained under constant displacement which can release more heat after burning to convert a greater driving force thereby. This is the supercharger working principle. In addition, the combustion is more thorough due to sufficient amount of air entering not only improving fuel economy but also reducing harmful exhaust emissions.

The Researching Status of Diesel Turbocharger

Since the 1920s when the first turbocharged diesel engine comes into being, diesel engine supercharger technology has been developing rapidly. Currently the diesel engine supercharger technology which is used most commonly is turbocharger, mechanical supercharger and electric supercharger in three ways.

Turbocharger

Turbocharger system is the supercharger technology which is used most currently on diesel engine. The exhaust gas turbocharger is usually mounted at the rear end turbocharged diesel engine, which is essentially an air compressor compressing air to increase the diesel engine intake air, greatly improving the diesel inflatable coefficient, thus increasing the amount of fuel injection in the cylinder, so that the diesel engine can output more power and torque.

In general, the power and torque of turbo diesel engine can be increased by 20% to 100%, which can make a small displacement diesel engine to achieve the power of large displacement diesel, so as to make the quality of the diesel engine lighter, the combustion more thorough, the consumption of fuel lower and the exhaust emissions smaller relatively.

The greatest disadvantage of supercharger system is the turbo hysteresis. When the speed of

engine is low, the energy of exhaust gas is often too small to drive the turbocharger that will reduce the amount of intake air conversely. When the supercharger works at high speed and large flow, a greater backpressure will come into being to diminish the volumetric efficiency influencing the process of exhaust gas discharged. Additionally the operating temperature of turbocharger is high, so that the lubrication conditions and usage requirements is also strict.

In order to reduce the turbo hysteresis of turbocharging system, the sequential turbocharger, variable geometry turbocharger, waste gated turbocharger, multi-stage turbocharger system are developed gradually, which significantly reduce the turbo hysteresis phenomenon, so that turbocharging technology has made greater development.

The MT890 series diesel engines with high volumetric power developed by Germany MTU company have a major breakthrough in terms of volumetric power up to 92 kW/L, which adopt highly efficient turbocharging technology, becoming the world's most powerful diesel engine series[1]. The turbocharger of the diesel engine is specially developed and manufactured in the affiliated factory of MTU companies, the supercharging pressure ratio of which is 4.5, using continuous variable geometry sectional technology to improve output power, low-speed torque and fuel economy of diesel engine. The engine has low fuel consumption, the power per unit volume of which is higher than the gas turbines, achieving a jump of diesel engine technology.

The basic characteristics of the ultra high supercharging system on turbocharged diesel engine UDV8X1500 successfully developed by France is a turbocharger connected in parallel with the diesel engine, which a bypass staged combustion system is also in parallel with[2]. Air from the compressor is not all into the diesel engine, part of which makes up the fuel gas into the turbine through the bypass and afterburning, making the turbocharger diesel engine maintain at a high work efficiency not affected by operating conditions, so that the supercharging pressure can be much higher than conventional turbochargers. The turbocharger can work independently of the diesel engine and greatly improve the torque performance and acceleration problems of diesel engine.

When the M2 and M3 tanks equipped by American Army began to use diesel engine for power, American Army proposed Cummins Engine Company to develop a engine with low compression ratio in order to meet the high vehicle engine power per unit volume and high fuel economy requirements. Cummins Engine Company adopts the turbo compound system consisting of variable geometry turbochargers with high pressure and low pressure fixed gear ratio connected to engine crankshaft by a fixed transmission ratio, which increases the chariot force from 368kW to 735kW, so that the turbocharger overall efficiency is up to 64%.

China CNR Corporation Limited independently developed a new type of turbocharger in view of the locomotive high-power diesel[3]. The turbocharger uses new structures and new technology of non-water-cooled, efficient wide flow compressor wheel and big cavities, the calibration voltage ratio of which is 3.5 to 3.6 and the overall efficiency of which is up to 61%.

Mechanical Supercharger

The principle of mechanical supercharger system is substantially consistent with turbocharger system different from the source of drive force. The dynamic of mechanical supercharging system generates from the diesel engine working power, which is connected to the crankshaft with a belt and driven by the torque of diesel engine crankshaft.

The most commonly used mechanical supercharger is Roots superchargers, twin-screw supercharger and centrifugal supercharger. Roots-type supercharger will suck air into the gas tank between the flanges when rotating at the engaging flange, a large amount of which is transferred between the intake and exhaust ports entering the intake manifold to accumulate up a positive pressure. Twin-screw supercharger intakes air by the engaging flange similar to a group of two turbine transmission, which is also sucked together by the rotor flange, while twin-screw supercharger compresses the air inside the rotor casing. Centrifugal supercharger sucks air into narrow high-speed compressor housing by the powered of the propeller. Since the air is sucked at the impeller hub, so the centrifugal force will lead air to spread out, while the air flow speed is reduced and the pressure is increased.

In 2005, Japan Siam Kubota company has carried out research on agricultural single-cylinder diesel engine supercharging, the object of which is 195 single-cylinder diesel engine, using a Roots-type supercharger to increase the intake pressure of the engine[4]. The final result shows that the torque can be increased significantly at low-speed while fuel consumption and smoke density reduce significantly; however, due to the intermittent intake of single-cylinder engine, leading to the great fluctuates of intake air flow, coupled with the limited installation space of supercharger, a lot of indicated power brought by supercharger is forfeited on the pumping loss and flow loss of supercharger, which is particularly evident in the high range, so that the actual gain is less than the theoretical calculation.

Mechanical supercharging system can boost at low speed, solving the problem that turbocharger system can only boost up to a certain speed and turbo lag occurs. The output power of mechanical supercharger is naturally gentle, which is linear with the crankshaft speed.

The main disadvantage of mechanical supercharger is the lower efficiency, because mechanical supercharging system is driven by the crankshaft which always consumes power of diesel engines and the engine load increases at high speed.

Electric Supercharger

Electric supercharger system is mainly consisted with two parts of the motor and compressor, powered directly from the battery to the motor or by the power supply voltage conversion through the frequency changer. In operation, the rotating motor drives the compressor of coaxial connections to rotate in order to achieve the purpose of increasing the intake air.

The electric supercharger produced by US North End Performance Inc is used for 6.8L naturally aspirated diesel engine, the average power of which is lifted by 24-25kW. Supercharger is mounted between the air filter and the intake manifold, the control chip of which is connected in parallel with the engine ECU that can always control the air-fuel ratio curve to achieve the best levels of efficiency[5].

A new small power diesel generator electric supercharger is designed in order to solve the problem of power shortage and black smoke on small power diesel generator in a high altitude environment[6]. The device consists of a compressor and a low-voltage DC motor with variable speed, which is powered by the engine charger 12V power source, designed to work at high altitude environment and rated conditions. The device can improve the power and torque of small power diesel engine and reduce smoke emissions, thereby increase the output power of turbine, enhance adaptability of turbines at high altitude environment and reduce the smoke emissions of generators.

A match principle is determined between electric supercharger and diesel engine, which can make the air-fuel ratio of diesel engine up to 23-24 above at minimum operating speed on full load operating conditions, in order to solve the problem of large smoke at low speed[7]. An appropriate motor is chosen to match with compressor of a certain type turbocharger, assembling into a motor-driven supercharger, which can compose into combined charging system with the original machine exhaust gas turbocharger supercharging system for diesel engine intake plenum. Tests showed that electric supercharger can be a good solution to the large smoke problem of diesel engine at low-speed, but the diesel engine torque increase is not obvious.

The advantage of electric supercharger is at early stage of accelerated working conditions when the engine speed is lower than the maximum torque speed, which can effectively improve the intake air at accelerate early stage, solving the problem of poor low-speed acceleration and black smoke of diesel engine.

However electric supercharger can not effectively improve the speed at higher engine speed, so the pressure ratio is not high enough to achieve the desired supercharging effect, at the same time electric supercharger will consume the engine power, therefore electric supercharging effect is not significant at high speed.

Currently supercharger technology has made considerable progress, while the applications range of turbocharger, mechanical supercharger and electric supercharge is increasingly wide, but turbocharger is still the main supercharged manner of diesel engine. Significant turbo lag

phenomenon of turbocharger exists although the new turbocharger can reduce hysteresis, but it can not completely eliminate. Volkswagen introduced a new intake air pressurization system of mechanical supercharger & turbocharger, which can completely eliminate turbo lag effects.

The Development Trends of Diesel Supercharger

The development of supercharged technology is closely related with future development claim of supercharged diesel engine, mainly to meet stringent emissions regulations and improve the whole performance conditions of the engine. Future pressurization system may have a higher thermal efficiency, on which the electronic control systems will be adopt to match with the engine in order to achieve the best match in the whole engine operating conditions. With diesel technology especially supercharger technology continues to develop, variable geometry supercharger system and twin-turbo system have begun to try on the high-end engine, while mechanical supercharger & turbocharger on behalf of the highest technical level will obtain comprehensive application.

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