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STUDY OF TURBO CHARGING

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ABSTRACT

The purpose of supercharging is to increase the mass of air trapped in the cylinders of the engine, by raising air density. This allows more fuel to be burnt, increasing the power output of the engine, for a given swept volume of the cylinders. Thus the powers to weight and volume ratios of the engine increase. Since more fuel is burnt to achieve the power increase, the efficiency of the engine cycle remains unchanged.[1] Turbochargers were originally known as turbo superchargers when all forced induction devices were classified as superchargers. Now a days the term "supercharger" is usually applied to only *mechanically* driven forced induction devices.[2] The key difference between a turbocharger and a conventional supercharger is that the conventional is mechanically driven by the engine, often through a belt connected to the crankshaft, whereas a turbocharger is powered by a turbine driven by the engine's exhaust gas. Compared to a mechanically driven supercharger, turbochargers tend to be more efficient, but less responsive.[3]

Turbocharging of large two-stroke engines, four-stroke medium speed engines, and high speed truck and passenger car diesel engines all make different requirements on the turbocharger.[1] In this section, a description of the different types of turbocharging systems used to deliver exhaust gas to the turbine. Later sections deal with application of turbochargers to the different classes of engine and advantages described above.

Keywords: Turbo Charger, Turbine, Compressor, Engine, Exhaust Gas Etc

I. INTRODUCTION

A turbocharger, or turbo (colloquialism), from Greek "τύρβη" ("wake"), [4] (also from Latin "turbo" ("spinning top"),[5]) is a turbine driven forced induction device that increases an engine's efficiency and power by forcing extra air into the combustion chamber.[6][7] This improvement over a naturally aspirated engine's output results because the turbine can force more air, and proportionately more fuel, into the combustion chamber than atmospheric pressure alone.[3] A compressor is used to achieve the increase in air density. If the compressor is driven by a turbine, which itself is driven by the exhaust gas from the cylinders, the system is called 'turbo charging'. The shaft of the turbocharger links the compressor and turbine, but is not connected to the crankshaft of the engine.. Thus the power developed by the turbine dictates the compressor operating point, since it must equal that absorbed by the compressor.[1]

The essential components of the 'turbocharger' are the turbine, compressor, connecting shaft, bearings and housings. The advantage of the turbocharger, over a mechanically driven supercharger, is that the power required to drive the compressor is extracted from exhaust gas energy rather than the crankshaft. Thus turbo charging is more efficient than mechanical super charging. However the turbine imposes a flow restriction in the exhaust system, and therefore the exhaust manifold pressure will be greater than atmospheric pressure. If sufficient energy can be extracted from the exhaust gas, and converted into compressor work, then the system can be designed such that the compressor delivery pressure exceeds that at turbine inlet, and the inlet and exhaust processes are not adversely affected.[1]

II. HISTORY

The turbocharger was invented by Swiss engineer Alfred Büchi (1879-1959), the head of Diesel engine research at Gebrüder Sulzer engine manufacturing company in Winterthur,[8] who received a patent in 1905 for using a compressor driven by exhaust gasses to force air into an internal combustion engine to increase power output, but it took another 20 years for the idea to come to fruition.[9][10] During World War I French engineer Auguste Rateau fitted turbochargers to Renault engines powering various French fighters with some success.[11] In 1918, General Electric engineer Sanford Alexander Moss attached a turbocharger to a V12 *Liberty* aircraft engine. The engine was tested at Pikes Peak in Colorado at 14,000 ft (4,300 m) to demonstrate that it could eliminate the power loss usually experienced in internal combustion engines as a result of reduced air pressure and density at high altitude.[11] General Electric called the system turbo supercharging.[12] At the time, all forced induction devices were known as superchargers, however more recently the term "supercharger" is usually applied to only mechanically driven forced induction devices.[14]

Turbochargers were first used in production aircraft engines such as the Napier Lioness[13] in the 1920s, although they were less common than engine driven centrifugal super chargers. Ships and locomotives equipped with turbocharged. Diesel engines began appearing in the 1920s. Turbochargers were also used in aviation, most widely used by the United States. During World War II, notable examples of U.S. aircraft with turbochargers include the B17 Flying Fortress, B24 Liberator, P38 Lightning, and P47

Thunder bolt. The technology was also used in experimental fittings by a number of other manufacturers, notably a variety of Focke Wulf Fw 190 models, but the need for advanced high temperature metals in the turbine kept them out of widespread use.[3]

III. KEY COMPONENTS

The turbocharger has three main components:

1. The turbine, which is almost always a radial inflow turbine (but is almost always a single stage axial inflow turbine in large Diesel engines)
2. The compressor, which is almost always a centrifugal compressor
3. The center housing/hub rotating assembly

Many turbocharger installations use additional technologies, such as wastegates, inter cooling and blow off valves.[3]

3.1 Turbine

Energy provided for the turbine work is converted from the enthalpy and kinetic energy of the gas. The turbine housings direct the gas flow through the turbine as it spins at up to 250,000 rpm.[15][16] The size and shape can dictate some performance characteristics of the overall turbocharger.[3]

The turbine and impeller wheel sizes also dictate the amount of air or exhaust that can be flowed through the system, and the relative efficiency at which they operate. In general, the larger the turbine wheel and compressor wheel the larger the flow capacity. Measurements and shapes can vary, as well as curvature and number of blades on the wheels.[3]

Turbine blades are usually a nickel chrome alloy or a nimonic material (a nickel alloy containing chrome, titanium, aluminium, molybdenum and tungsten) which has good resistance to creep, fatigue and corrosion. Manufactured using the investment casting process. Blade roots are of fir tree shapes which give positive fixing and minimum stress concentration at the conjunction of root and blade. The root is usually a slack fit to allow for differential expansion of the rotor and blade and to assist damping vibration. On small turbochargers and the latest designs of modern turbochargers the blades are a tight fit in the wheel.[17]

A turbocharger’s performance is closely tied to its size.[18] Large turbochargers take more heat and pressure to spin the turbine, creating lag at low speed. Small turbochargers spin quickly, but may not have the same performance at high acceleration. [19][20] To efficiently combine the benefits of large and small wheels, advanced schemes are used such as twin turbochargers, Twin scroll turbo chargers, or variable geometry Turbo chargers.[3]

3.1.1 Twin turbo

Twinturbo or biturbo designs have two separate turbochargers operating in either a sequence or in parallel.[21][22] In a parallel configuration, both turbochargers are fed onehalf of the engine’s exhaust. In a sequential setup one turbocharger runs at low speeds and the second turns on at a predetermined engine speed or load.[22]

Two stage variable twin turbo employ a small turbocharger at low speeds and a large one at higher speeds. They are connected in a series so that boost pressure from one turbocharger is multiplied by another, hence the name "2stage."The distribution of exhaust gas is continuously variable, so the transition from using the small turbocharger to the large one can be done incrementally.[23] Twin turbochargers are primarily used in Diesel engines.[22] For example, in Opel bi turbo Diesel, only the smaller turbo charger works at low speed, providing high torque at 1,500–1,700 rpm. Both turbochargers operate together in mid range, with the larger one pre compressing the air, which the smaller one further compresses.[3]

3.1.2 Twin scroll

Twin scroll or divided turbochargers have two exhaust gas inlets and two nozzles, a smaller sharper angled one for quick response and a larger less angled one for peak performance. With high performance camshaft timing, exhaust valves in different cylinders can be open at the same time, overlapping at the end of the power stroke in one cylinder and the end of exhaust stroke in another. In twins croll designs, the exhaust manifold physically separates the channels for cylinders that can interfere with each other, so that the pulsating exhaust gasses flow through separate spirals (scrolls). With common firing order 1-3-4-2, two scrolls of unequal length pair cylinders 1-4 and 3-2. This lets the engine efficiently use exhaust scavenging techniques, which decreases exhaust gas temperatures and NOx emissions, improves turbine efficiency, and reduces turbo lag evident at low engine speeds.[24]

3.1.3 Variable Geometry

Variable geometry or variable nozzle Turbo chargers use moveable vanes to adjust the airflow to the turbine, imitating a turbocharger of the optimal size throughout the power curve. [18][19] The vanes are placed just in front of the turbine like a set of slightly overlapping walls. Their angle is adjusted by an actuator to block or increase air flow to the turbine.[19][20] This variability maintains a comparable exhaust velocity and back pressure throughout the engine’s rev range. The result is that the turbocharger improves fuel efficiency without a noticeable level of turbocharger lag.[18]

3.2 Compressor

The compressor increases the mass of intake air entering the combustion chamber. The compressor is made up of an impeller, a diffuser and a volute housing.The operating range of a compressor is described by the "compressor map".[3]

3.2.1 Ported Shroud

The flow range of a turbocharger compressor can be increased by allowing air to bleed from a ring of holes or a circular groove around the compressor at a point slightly downstream of the compressor inlet The ported shroud is a performance enhancement that allows the compressor to operate at significantly lower flows. It achieves this by forcing a simulation of impeller stall to occur continuously. Allowing some air to escape at this location inhibits the onset of surge and widens the operating range. While peak efficiencies may decrease, high efficiency may be achieved over a greater range of engine speeds. Increases in compressor efficiency result in slightly cooler (more dense) intake air, which improves power. This is a passive structure that is constantly open. The ability of the compressor to provide high boost at low rpm may also be increased marginally. Ported shrouds are used by many turbocharger manufacturers.[3]

The compressor impeller is of aluminium alloy or the more expensive titanium. Manufactured from a single casting it is located on the rotor shaft by splines. Aluminium impellers have a limited life, due to creep, which is dictated by the final air temperature. Often the temperature of air leaving the impeller can be as high as 200°C. The life of the impeller under these circumstances may be limited to about 70000 hours.[17]

3.3 Center Housing/Hub Rotating Assembly

The center hub rotating assembly (CHRA) houses the shaft that connects the compressor impeller and turbine. It also must contain a bearing system to suspend the shaft, allowing it to rotate at very high speed with minimal friction. For instance, in automotive applications the CHRA typically uses a thrust bearing or ball bearing lubricated by a constant supply of pressurized engine oil. The CHRA may also be considered "water cooled" by having an entry and exit point for engine coolant. Water cooled models use engine coolant to keep lubricating oil cooler, avoiding possible oil coking (destructive distillation of engine oil) from the extreme heat in the turbine.[3]Ball bearings designed to support high speeds and temperatures are sometimes used instead of fluid bearings to support the turbine shaft. This helps the turbocharger accelerate more quickly and reduces turbo lag.[25]

Bearings are either of the ball or roller type or plain white metal journals. The ball and roller bearings are mounted in resilient mountings incorporating spring damping to prevent damage due to vibration. These bearings have their own integral oil pumps and oil supply, and have a limited life (8000 hrs). Plain journal bearings are lubricated from the main engine oil supply or from a separate system incorporating drain tank, cooler and pumps. Oil is supplied in sufficient quantity to cool as well as lubricate. The system may incorporate a header tank arrangement to supply oil to the bearings whilst the turbocharger comes to rest should the oil supply fail.[17]

IV. CONSTRUCION & WORKING

The components that make up a typical turbocharger system are:

- The air filter (not shown) through which ambient air passes before entering the compressor (1)
- The air is then compressed which raises the air’s density (mass / unit volume) (2)
- Many turbocharged engines have a charge air cooler (aka intercooler) (3) that cools the compressed air to further increase its density and to increase resistance to detonation
- After passing through the intake manifold (4), the air enters the engine’s cylinders, which contain a fixed volume. Since the air is at elevated density, each cylinder can draw in an increased mass flow rate of air. Higher air mass flow rate allows a higher fuel flow rate (with similar air/fuel ratio). Combusting more fuel results in more power being produced for a given size or displacement
- After the fuel is burned in the cylinder it is exhausted during the cylinder’s exhaust stroke in to the exhaust manifold (5)
- The high temperature gas then continues on to the turbine (6). The turbine creates backpressure on the engine which means engine exhaust pressure is higher than atmospheric pressure
- A pressure and temperature drop occurs (expansion) across the turbine (7), which harnesses the exhaust gas’ energy to provide the power necessary to drive the compressor[26]

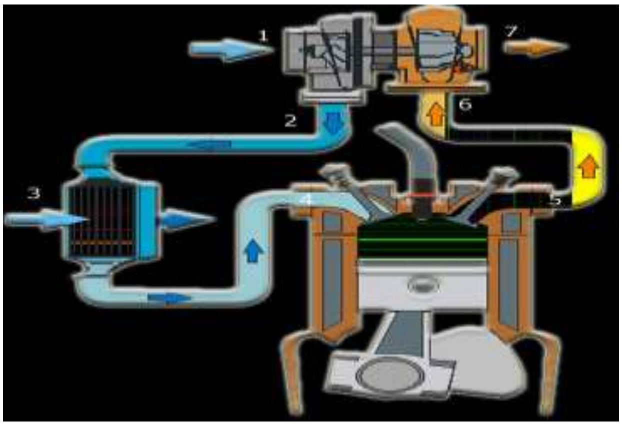

Fig:-Turbo Charger System

1 Compressor Inlet
2 Compressor Discharge
3 Charge air cooler (CAC)
4 Intake Valve
5 Exhaust Valve
6 Turbine Inlet
7 Turbine Discharge

V. APPLICATIONS

3.1 Petrol Powered Cars

The first turbocharged passenger car was the Oldsmobile Jet fire option on the 19621963 F85/Cutlass, which used a turbo charger mounted to a 215 cu in (3.52 L) all aluminum V8. Also in 1962, Chevrolet introduced a special run of turbo charged Corvairs, initially called the Monza Spyder (1962 1964)and later renamed the Corsa (1965 1966),which mounted a turbocharger to its air cooled flat six cylinder engine Turbocharging can increase power output for a given capacity[27] or increase fuel efficiency by allowing a smaller displacement engine. The 'Engine of the year 2011' is an engine used in a Fiat 500 equipped with an MHI turbocharger. This engine lost 10% weight, saving up to 30% in fuel consumption while delivering the same HP (105) as an 1.4 litre engine. The 2013 Chevrolet Cruze is available with either a 1.8 litre nonturbocharged engine or a 1.4 litre turbocharged engine—both produce the same 138 horsepower. Low pressure turbo charging is the optimum when driving in the city, whereas high pressure turbo charging is more for racing and driving on highways/motorways/freeways.[3]

5.2 Diesel Powered Cars

The first production turbocharger Diesel passenger car was the Garrett turbo charged [28] Mercedes 300SD introduced in 1978.[29][30] Today, most automotive Diesels are turbocharged, since the use of turbo charging improved efficiency, driveability and performance of Diesel engines,[29][30] greatly increasing their popularity. The Audi R10 with a Diesel engine even won the 24 hours race of Le Mans in 2006, 2007 and 2008.[3]

5.3 Trucks

The first turbocharged Diesel truck was produced by *Schweizer Maschinenfabrik Saurer* (Swiss Machine Works Saurer) in 1938.[31]

5.4 Motorcycles

The first example of a turbocharged bike is the 1978 Kawasaki Z1R TC.[32] Several Japanese companies produced Turbo charged high performance motorcycles in the early 1980s, such as the CX500 Turbo from Honda a transversely mounted, liquid cooled V Twin also available in naturally aspirated form. The Dutch manufacturer EVA motorcycles builds a small series of turbocharged Diesel motorcycle with an 800cc smart CDI engine.[3]

5.5 Aircraft

A natural use of the turbocharger — and its earliest known use for any internal combustion engine, starting with experimental installations in the 1920s — is with aircraft engines. As an aircraft climbs to higher altitudes the pressure of the surrounding air quickly falls off. At 5,486 m (18,000 ft), the air is at half the pressure of sea level and the airframe experiences only half the aerodynamic drag. However, since the charge in the cylinders is pushed in by this air pressure, the engine normally produces only half power at full throttle at this altitude. Pilots would like to take advantage of the low drag at high altitudes to go faster, but a naturally aspirated engine does not produce enough power at the same altitude to do so.[3]

VI. ADVANTAGE

By turbo charging an engine, the following advantages are obtained.

- Increased power for an engine of the same size OR reduction in size for an engine with the same power output.
- Reduced specific fuel oil consumption mechanical, thermal and scavenge efficiencies are improved due to less cylinders, greater air supply and use of exhaust gasses.
- Thermal loading is reduced due to shorter more efficient burning period for the fuel leading to less exacting cylinder conditions[17]

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