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Increasing the Efficiency of an Engine by the use of Variable Geometry Turbochargers

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ABSTRACT— The automobile of today is the result of the accumulation of many years of pioneering research and development. The purpose behind this study of variable geometry turbocharger is to overcome the fundamental drawback of the internal combustion engine, its volumetric efficiency limit. Here, The VGT with no wastegate uses the exhaust energy to drive the turbine, which inturn drives the compressor to increase the volumetric efficiency and simultaneously increasing the expansion ratio, power output, Output Torque and to get the increased results on an IC Engine. This additional power, the alternate power must be much more convenient in availability and usage.

KEYWORDS:VGT, Wastegate, Expansion Ratio, volumetric efficiency

I. INTRODUCTION

Turbochargers used on automotive engines are well known for their ability to increase engine output. By forcing more air into the engine via the turbocharger's compressor, more fuel can be injected into the engine thus increasing its output. Using a turbocharger also makes an engine eco-friendlier.The turbocharger improves engine efficiency by using the energy contained in the exhaust gasses in the form of pressurized gas and heat to drive the compressor. A second ecological advantage is that it enables the use of a smaller and more efficient engine delivering the same level of performance, which makes for a lighter vehicle and thus further reduces fuel consumption. Here, Variable-geometry turbochargers (VGTs) are a family of turbochargers, usually designed to allow the effective aspect ratio (A: R) of the turbo to be altered as conditions change. This is done because optimum aspect ratio at low engine speeds is very different from that at high engine speeds. If the aspect ratio is too large, the turbo will fail to create boost at low speeds; if the aspect ratio is too small, the turbo will choke the engine at high speeds, leading to high exhaust manifold pressures, high pumping losses, and ultimately lower power output. By altering the geometry of the turbine housing as the engine accelerates, the turbo's aspect ratio can be maintained at its optimum. Because of this, VGTs have a minimal amount of lag, have a low boost threshold, and are very efficient at higher engine speeds. VGTs do not require a waste gate. VGTs tend to be much more common on diesel engines as the lower exhaust temperatures mean they are less prone to failure. The few early gasoline-engine VGTs required significant pre-charge cooling to extend the turbocharger life to reasonable levels, but advances in material technology has improved their resistance to the high temperatures of gasoline engine exhaust and they have started to appear increasingly in, e.g., gasoline-engined sports cars.

II. HISTORY

The first successful application of exhaust gas turbocharging succeeded the Swiss Alfred Büchi (July 11, 1879, October 27, 1959) in 1925, with a power increase of over 40%. From this time the phased introduction of exhaust gas turbocharging began initially limited to the first commercially use in turbocharger applications for very large motors, such as Ship engines. On wheels starts turbocharging in the commercial vehicle sector. In 1938, The Swiss company Saurer brings the first turbocharged engine for commercial diesel-engines on the market.The idea of using a variable geometry turbine in a turbocharger dates back at least to the 1950s.

In the year 1962/63 were in the USA the Chevrolet Corvair Monza and the Oldsmobile Jet fire the first production car equipped with exhaust turbocharger. Due to the high compression ratio of 10.25:1 tilted the engine very easy to self-ignition (knocking), which Oldsmobile led to install a water injection system. In the 70's won the turbo engine with the introduction a high popularity of the turbocharger in Formula 1. After all, could the engine power increase to ~ 1500 HP, which is triple the current output corresponded. The seventies were also the start of series production for turbocharged gasoline engines in Europe. Indeed, BMW is the first manufacturer in Germany who brought 1973 the "2002 turbo" on the

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market. High engine power, but high fuel consumption coupled with a low reliability brought this era of fast. In 1990s, after the turbo fascination in the early years is changing the turbocharger from the power unit to a small helper to us today to help cut carbon dioxide (CO2) reduction and the environment. In recent years, again reinforced gasoline engines with exhaust turbo in series on the market.

III.TURBOCHARGER PARTS AND FUNCTION

A turbocharger consists of two fundamental components, a turbine and a compressor. The function of the turbine is to scavenge waste exhaust heat and translate it into rotational motion. This rotational motion is then used to drive the compressor, which compresses air for the consumption of the engine. The purpose behind the turbocharger is to overcome the fundamental drawback of the internal combustion engine, its volumetric efficiency limit. An engine drawing air in from the atmosphere can only achieve a volumetric efficiency of up to 100%, meaning that the pressure inside an individual cylinder is equal to atmospheric pressure while the intake cycle is occurring. Since the amount of power that can be extracted from an engine is proportional to the fuel it burns, and the fuel consumption is limited by the amount of air present in a cylinder, times the number of cylinders (the so-called "displacement"), the volumetric efficiency limit effectively constrains the power of the engine. To make an engine more powerful, one must increase its displacement.

Unfortunately, the consequence to this is that the engine burns more fuel under all conditions, adversely affecting its fuel mileage. The turbocharger provides an alternative means of extracting more power from a given displacement by increasing the volumetric efficiency to points significantly above 100%. The pressure in the cylinders is greater than atmospheric, thanks to the compressor on the turbocharger. One might wonder how this improves the fuel-economy situation at all. Because of the way gasoline engines are controlled, it turns out that a turbocharger can be set up to only function when one wants additional power, so that most of the time, the turbocharger doesn't adversely affect fuel economy (perhaps a 5% reduction overall), but when needed, the engine is capable of turning out significantly more power.

IV. THE DRAWBACK OF TRADITIONAL TURBOCHARGERS

The turbines driving turbochargers are characterized by two chief parameters: A/R ratio and turbine radius. The A/R ratio is the ratio of the Area of the exhaust gas passage to the Radius from the centre of the turbine wheel to the point defining the center of that area1. Turbochargers are designed such that the A/R ratio is always a constant: as the exhaust gasses are directed closer towards the turbine wheel, the area the gas flows through gets smaller. Funnelling the exhaust down into a smaller area produces a higher velocity stream; a higher velocity stream imparts more power to the turbine wheel. It is clear, then, that the turbine can drive the compressor at a higher speed (and thus produce a greater pressure inside the engine) when the A/R ratio is low. Unfortunately, as gas velocity increases, so does the exhaust gas pressure. For the same exhaust flow rate from the engine, the larger A/R will build up less pressure than the smaller A/R. When designing a real-world system, both of these factors are important. Using traditional turbochargers, an engine designer would have to balance desire for high exhaust flow to drive the compressor against low back-pressure in the exhaust system, which robs the engine of efficiency, and in extreme cases, significantly reduces the amount of power that can be gained from an engine.

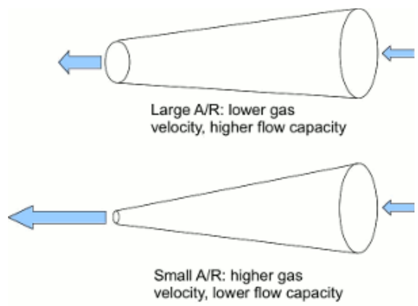

Fig: Effect of A/R ratio on exhaust flow speed and flow capacity.

Effectively, this means that there is a narrow range of operation of a turbocharger/engine combination in which the system is capable of putting out significantly more power, with tails at either end where power is building up or falling off. This distribution of power is pivotal to the individuals that actually sell the cars, since they have to show people on test-drives that the car is a powerful one. Unfortunately, because of the relationship between A/R ratio and exhaust flow, a designer must choose between having a quick onset of power (which subsequently robs the engine of power at higher speeds) or a slow onset of power (which results in a more powerful car at higher speeds).

V.NEEDS OF A VARIABLE GEOMETRY TURBOCHARGER:

In power boosting of engines, the application ofConventional turbochargers could realize only a limited improvement because it is effective in a narrow flow range. Charging effect of a conventional turbocharger is too poor in a low flow range below the matching point to realize a high power output at a low engine speed region.The waste gated turbochargers that bypass some portion of an exhaust gas are generally used for boosting high speed Diesel engines. But, recently, VGT (Variable Geometry Turbocharger) is increasingly used in HSDI Diesel engines, which makes it possible to raise the boost pressure even at lower engine speeds, together with the reduction of pumping losses at higher engine speeds compared with a waste gated turbocharger. In this study, anVGT was applied to an HSDI Diesel engine, and theImprovement of a full load performance over the case with a mechanically controlled waste gated turbocharger is confirmed. The test engine is a prototype 2.5 litre direct injection Diesel engine, equipped with a common rail fuel injection system with a maximum rail pressure of 1350 bar and 4 valves per cylinder. The VGT tested in this studywas a Variable Nozzle Turbine (VNT) type, and the vane angle of the turbine nozzle can be varied,

VI.OPERATION OF A VARIABLE GEOMETRY TURBOCHARGER:

Variable Nozzle Turbine (VNT). A turbocharger equipped with Variable Turbine Geometry has little movable vanes which can direct exhaust flow onto the turbine blades. The vane angles are adjusted via an actuator. The angle of the vanes vary throughout the engine RPM range to optimize turbine behaviour.

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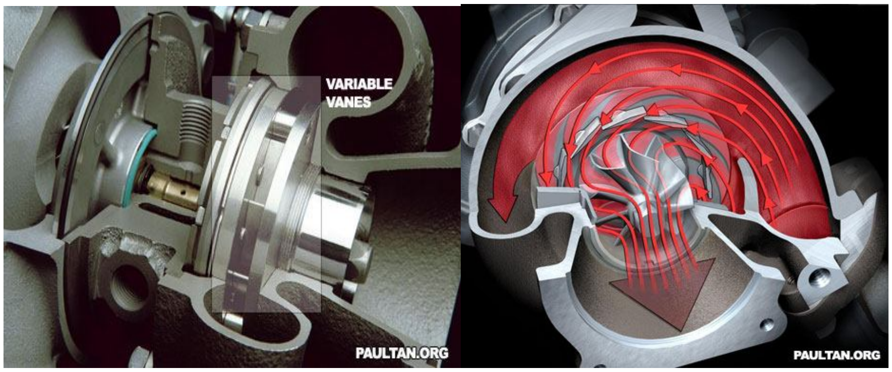
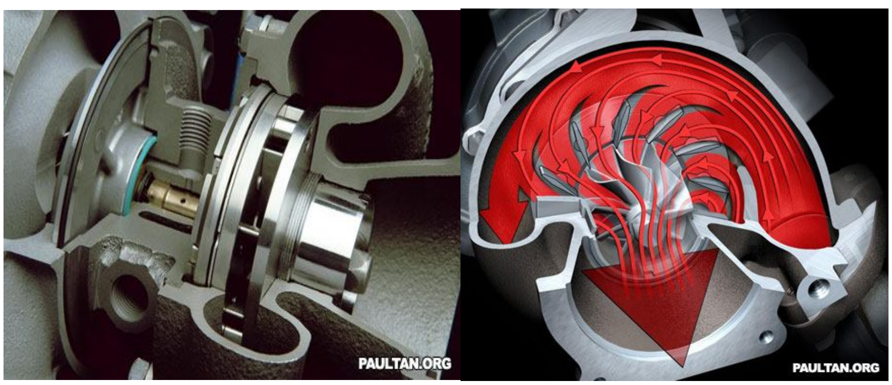


In the 3D illustration above, you can see the vanes in a angle which is almost closed. I have highlighted the variable vanes so you know which is which. This position is optimized for low engine RPM speeds, pre-boost.In this cut-through diagram, you can see the direction of exhaust flow when the variable vanes are in an almost closed angle. The narrow passage of which the exhaust gas has to flow through accelerates the exhaust gas towards the turbine blades, making them spin faster. The angle of the vanes also directs the gas to hit the blades at the proper angle.



Above are how the VGT vanes look like when they are open. I've not highlighted where the vanes are in this image since you already know where they are, as to not spoil the mechanical beauty. This cut-through diagram shows the exhaust gas flow when the variable turbine vanes are fully open. The high exhaust flow at high engine speeds are fully directed onto the turbine blades by the variable vanes.

VII.BENEFITS OF VGT

An alternative to the fixed geometry turbine is the variable geometry turbine. The benefits of variable geometry turbines over waste gated turbines include:

- no throttling loss of the waste gate valve;
- higher air–fuel ratio and higher peak torque at low engine speeds;
- improved vehicle accelerations without the need to resort to turbines with high pumping loss at high engine speeds;
- potential for lower engine ΔP (the difference between exhaust manifold and intake manifold pressures);
- control over engine ΔP that can be used to drive EGR flow in diesel engines with High Pressure Loop (HPL) EGR systems;
- a better ability to cover a wider region of low BSFC in the engine speed–load domain;

- ability to provide engine braking;
- Ability to raise exhaust temperature for after treatment system management.

III.RESULT AND DISCUSSION

With the use of the VGT, it is possible to increase the charge air mass by about 10 ~ 20 % at a low speed range. As a result of this, the exhaust smoke is reduced and the fuel consumption is improved with the same fuel delivery and start timing of injection. At low speed, over 40 % of additional torque increase can be observed within the same exhaust smoke, the cylinder pressure, and the exhaust gas temperature limit, by adjusting the boost pressure and fuel delivery with the VGT. In the medium engine speed range, there is a marginal gain in the fuel consumption for the VGT, with the same fuel delivery. When the boost pressure and fuel delivery are increased, more torque could be achieved with the expense of the deterioration in fuel consumption. This is because the injection timing should be retarded not to exceed the maximum cylinderPressure limit. At high engine speed, with the same fuel delivery, the rated power can be enhanced by 3.5 %, mainly caused by the reduction of pumping loss. However, within the same boundary conditions, the power increase for the VGT could reach about 7.9 %.

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