UNIT II **TURBOCHARGING**

Turbocharging Basic concept :

Turbocharger: It is a device that helps in compression of additional air required for the efficient combustion of the fuel air mixture. The advantage of compressing the air is that it lets the engine stuff more air into a cylinder. At high speed and at high altitude there is a shortage of the intake air. At such times there is incomplete combustion which may lead to the loss of power. To avoid this loss, a device is installed in an automobile which increases the compression of air thus ensuring sufficient supply of air.

Turbocharging principle:

A turbocharger consists of a compressor wheel and exhaust gas turbine wheel coupled together by a solid shaft and that is used to boost the intake air pressure of an internal combustion engine. The exhaust gas turbine extracts energy from the exhaust gas and uses it to drive the compressor and overcome friction.

It is the job of the turbocharger to compress more air flowing into the engine's cylinder. When air is compressed the oxygen molecules are packed closer together. This increase in air means that more fuel can be added for the same size naturally aspirated engine.

Comparison between turbocharging and supercharging:

The key difference between a supercharger and a turbocharger is the source of power for their operation. A supercharger consumes that is generated from the engine of the vehicle. It runs through a belt that is connected to engine shaft. Thus it is less efficient.

On the other hand, Turbocharger operates on the exhaust gas energy that would otherwise go waste. Thus it is an efficient device as compared to supercharger. But there is a uncertainty involved with the turbocharger. For example the exhaust gas energy varies with speed and thus there is a certain lag when turbocharger is in operation. A supercharger has constant supply of energy and thus lag is negligible. But a supercharger is constant supply of energy and thus lag is negligible.

When both of the above- Supercharger and Turbocharger are used together, it is called Twincharging.

Both of them serve the same purpose of compressing the air and then send it into the cylinder! which is simply called as Forced Induction.

Difference lies in the operation, position and lag

Super Charger

A Super Charger is Placed generally a top of the engine, It is driven by a Belt from the Engine which further drives a motor which sucks air and compresses the air.
A Twin Screw compresses the air which enters the combustion chamber.

Main Advantage of a Super charger is it's Driven Directly by Engine, which gives us less lag

This Setup is connected to Intake Manifold.

Turbocharger

It is also considered as a type of super charger. You can call it Turbo-Super-Charger

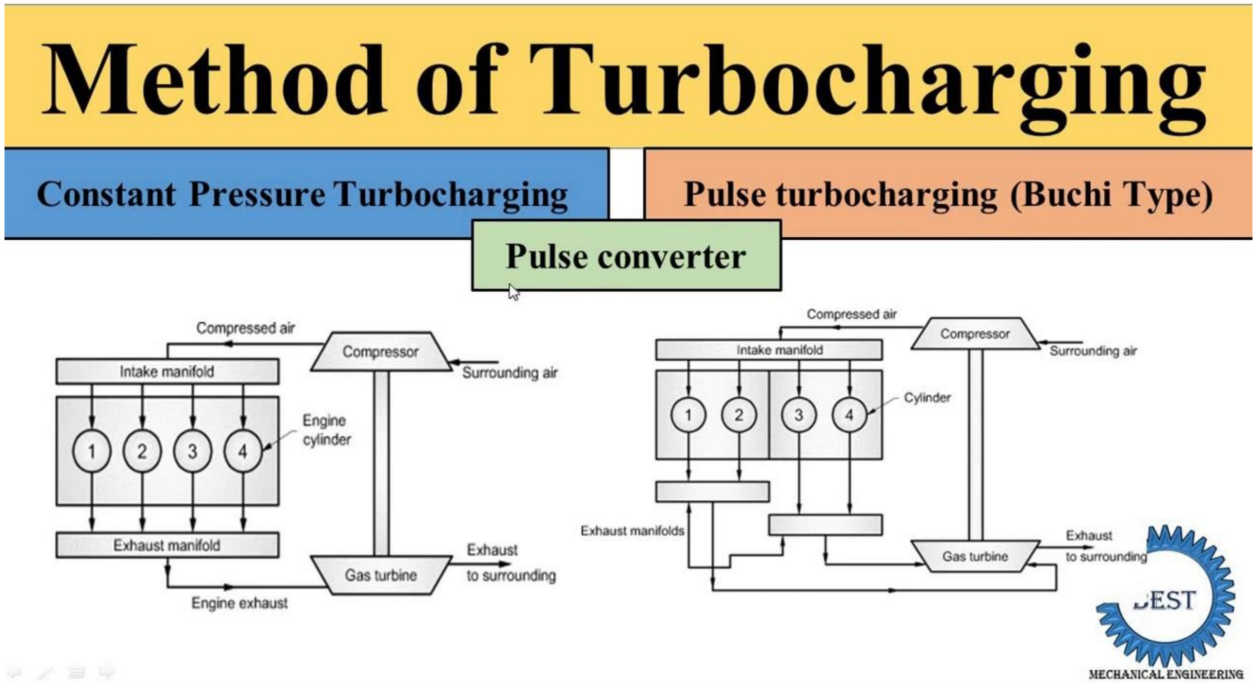
This is a combination of a turbine and a Compressor, Where Turbine lies at the Exhaust Manifold and Compressor lies beside it near the Intake Manifold.

The Exhaust Carries a lot of kinetic energy, this energy is used to drive the turbine which rotates the compressor, which further compresses the air going into the cylinder.

Effects on Engine performance :

A turbocharged engine can be more powerful and efficient than a naturally aspirated engine because the turbine forces more intake air, proportionately more fuel, into the combustion chamber than if atmospheric pressure alone is used. Its purpose is to increase the volumetric efficiency of the combustion chamber.

Turbocharging methods:



1. Constant Pressure System Turbocharging
- ❖ Exhaust gas from all cylinders into a common large manifold where pulse energy is largely dissipated.
- ❖ The gas flow will steady rather than intermittent and at a constant pressure at turbine inlet.

Turbocharger Arrangement in Constant Pressure System
- ❖ No exhaust grouping
- ❖ Exhaust gases enter into large common manifold and then to turbine

Firing order not considered

Advantages and Disadvantages for Constant Pressure System

Advantages
- ❖ Good performance in high load (Efficient when Bmep is above 8 bar)
- ❖ More suitable for high output engine.
- ❖ There is no need to group the cylinders exhaust into multiple of three. (Simple piping system)
- ❖ No exhaust grouping
- ❖ High turbine efficiency due to steady flow of exhaust.
- ❖ The work transfer at the turbine wheel is smooth.
- ❖ Reduction in SFOC (Specific Fuel Oil Consumption) of 5% – 7%

Disadvantages
- ❖ When running at reduced speed and starting up low available energy at turbine.

- Thus it supplies inadequately air quantity of the scavenge pressure necessary for efficient scavenging and combustion.
- It require scavenge assistant (Auxiliary Blowers).

Poor response in changing load.

2. Pulse System of Turbocharging

- Makes full use of the higher pressure and temperature of the exhaust gas during the blow down period
- While rapidly opening the exhaust valves, exhaust gas leave the cylinder at high velocity as pressure energy is converted into kinetic energy to create the pressure wave or pulse in exhaust
- These pressure waves or pulses are lead directly to the turbocharger
- Exhaust pipe, so constructed in small diameter, is quickly pressurized and boosted up to form pressure pulse or wave

Pressure waves reach to turbine nozzles and further expansion takes place.

Turbocharger Arrangement in Pulse System

- Interference exists between exhausting and scavenging among cylinders
- To prevent this, cylinders are grouped relatively with connections to two or more exhaust pipes
- Pipes are arranged, in small diameter to boost up pressure pulse and in short, straight length to prevent energy loss
- Number of exhaust branch depends upon firing order, number of cylinders and turbocharger design

Advantages and Disadvantages of Pulse System

Advantages

- At low load and low speed it is more efficient (Still efficient when Bmep is < 8 bar)
- No need assistant of scavenge pump and blower at any load change.
- It is highly response to change engine condition giving good performance of all speed of engines.
- High available energy at turbine
- Good turbocharger acceleration

Disadvantages

- The exhaust grouping is complicated.
- Different sizes of exhaust pipes are needed for spare.
- High pressure exhaust from one cylinder would pass back into another cylinder during the low pressure scavenging period thus adversely effecting the combustion efficiency.

Variable Geometry Turbocharging :

VGTs offer improved transient response over conventual fixed geometry turbochargers. This makes VGTs ideal for use in vehicles where power demand is very dynamic. In situations where engine load is constant like in stationary generators, fixed geometry turbochargers can provide higher efficiency over VGTs.

Variable-geometry turbochargers (VGTs), occasionally known as variable-nozzle turbochargers (VNTs), are a type of turbochargers, usually designed to allow the effective aspect ratio (A/R ratio) of the turbocharger to be altered as conditions change. This is done with the use of adjustable vanes located inside the turbine housing between the inlet and turbine, these vanes affect flow of gases towards the turbine. The benefit of the VGT is that the 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, a low boost threshold, and high efficiency at higher engine speeds.

The most common implementations of VGTs are Variable-Nozzle Turbines (VNT), Sliding Wall Turbines, and Variable Flow Turbines (VFT).

Variable-Nozzle Turbines are common in light-duty engines (passenger cars, race cars, and light commercial vehicles), the turbine's vanes rotate in unison, relative to its hub, to vary its pitch and cross-sectional area. VNTs offer higher flow rates and higher peak efficiency compared to other variable geometry designs.

Sliding Wall Turbines are commonly found in heavy-duty engines, the vanes do not rotate, but instead, their effective width is changed. This is usually done by moving the turbine along its axis, partially retracting the vanes within the housing. Alternatively, a partition within the housing may slide back and forth. The area between the edges of the vanes changes, leading to a variable-aspect-ratio system with fewer moving parts.

Variable Flow Turbines are another simplified version of a VGT when compared to a VNT. This design uses a two-volute turbine housing with a blend gate located in the neck. The gate can vary the flow between the scrolls to average the optimal A/R ratio. In low flow conditions exhaust gas is routed through the primary volute and under peak flow it is directed through both the primary and secondary. This design has a lower flow rate compared to VNT types so a wastegate may be incorporated with this design.

VGTs may be controlled by a membrane vacuum actuator, electric servo, 3-phase electric actuation, hydraulic actuator, or pneumatic actuator using air brake pressure.

Unlike fixed-geometry turbines, VGTs do not require a wastegate. Although VGTs do not require a wastegate, some applications requiring a high mass air flow ratio will benefit from an additional wastegate most commonly found in high performance spark ignition engines. This is in contrast to diesel engines.

Use:

VGTs tend to be much more common on diesel engines, as lower exhaust temperatures mean they are less prone to failure. Early gasoline-engine VGTs required significant pre-charge cooling to extend the turbocharger life to reasonable levels, but advances in technology have improved their resistance to high-temperature gasoline exhaust, and they have started to appear increasingly in gasoline-engine cars.

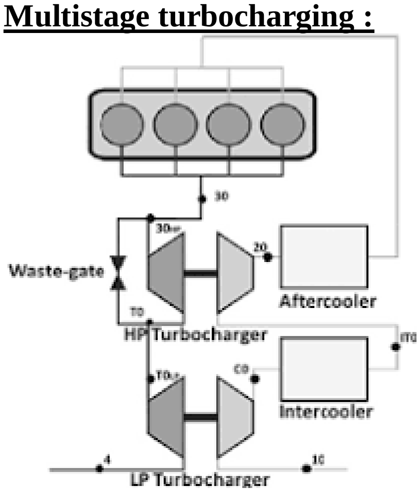
Typically, VGTs are only found in OEM applications due to the level of coordination required to keep the vanes in the most optimal position for whatever state the engine is in. However, there are aftermarket VGT control units available, and some high-end aftermarket engine management systems can control VGTs as well.

In trucks, VGTs are also used to control the ratio of exhaust recirculated back to the engine inlet (they can be controlled to selectively increase the exhaust manifold pressure until it exceeds the inlet manifold pressure, which promotes exhaust gas recirculation). Although excessive engine backpressure is detrimental to overall fuel efficiency, ensuring a sufficient EGR rate even during transient events (such as gear changes) can be sufficient to reduce nitrogen oxide emissions down to that required by emissions legislation (e.g., Euro 5 for Europe and EPA 10 for the USA).

Another use for sliding-vane turbochargers is as a downstream exhaust brake, so that an extra exhaust throttle valve is not needed. The mechanism can also be deliberately modified to reduce the turbine efficiency in a pre-defined position. This mode can be selected to sustain a raised exhaust temperature to promote "light-off" and "regeneration" of a diesel particulate filter (this involves heating the carbon particles stuck in the filter until they oxidize away in a semi-self-sustaining reaction - rather like the self-cleaning process some ovens offer). Actuation of a VGT for EGR flow control, or to implement braking or regeneration modes in general, requires hydraulic actuators or electric servos.

VGTs offer improved transient response over conventual fixed geometry turbochargers. This makes VGTs ideal for use in vehicles where power demand is very dynamic. In situations where engine load is constant like in stationary generators, fixed geometry turbochargers can provide higher efficiency over VGTs. This is due to the added exhaust resistance created from the tolerances of the moving parts within a VGT.

Multistage turbocharging :



A parallel configuration refers to using two equally-sized turbochargers which each receive half of the exhaust gases. Some designs combine the intake charge from each turbocharger into a single intake manifold, while others use a separate intake manifold for each turbocharger.

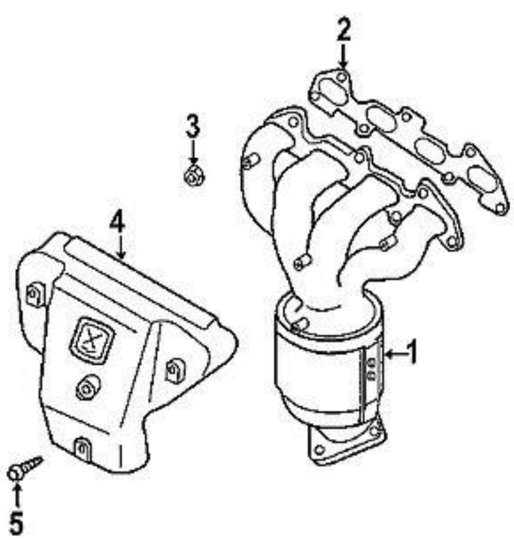
Parallel configurations are well suited to V6 and V8 engines since each turbocharger can be assigned to one cylinder bank, reducing the amount of exhaust piping needed. In this case, each turbocharger is fed exhaust gases by a separate exhaust manifold. For four-cylinder engines and straight-six engines, both turbochargers can be mounted to a single exhaust manifold.

The aim of using parallel twin-turbos is to reduce turbo lag by being able to use smaller turbochargers than if a single turbocharger was used for the engine. On engines with multiple cylinder banks (e.g. V engines and flat engines) use of parallel twin-turbos can also simplify the exhaust system.

Engine exhaust manifolds arrangements:

In automotive engineering, an exhaust manifold collects the exhaust gases from multiple cylinders into one pipe. The word manifold comes from the Old English word manigfeald (from the Anglo-Saxon manig [many] and feald [fold]) and refers to the folding together of multiple inputs and outputs (in contrast, an inlet or intake manifold supplies air to the cylinders).

The most common types of aftermarket headers are made of mild steel or stainless steel tubing for the primary tubes along with flat flanges and possibly a larger diameter collector made of a similar material as the primaries. They may be coated with a ceramic-type finish (sometimes both inside and outside), or painted with a heat-resistant finish, or bare. Chrome plated headers are available but these tend to blue after use. Polished stainless steel will also color (usually a yellow tint), but less than chrome in most cases.



waste gate:

A wastegate is a valve that controls the flow of exhaust gases to the turbine wheel in a turbocharged engine system. Diversion of exhaust gases regulates the turbine speed, which in turn regulates the rotating speed of the compressor.

Turbocharger lag :

Turbo lag can be defined as a delayed response when you hit the throttle of a turbocharged car. The engine needs time to respond to throttle changes, and the driver may experience turbo lag as a slight hesitation on the engine's part.

Engine modification required for turbocharging :

You need the correct fuel to maximize performance in your turbocharged engine. The combustion rate is different that other cars and it needs to match up or you'll end up blowing up or melting your engine. Special attention paid to upgrading your fuel pumps and fuel injectors will give your car a serious power boost.

1. Tuning up and Modifying Your Turbocharger's Intercooler

When air enters your turbochargers it heats up. The hotter the air is, the less dense it is. This means it contains less oxygen, which equals less power. Hot air also increases the chance of detonation, which is dangerous for your car's overall engine.

To cool the air, your turbocharger has an intercooler that lowers the temperature using air. Most factory intercoolers leave a lot to be desired, so upgrading to a higher end or more efficient intercooler, the better the airflow, the more power you'll get.

2. Modifying Your Car's Boost Pressure

Boost is directly related to your engine's power. The more boost the better, as long as your engine can handle it. Too much boost for your system will blow your engine.

By maximizing the appropriate level of boost in your car, and adding improvements such as an ECU chip upgrade or fueling improvements, you can give your vehicle more power.

3. Swapping Out Your Car's Turbo

Adding an aftermarket turbocharger to a car that doesn't have one can be a huge undertaking. However, you can upgrade the actual turbocharger itself, giving you more power due to it's ability to handle more boost. You can also tune up the system with a larger compressor or exhaust housing right for your system.

4. Water Injection

If you can't get a larger intercooler in your vehicle, water injection is an option that helps to cool the inlet charge. The system sprays mist on your inlet pipe and the water absorbs heat from the air as it evaporates, brining the air temperature down.

5. Adding Nitrous Oxide to Your Turbocharger

Nitrous is a good booster on any engine, when used moderately, but when you've got a pre-existing turbocharger in your car, it comes in even more handy. Nitrous is extremely cold, so when injected it cools the boost pressure tremendously, giving your car the ability to create even more power.

It also prevents turbo-lag. By kicking in the NOS at a low rpm, your boost will get in performance much faster.

6. Screamer Pipe

A screamer pipe is an un-silenced exhaust that is separate from your regular exhaust system. Exhaust gas only escapes down the screamer pipe once maximum boost has been achieved. When this happens, the pipe starts to scream, unfortunately making a lot of noise.

7. Correct Fuel for Your Turbocharged Engine

You need the correct fuel to maximize performance in your turbocharged engine. The combustion rate is different that other cars and it needs to match up or you'll end up blowing up or melting your engine.

Special attention paid to upgrading your fuel pumps and fuel injectors will give your car a serious power boost.

8. High Octane Fuel

When it comes to turbocharged engines, you need to fill up with a high octane fuel. No more of the cheap stuff. The higher the octane the more resistant your car will be to detonation (or knocking) and allows your turbocharger to safely run on a higher boost.

9. Air Filter Positioning

Where your air filter is positioned in your car is extremely important, especially when it comes to turbocharged engines. A good system setup will help boost horsepower. If your filter is too close to hot engine parts, it will drive in hot air that will lower your performance. Optimizing your air filter location can also help your car to reach it's maximum boost faster.

10. Avoiding Pre-ignition/Detonation

If you don't pay careful attention to the heat and pressure buildup in your car's engine, your fuel and air will ignite before it receives the spark. This is called detonation. Detonation increases temperature and pressure, which slows down the rate at which the air moves through the engine, the amount of air moving through, and the power the engine can create. In some cases your engine can blow up right away. Talk to a professional about your tuning and modifications and make sure you avoid blowing your headgasket or pistons.

11. Dump Valves

When it comes to extending the life of your turbo, dump valves can help. They stop the turbo from stalling as the throttle is closed, by letting the air escape out. Because the turbocharger is allowed to continue spinning, it will be then able to reach it's boost quickly. Your throttle response will be improved. The more boost you run, the more effective your dump valve will be.

12. Wastegates

A wastegate is a valve that separates the gas from the manifold to the exhaust without passing through the turbocharger first. This regulates and prevents the turbo from spinning to fast. Cars usually come with a wastegate, but larger turbos can benefit or sometimes need a separate wastegate fitted to the exhaust manifold.

13. Head Gasket Upgrade for Your Turbo

Head gaskets are purposely made to be blown. Why? So if your engine builds up too much pressure or combustion, they blow before the rest of or the more expensive parts of your engine does, like your pistons or your engine block. Cylinder pressure is what makes your head gasket blow.

Upgraded head gaskets and bolts can help prevent failure, especially in turbo cars. In addition to a good set of head gaskets, you've got to make sure you've got any detonation issues under control and that they're compatible with your turbo's boost levels so the gaskets don't blow in the first place due to too much pressure.

14. Aftermarket Engine Management System

Keep your car's ignition and boost in check with an engine management system. These systems create the adjustment needed to keep your car's engine components performing properly, and making the proper adjustments when they don't.

A good EMS will improve your car's performance, drivability, reliability as well as engine life.

15. Exhausts for Turbocharged Engines

If you see a vehicle with a mega exhaust, it most likely has a turbocharged engine. You can't have an exhaust that's too big on a turbo. The reasoning behind this is that you want zero backpressure from the car's exhaust, allowing more air to escape and run through the engine more efficiently.

16. Compression Ratios for Turbochargers

The compression ration is how much fuel/air is compressed by the car's pistons before it's ignited. Compress the air/fuel too much and you get detonation, which is very bad for your engine.

If you increase your boost, you will need to adjust/drop the compression to keep the cylinder pressures regulated to avoid detonation.

17. Stronger Engine Parts

Improving the strength of the internal parts of your system, you will extend the life of your car's engine. Upgrades like forged pistons will help your engine be more resistant to detonation and other issues.