Garrett
ADVANCING MOTION

INSTALLER CONNECT TURBO EXPERT TRAINING COURSE

LEVEL 1 - ANIMATION 1

The take-aways below relate to the sequence of each instructional video and will help you gather the knowledge you need to complete the Garrett Motion Installer Connect training modules. You can return to the video as often as you wish.

Introducing the turbine and compressor concept in turbocharging

This module covers the basics of turbocharging and relates to the Level 1 training course.

Please use these notes in conjunction with the course video. Using both resources will help you succeed in gaining Level 1 certification on the road to becoming a turbo expert!

What is a turbocharger?

A turbocharger is an air pump. It supplies air for the engine combustion process at higher pressure and density than ambient air. This higher concentration of oxygen provides a greatly improved combustion process, offering more power, cleaner emissions and improved engine torque output, while reducing the pumping losses. This means better all-round engine performance.

A turbo comprises a turbine stage and a compressor stage.

The turbine is driven by waste exhaust gas from the engine which, in turn, drives the compressor, which draws in ambient air and compresses it. This process results in a much more efficient combustion process.

Exhaust gas flow

About the turbine:

<u>Knowledge booster</u>

- The turbine wheel sits on the same shaft as the compressor wheel and spins when exhaust gas is directed into the turbine inlet.
- The gas passes through a reducing nozzle to accelerate its velocity – the size of the nozzle is key in determining the performance of the turbine through a ratio known as A/R (which is explained in more detail in a later video).
- A shell-shaped volute is used to accelerate the gas on its journey and then another nozzle area around the turbine wheel inlet boosts the gas to maximum velocity.
- At this stage, the gas enters the turbine wheel and passes between the turbine blades, releasing energy in the process and causing the turbine wheel to spin at high speed.

- When the exhaust gas exits the turbine housing, it is at a lower pressure – and this pressure difference (between the inlet and the outlet) is key to turbocharger performance.
- The exhaust gas, now travelling at lower velocity, at lower temperature and lower pressure, continues its journey through the rest of the vehicle's exhaust system. As you will see in later training modules, this 'journey' is also an important element in the correct functioning of the turbine.

Air flow

About the compressor:

Knowledge booster

- For an engine to burn fuel more efficiently, it needs as much oxygen as possible. Compressing the air increases its density, which provides more oxygen per unit of volume.
- In a turbo, a compressor wheel – situated on the other end of the turbine shaft and spinning at the same speed at the turbine wheel - draws ambient air in through an air filter into the compressor inlet.
- As the air passes between the compressor inducer or inlet blades, it accelerates to extremely high speeds. Indeed, at high loads, the air passing through the compressor can reach a velocity close to Supersonic.
- At this stage in the journey, the air contains a lot of Kinetic energy. This needs to be converted into pressure energy, so a diffuser situated between the compressor housing and the backplate is used to slow it down. This creates a high-pressure zone, allowing the air to expand.
- As the air exits the diffuser, it enters a snail-shaped volute (with an increasing section) towards the compressor outlet. The air continues to expand and slow down, achieving maximum pressure and density as it reaches the compressor outlet.

Turbo operating conditions

About turbo speed:

Knowledge booster

- A turbocharger runs at extremely high speeds for maximum efficiency.
- Garrett turbos can rotate at more than 300,000 rpm, depending on size.
- It such a high-speed environment, it is critical that air is properly filtered before it enters the compressor to avoid the possibility of catastrophic damage from a foreign object.
- Turbochargers are designed to operate at extremely high temperatures.
- At the same time, the compressor ambient inlet temperature can range between minus 30 and plus 45 degrees centigrade.
- This huge temperature difference between the compressor and the turbine means that Garrett turbochargers are designed and manufactured with extremely high precision and installed by expert technicians.

Turbo and engine schematic

About the turbo and engine:

Knowledge booster

- Ideally, the turbo is situated as close as possible to the exhaust manifold, but this will depend upon the design of the engine and vehicle.
- As soon as the engine starts to run, the exhaust gas spins the turbine.
- Filtered, ambient air is drawn into the compressor, accelerated to high speed, and then slowed down to create high density air for the engine – this is called charge air.
- Heat is created by this process and because hot air is less dense than cold air, the charge air leaving the compressor is usually passed through a charge air cooler or intercooler.
- An intercooler involves passing ambient air from outside the moving vehicle across the surface of hollow tubes. A charge air cooler can contain many hundreds of folded metal fins, which provide a large surface area, increasing heat rejection and improving the efficiency of the cooling process. The effect of both these processes is to increase the density of the charge air before it enters the engine.

Knowledge Check

After watching the animation, your new understanding should enable you to answer the following questions.

Exhaust gas flow:

- How does the exhaust gas enter the turbine inlet?
- Why is the turbine inlet nozzle important?
- What happens to exhaust gas velocity, temperature and pressure as it exits the turbine?

Air flow:

- Why is it important to compress the air in the combustion process?
- The compressed air contains a lot of Kinetic energy, which is motion energy. What is sort of energy is this converted into by slowing it down?
- What does the diffuser do?

Turbo operating conditions:

- What might happen should unfiltered air enter the compressor?
- What typically are the highest exhaust temperatures withstood by turbos in modern diesel engines and modern gasoline engines?
- When operating at full load, what speed (in kph) is recorded on any given point on the circumference of the turbine wheel.

Turbo & engine schematic:

- When the engine starts, what effect does the exhaust gas have on the turbine?
- What is high density air called in turbocharging?
- Which has a greater density – hot air or cold air?

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INSTALLER CONNECT TURBO EXPERT TRAINING COURSE

LEVEL 1, ANIMATION 2

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A/R, turbo performance and families

This module continues the Level 1 training course.

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A/R

In the previous animation, we saw a feature called A over R (A/R), which is a major factor in defining the performance of a turbine.

About A/R:

<u>Knowledge booster</u>

- From the turbine inlet flange, looking down into the housing, we can see that the size of the gas inlet passage reduces. The point at which the gas passage meets the volute is called the tongue and we calculate the area at that location, which we call A. We calculate the radius from centreline of the rotating parts to the centroid of area A, which we call R. We divide area A by distance R to give us the ratio A over R.
- A lower A/R number means a smaller gas passage and higher number means a larger gas passage. Some typical examples are shown in the animation and these may vary by turbo model.
- The A/R of every housing is marked on the casting, in a location close to the turbine inlet. Remember, turbine housings with different A over Rs may look identical externally but they will offer very different performance.
- With a small A/R, the exhaust gas passing through the reducing section is accelerated to its maximum velocity, optimising boost response when the engine is at low speed and the energy from the exhaust gas is relatively low. At higher engine speeds, this small nozzle limits the flow of exhaust gas, increasing back pressure, affecting engine breathing and the maximum power output.
- With a large A/R, the exhaust gas has lower velocity at low engine speed, so the turbine wheel will accelerate more slowly, and boost response is slower. However, this larger nozzle allows a much greater mass flow of exhaust gas, so as engine speed increases, there is minimal restriction, reducing backpressure and allowing the engine to breathe freely and produce maximum power.
- The other effect of small versus large A over R is on the entry angle of the exhaust gas into the turbine wheel blades, which also has an influence on performance. With a small A/R, the tangential angle of the gas entering the wheel blades is quite small and this creates more torque from the wheel, for rapid boost response. However, this small angle limits the maximum flow through the blades and increases the backpressure of the exhaust gas towards the engine.

- With a large A/R, the more radial entry angle of the gas allows a greater flow through the wheel, reducing back pressure at high engine speed and allowing greater power. However, the exhaust gas velocity at low engine speed is reduced leading to a slower rise in boost pressure.
- Therefore, the selection of A/R for the turbine housing is based on the intended use for the engine, its power and torque curves, fuel economy and emissions requirements.

A/R & turbo families

About a free-floating turbo:

Knowledge booster

- A turbocharger with a single, fixed A/R is called a free-floating or fixed geometry turbo, because it has no integral control over speed or boost pressure.
- Turbo control is entirely dependent on the engine and its systems providing the correct amount of energy in the exhaust gas to power to the turbine.
- The turbocharger is precisely matched to the engine during the engine development phase, where the optimum A/R turbine housing is selected.

About a wastegate turbo:

Knowledge booster

- The wastegate or turbine bypass was introduced onto our turbochargers many years ago to improve turbo and engine performance.
- A wastegate turbo contains several additional components over a free-floating turbo providing control over the exhaust gas bypass flow.
- An internal wastegate valve is mounted on an arm which passes through a bush in the turbine housing. An external crank assembly is welded to it. This crank is controlled by either a pneumatic or electric actuator.
- A pneumatic actuator may be powered by air pressure or vacuum and controlled by a hose from the compressor outlet or by a control valve in the vehicle’s vacuum circuit. An electric actuator responds to commands from the vehicle’s own Electronic Control Unit.
- The wastegate allows a controlled flow of exhaust gas to bypass the turbine wheel. This allows the use of a smaller A/R turbine housing for maximum acceleration of the turbine at low engine speeds when the wastegate valve is closed.
- At higher engine speeds, when the turbine housing approaches its maximum flow, the wastegate valve opens to allow some exhaust gas to bypass the turbine wheel and merge directly with the exhaust outlet flow. This increases the flow capacity of the housing, reducing back pressure and allowing the engine to breathe freely for maximum power. So, the compromise of fixed geometry is reduced offering higher engine power with improved low speed response.
- In the simplest wastegate control circuit, a pressure actuator is connected directly to the compressor outlet by a hose. When the turbo is operating at low speed and low boost level, the pressure in the hose and the actuator is also low, so the turbine bypass valve is closed.
- When the vehicle driver accelerates, the turbo responds to the increasing energy in the exhaust gas by speeding up and providing more boost pressure and air flow to the engine. When this boost pressure reaches a pre-determined level, this causes the actuator rod to move and open the turbine bypass valve, allowing the excess exhaust gas to flow directly into the vehicle exhaust system.

- When the driver decelerates, the boost pressure from the turbo reduces and the bypass valve closes again.

Full details of actuator operation will be explained in a later training course.

About a VNT turbo:

Knowledge booster

- VNT turbochargers use a Variable Nozzle Turbine, which has a row of moveable vanes around the periphery of the turbine inlet or inducer blades.
- The turbine housing A/R is chosen to suit the maximum rated power of the engine and then by moving the vanes and varying the size of the gas passage into the wheel. This effectively gives a constantly variable range of A/R, offering greatly improved performance over a wider engine operating range.
- The movement of the vanes is controlled by an actuator connected to an external crank assembly. This crank connects via a short shaft to the internal control arm and transfers movement to a unison ring, which controls the movement of all the vanes by means of their vane arms.
- In the minimum flow position, the exhaust gas is accelerated through the vanes to higher velocity in a similar way to a small A/R housing to give maximum acceleration of the turbine and compressor with fast boost pressure rise.
- As engine speed and load increase, the vanes move towards the fully open position to give maximum flow capacity and reduced back pressure for better engine breathing in a similar way to a large A/R housing.
- On a modern VNT turbo, the vane position is constantly and rapidly changing in response to signals from the vehicle ECU to comply not only with the driver's commands, but with the many inputs controlling combustion efficiency and exhaust emissions.
- Garrett's VNT represented a step change in turbocharger performance compared to free-floating and wastegate turbos.

Knowledge Check

After watching the video, your new understanding should enable you to answer the following questions.

- What does the A/R ratio represent?
- What is the effect of a small or large A/R number on boost response?
- How can you quickly identify the A/R on a Garrett turbo?
- How is a free-floating turbo controlled?
- What is the main difference between free-floating and wastegate architecture in turbocharging?
- How does a wastegate impact turbo boost and power?
- How are wastegate actuators are controlled?
- How does a VNT turbo create a variable range of A/R?
- What effect does a VNT turbo have on engine performance at different speeds?
- How are the vane positions in a VNT turbo controlled?

Remember to use these notes in conjunction with the Installer Connect videos as you take the tests that support your journey to becoming a certified Garrett Motion turbo expert.

INSTALLER CONNECT LEVEL 1