Garrett
ADVANCING MOTION

INSTALLER CONNECT TURBO EXPERT TRAINING COURSE

LEVEL 2, ANIMATION 3

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 CHRA

This module is the first in the Level 2 training course. Free floating, wastegate and VNT turbos all include a CHRA or Center Housing and Rotating Assembly.

Please use these notes in conjunction with the course video. Using both resources will help you succeed in gaining Level 2 certification on the road to becoming a turbo expert!

Center Housing & Rotating Assemblies

About CHRA:

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- The CHRA includes the high-speed rotating parts often called the rotor assembly and the components used to control those parts.
- A CHRA may contain as few as eight separate components or as many as 25, all produced to extremely tight dimensional tolerances and made from the highest-grade materials, with specialised surface finishes, each specifically chosen for the task and operating conditions.

Shaftwheel assembly

About the shaftwheel:

Knowledge booster

- The shaftwheel assembly is made from two pieces, a high-grade steel shaft and a turbine wheel head which may be made from any of three different Super-Alloy materials, to suit the operating conditions of the turbine.
- The turbine wheel head is welded to the shaft which for modern turbos is completed by electron beam welding. The welds are extremely strong and reliable.
- The finished shaftwheel assembly must then be balanced to ensure reliable, quiet operation at very high speeds. We balance the turbine wheel dynamically in two planes. Metal is removed from the back face and from the nose of the wheel to comply with our stringent balance specifications.

- Each cast or machined feature on the shaftwheel assembly is designed for a specific task.
- On the turbine wheel, exhaust gas enters through the inducer section of the blades. The blades are a complex aerodynamic shape designed to maximise the transfer of energy from the exhaust gas and convert it into wheel rotation. The contour section follows precisely the shape of the turbine housing contour, with very small clearances to maximise efficiency and finally the exducer is where the exhaust gas passes out of the turbine to the exhaust system.
- The piston ring groove or grooves are part of the turbo sealing system and in conjunction with the piston rings, forms a highly effective sealing system to maintain the oil within the centre housing and prevent leakage. *The detailed operation of this system will be seen in a later training course.* At the end of the hub section is an oil thrower.
- The shaft bearing journals support the fully assembled rotating components in conjunction with the journal bearings themselves. The centre of mass of all the rotating parts is located at the turbine end bearing journal. *We will return to this feature in a later training module looking at turbo damage analysis.*
- The pilot shaft and the very accurately machined shoulder are where the thrust collar, thrust spacer and compressor wheel are located.
- The thread at the end of the shaft allows a locknut to be fitted, applying tension to the shaft as the undercut area below the thread stretches slightly compressing all the components together to ensure that they cannot loosen during operation. To achieve this, the nut is tightened in stages: firstly, seating torque is applied to compress the parts into their correct position. Then the nut is loosened, followed by tightening to a specified torque and finally applying an accurate angle of twist, which ensures the correct amount of stretch to the shaft. The tightening process ensures that the locknut cannot loosen during normal service.

Tolerances and cylindricity

About precision engineering:

<u>Knowledge booster</u>

- For good control of the rotating assembly and reliable, quiet operation, the journals need to be as close as possible to a perfect cylinder.
- We work in microns, which is one thousandth of a millimetre. A typical tolerance on that cylindrical shape is just 2½ microns. This is similar in size to a human hair, a human blood cell, a particle of dust and a tobacco smoke particle.
- We store and assemble these parts in very clean conditions. A new turbocharger must also be installed onto the engine with care, using only fresh clean oil of the correct type.

Lubrication and Bearing System

About turbo lubrication:

<u>Knowledge booster</u>

- Oil from the engine lubrication system enters the turbo and is distributed to the journal and thrust bearings.
- All turbochargers use two oil films, one between the centre housing and journal bearing and one between the bearing and the shaft.

- The clearances are often mistaken as being “excessive play” when examining a new, dry turbocharger, but this is correct and necessary for the correct functioning of the turbo. The oil flows through both the journal and thrust bearings.
- Oil throwers at the turbine end and compressor end then collect the oil and return it to the engine sump.
- The oil inlet is much smaller than the oil drain*. Full details of the bearing and oil system will be explained in a later training course.*

Heat Soak and Cooling

About temperature control:

<u>Knowledge booster</u>

- The oil has another important function; to cool the rotating parts and bearing system, preventing damage due to heat soak from the extremely hot turbine end.
- When the engine and turbo stops, the cooling oil flow stops and the temperature in the bearing area reaches its maximum approximately 2 or 3 minutes later.
- If the temperature is excessive, this can cause the residual oil in the bearing to burn and turn to hard black carbon, called coking, which will rapidly damage the turbo.
- The use of a shroud, or heatshield, controls heat soak by diverting the path of the high temperature away from the bearing system, towards the turbine housing flange, reducing maximum temperature in the bearing area.
- For higher temperature conditions or where cooling air flow is minimal, we may use water-cooling connected to the engine’s own cooling system. Even when the engine stops running, the thermo-syphon effect of the system continues to cool the turbo.

Compressor Wheel

About compressor wheels:

<u>Knowledge booster</u>

- Compressor wheels have complex aerodynamic designs requiring optimization of pressure, flow and efficiency for each application.
- Ambient air enters via the inducer and exits at high speed from the exducer section of the blade.
- Air passages formed between the large main blades are often divided by smaller splitter blades to optimise performance for many applications.
- The wheel is balanced in two planes with balance cuts typically on the nose and back disc.

CHRA summary and assembly of parts

About CHRA assembly:

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- All CHRA components are assembled following a tightly controlled process which includes many "Poka-yoke" (mistake-proof) devices to help eliminate possible errors of wrong components or incorrect assembly.
- A red light prevents operators from passing errors forward to the next stage and green lights indicate a correctly completed process, which then allows the next stage of assembly to continue.
- The final stage of the assembly process is to correctly tighten the locknut, test for oil leakage and then the CHRA passes into the high speed VSR machine for a balance check.
- Any final balance corrections are made at this point and then the finished CHRA is ready for assembly into a turbocharger.

Knowledge Check

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

- What are the component parts of the CHRA?
- What feeds the oil to the turbo?
- Where do the two oil films associated with the CHRA operate and what do they do?
- What is the function of the shaft bearing journals?
- How is the CHRA heat soak controlled?
- How is the correct balance achieved for the turbine and compressor wheels?

LEVEL 2, ANIMATION 4

Turbocharger bearing systems

This module is the second in the Level 2 training course. Turbocharger bearing systems are split into two main families: hydrodynamic bearings and ball bearings. In the previous training module, we saw how the oil flows through a normal hydrodynamic bearing system. We will now study in detail the two sub-families of hydrodynamic bearing systems.

Please use these notes in conjunction with the course video. Using both resources will help you succeed in gaining Level 2 certification on the road to becoming a turbo expert!

Hydrodynamic bearings

About fully floating and semi-floating bearings systems:

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- A fully floating bearing system has been used since Garrett turbos began production in the 1950s and are still widely used today.
- This uses two bearings, with two oil films: an outer oil film between the bearing and centre housing, which provides both stiffness and damping to control the motion of the rotor assembly and reduce the transmission of vibration and noise. The oil also passes through feed holes in the bearings themselves, to provide an oil film between the bearing and the shaft. Due to the rotation of the shaft, the viscous oil is

dragged in the direction of rotation, which also drags the bearing in the direction of rotation. So, the fully floating bearings rotate within the housing at around ½ the speed of the shaft.

- There is also a semi-floating bearing system. This design is preferred for our smaller, higher speed turbos, which may rotate at over 300,000rpm. These also have two oil films but are prevented from rotating by an anti-rotation pin or locating pin. The outer oil film in this case is only providing stiffness and damping. Some of the oil passes through feed holes in the bearing and flows between the bearing and shaft. It is this inner oil film which provides the hydrodynamic support to the rotor assembly.

Lubrication

- The oil has the most important job to do inside the turbo, to support the high-speed rotor assembly and prevent contact between the wheels and housings. The movement of the rotor assembly is complex and the constantly changing load on both turbine and compressor ends means that the oil must work hard. Therefore, high quality oil is essential for the turbo.
- When viewing a section through a bearing system, it will be noticed that the shaft is not running exactly in the centre, but due to the load it is off centre and low. As the oil is dragged in the direction of rotation, it passes into a gradually reducing section, squeezing the oil hard and creating a wedge shape of very high-pressure oil towards the bottom of the bearing system. This high-pressure oil film prevents the parts from coming into contact and controls the motion of the rotor assembly, avoiding any wheel to housing contact.
- When running at full load, the clearance between the shaft and the bearing are filled by an oil film which may be as thin as 7 microns which is why clean oil is critically important to the operation and life of the turbo.
- The oil also feeds the thrust bearing assembly, which controls the axial motion of the rotor, flowing through feed holes in the thrust bearing to each thrust pad on both inboard and outboard sides of the bearing.
- The oil is dragged in the direction of rotation across each thrust pad, which has an angled ramp with reducing wedge shaped section squeezing the oil hard and creating an area of high-pressure oil at the trailing edge of the thrust pad. This occurs on both sides of the thrust bearing and as the load from the turbine or compressor varies, the oil compensates for this; as it is squeezed harder, the oil pressure increases and pushes back against the load. The thrust bearing system compensates for these constantly changing loads automatically, up to its designed limit.
- The oil is working extremely hard in the thrust assembly and under full load conditions, the oil temperature can increase by as much as 50°C as it travels just a few millimetres across each thrust pad.
- With such extreme demands on the bearing system, using the correct grade and type of well-filtered oil is critical to correct operation and a long operating life.
- The oil must also be changed at the recommended interval, along with a new OE quality oil filter. Failing to comply with these basic requirements brings a high risk of turbo damage from the single biggest killer of turbos - contaminated oil.

Damage due to oil contamination

There are many types of contamination which may be carried by the engine oil into the turbo bearing system and cause damage.

About particle damage:

<u>Knowledge booster</u>

- The most common cause of turbo bearing system damage is fine particles, usually carbon from the combustion process. If the concentration of these particles becomes too high, it acts as a very effective abrasive, gradually eroding and polishing the running surfaces of the bearing and shaft, increasing the clearances, and closing up the oil feed holes, until the oil is no longer able to control the shaft.

- This damage is usually accompanied by a sharp increase in noise level and oil leaking past the turbine end seal causing oil to be burned and noticeable exhaust smoke.
- Oil may also leak past the compressor end seal and be blown into the compressor outlet pipework and charge air cooler.
- By the time this happens, the remaining life of the turbo may be extremely short, because metal to metal contact will occur between the shaft, bearing and housing, quickly followed by the turbine and compressor wheels contacting and rubbing on their housings. This causes wheel imbalance, leading to the shaft bending and often followed by fracture of the shaft. Catastrophic damage of this sort may lead to fragments of wheel passing into the air pipework, charge air cooler and exhaust systems of the vehicle.

Heavy contamination

- Contaminated oil may also contain large particles, for example, fragments of metals from worn engine components or even steel shot used for cleaning at engine overhauls. These should be trapped by an effective, OE quality oil filter, but if the filter is of poor quality or is blocked and bypassing, these fragments may find their way into the turbo bearing system.
- Typically, this causes deep irregular scoring to any or all the following: shaft, bearings, housing, thrust pads, thrust collar and spacer.
- Scoring of the hard steel shaft cannot be caused purely by contact with the journal bearing, which is made from a much softer bronze material, so a scored shaft generally indicates contamination, with hard particles being carried in the oil. This scoring prevents the oil in the bearings from functioning correctly and metal to metal contact occurs, followed by the same sequence of catastrophic damage seen previously.

Root cause diagnostics

- The root cause of damage to a turbo must be accurately diagnosed before fitting a replacement or this may become damaged in the same way.
- The easy way to ensure that a new Garrett turbo will continue performing to OE standards throughout a long service life is to ensure that it always has top quality clean oil of the correct grade running through it.
- *Note: Our turbocharger warranty does not cover damage due to contaminated oil, which is mostly entirely preventable. Always check for any OE manufacturers service bulletins relating to known problems with oil contamination for specific engines & vehicles and rectify the route cause.*

Knowledge Check

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

- What prevents a semi-floating bearing system from rotating?
- What effect does contaminated oil have on turbo performance?
- What damage can be caused by heavily contaminated oil?
- What job does oil do inside the turbo?
- What is the rotational speed of fully floating bearings relative to the speed of the shaft?
- Where would you mostly find semi-floating bearing systems?

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.