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REPAIR OF A DAMAGED TURBOCHARGER

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Abstract: *The turbocharger is among the highest quality assemblies for modern internal combustion engines. Its contribution to engine operation is immeasurable – it increases the power output of the engine while indirectly reducing fuel consumption. Like all devices, turbochargers require quality maintenance as they are susceptible to failure. Faulty turbochargers are either repaired or replaced with new ones. Repair ensures substantial financial savings. The paper presents the consequences of damage to the turbocharger and the process of its repair.*

Keywords: *turbocharger, damage, repair.*

1. INTRODUCTION

Most failures of the turbocharger are due to problems occurring outside the device. If the turbocharger is faulty, apart from its repair or replacement, it is imperative to determine and eliminate the cause of failure to prevent its recurrence.

Figure 1 shows damage to the turbocharger caused by the entry of a foreign object into its housing. The foreign object has damaged the compressor wheel at the front i.e. inlet, leading to a partial fracture of its blades. Blade damage causes rotor imbalance as well as rapid wear to the bearings and seal rings. This results in increased lubricating oil consumption, power loss and black or white smoke coming from the exhaust pipe. Also, these problems are often accompanied by a squeaking sound, which clearly indicates turbocharger malfunction. Foreign objects may enter the inlet manifold: due to a damaged air filter, due to holes or cracks in the air hoses or worn-out hose clamps, or if the entire air supply system has not been properly cleaned during the previous servicing of the turbocharger [2].

Figure 1. Compressor wheel damaged by a foreign object

Figure 2. Compressor wheel damaged by a large foreign object

Before reinstalling the turbocharger, it is necessary to determine the routes of foreign object ingestion into the turbocharger in order to prevent recurring impact damage. To this end, the inlet manifold hoses should be inspected and washed, the hose clamps and the air filter should be checked for foreign objects and replaced as required. Otherwise, the turbocharger will suffer the same failure.

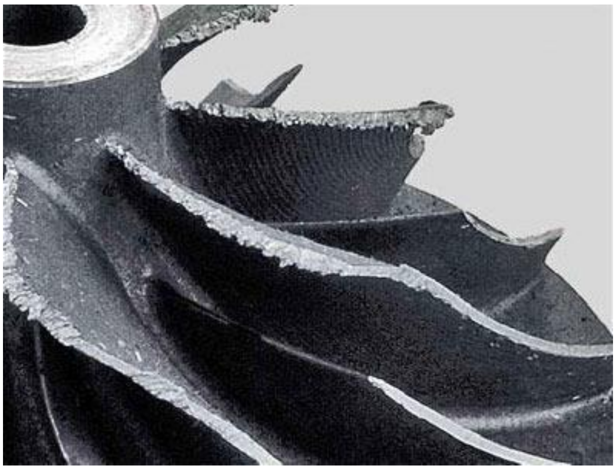

Figure 3. Compressor wheel damaged by dirt

Figure 4. Rotor damaged by foreign objects with soot build-up

Figure 5. Rotor damaged by foreign objects

2. DAMAGE TO THE TURBOCHARGER

After disassembly of the turbocharger, damage typical of a partial or complete blockage in the exhaust pipe has been identified. This type of blockage in the pipe causes a high exhaust gas pressure in the turbine housing. As exhaust gases cannot exit the engine freely, they push the turbocharger rotor forward to the compressor side. Therefore, on the front side of the turbine wheel, there are clearly visible marks of its unallowable wear against the flame guard, leading to turbocharger oil leaks. This failure is caused by a faulty (blocked) engine brake (a faulty brake cylinder or a clogged butterfly valve shaft) or by a foreign object blocking the exhaust pipe.

Before reinstalling the turbocharger, the cause of the failure (in this case, the faulty engine brake and/or blocked exhaust pipes) must be eliminated.

Figure 6. Damage to the turbocharger rotor due to blockage in the exhaust pipe

Wet oil found at the turbine inlet is a characteristic sign of a forced oil leak. The compressor housing is soiled with oil at the inlet; therefore, as the turbocharger sucks in air, the oil can only come from the breather. The inspection of the intake hose clearly shows that the leaking oil is working its way from the breather towards the turbocharger. Due to an engine problem, pressure builds up in the engine crankcase. Increased pressure raises the oil level in the crankcase, resulting in fresh oil at the breather. As the turbocharger is connected to the engine crankcase through the oil return pipe, the seal rings become overloaded with pressurised oil, which forces its way through them, eventually causing physical damage to them, resulting in the need for repair. In such failures, oil consumption is always higher due to an engine problem than due to a problem in the turbocharger. Therefore, this problem (increased oil consumption) cannot be solved only by turbocharger repair.

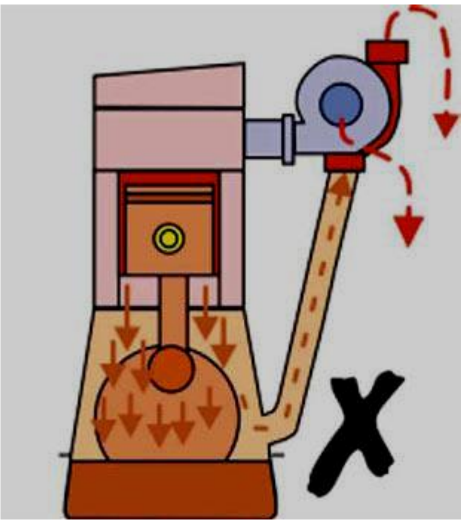

Figure 7. Effect of oil pressure in the engine crankcase on the turbocharger

The increased pressure in the crankcase is due to a variety of reasons:

1. The breather is clogged. The intake hose on the turbocharger is dry.
2. The oil return line which allows oil to drain from the turbocharger to the crankcase is bent, clogged, with a restricted flow. Normally, it must have an appropriate oil drain angle (±15 degrees from the vertical).
3. The air filter is dirty.
4. The internal pressure in the engine is too high, due to the wear of engine parts and assemblies (worn-out piston rings, cylinder liners and other parts of the engine).

The excessive oil pressure problem in the crankcase must be fixed before reinstalling a new or repaired turbocharger, since otherwise the problem will not be permanently solved.

After the core assembly of the turbocharger has been dismantled, high wear rates of the sliding surfaces of the bearings and the shaft have been found. Wear marks i.e. furrows in characteristic places, due to dirt in the lubricating oil, are clearly visible. The oil is contaminated with combustion by-products and shavings of engine parts. Depending on the degree of oil contamination, the gap between the bearings and the shaft increases over time, causing wear to the seal rings, imbalance of the turbocharger rotating assembly and even striking of the turbine and compressor wheel blades against the housing. The turbocharger consumes oil, the engine has no power, and black or white smoke appears at the exhaust outlet. When installing the hose with oil supply and return fittings, sealants must not be used because only original gaskets are permitted.

Figure 8. Radial bearings damaged by dirty oil

When performing major repairs of automobile engines, such as overhaul, leftover shavings may get into the oil and cause wear. Since the turbine rotor spins up to 50 times faster than other shafts on the engine, turbo wear is much higher and faster. After the overhaul, the engine crankcase should be thoroughly washed. Before reinstalling the turbocharger, the cause of the failure must be eliminated. It is necessary to replace both the oil and the oil filter and clean the engine crankcase to prevent recurring problems.

Figure 9. Damage to the turbocharger shaft caused by dirty oil

Figure 10. Damage to the turbocharger shaft due to lack of lubrication

In older types of turbochargers which do not have VSG valves, failure is caused by disruption in the fuel combustion system, due to which exhaust gas pressure and temperature exceed predetermined values. At high rotational speeds, the rotor material undergoes internal stress, which leads to blade fracture, and the turbocharger bearings cannot withstand such loads, resulting in frequent rotor impeller cracks. Turbochargers equipped with VSG valves are designed to operate at higher rotational speeds compared to the turbochargers without VSG valves. When the exhaust gas pressure in the turbocharger reaches the critical, maximum allowable value, the role of the VSG valve is to direct the exhaust gas flow out of the rotating zone of the rotor, thus reducing its rotational speed.

In the new generation of turbochargers having variable geometries, in addition to the abovementioned role, the electromagnetic valve regulates both the amount and pressure of exhaust gases during the operation. When the VSG valve is damaged or unprofessionally adjusted, the turbocharger rotor rotates at a rotational speed higher than the maximum limit. Therefore, the engine consumes more oil and loses power, and the turbocharger produces a characteristic squeaking sound. Often, the turbocharger rotor breaks due to internal load. In variable geometry turbochargers, there is damage to the rotor, the variable geometry and the central housing, and the only solution is to replace the turbocharger with a new one.

Figure 11. Typical fracture of the turbocharger impeller

Figure 12. Effect of high temperature on the turbocharger rotor

Figure 13. Cracks in the turbine housing due to a high exhaust gas temperature

3. REPAIR OF THE TURBOCHARGER

In practice, as a rule, successful repair of a turbine is possible only if its housing is not mechanically damaged. Repair generally involves replacement of the shaft coupled with the propellers, bearings and all seal components. This is the primary and cheapest repair.

When repairing the turbine, all its components are disassembled. They are usually rather dirty, which does not necessarily mean that they are damaged. However, soot build-up can block the stator blades. This is the cheapest intervention as there is no need for replacement of the turbine components. [1]

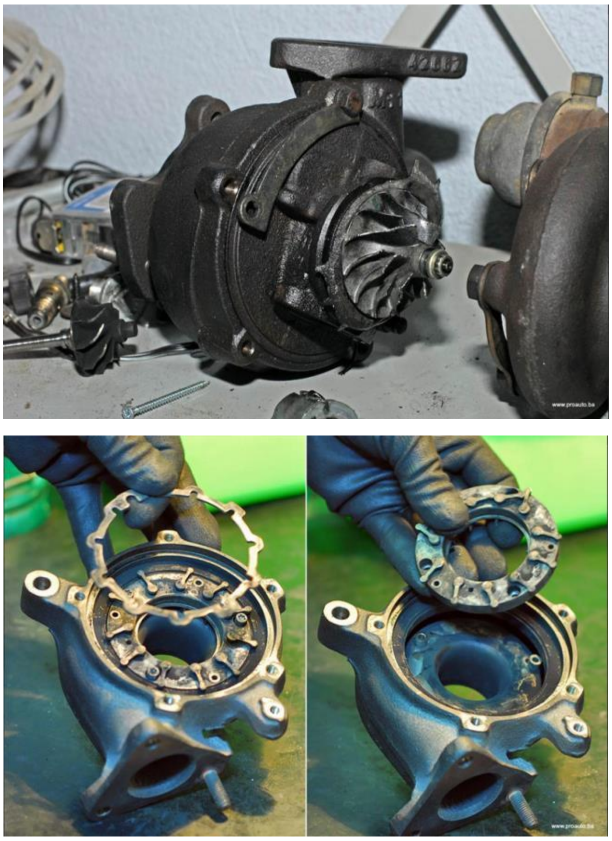

Figure 14. Turbine disassembly [1]

Before repair, all dismantled parts are thoroughly cleaned using a special liquid solvent, or petroleum, or a certain amount of a degreasing agent. After drying, they are subjected to sandblasting, which involves smoothing of large rough surfaces occurring due to mechanical operation, which may subsequently lead to undesirable effects. Since blasting is performed by quartz crystals of small grain size, all parts should be additionally washed in a solvent additive or in petroleum after the process. Also, they should be dried either with a soft cloth or simply under compressed air. It is only after these detailed cleaning and drying operations that certified service providers can determine the degree of repair needed.

Figure 15. Cleaning, degreasing and sandblasting [1]

Turbine failure is generally determined by visual inspection. The shaft with the blades on both sides is the most visible and, practically, the key part of the turbine. The blades on the side through which clean air passes are the most vulnerable. If any particle of dirt enters this area, at least one vane will become damaged, which will automatically lead to mass imbalance and unbalanced rotation. Such rotation will, by all means, cause damage to the nearest bearing in no time. If, for example, a stone or a piece of glass or some other hard object gets into this area, the entire section will be destroyed and the blades broken. This damage will probably result in a complete loss of symmetry in the shaft.

Similarly, the drive blades can suffer damage due to poor combustion and extremely high temperatures. The blades in such an operating environment erode over time, which reduces the operating life of the turbine.

Another reason for turbine damage is poor lubrication. The turbine shaft is lubricated with oil from the engine, and the oil also serves as a coolant. If for any reason lack of lubrication or oil starvation occurs, the bearings (bronze rings) will be the first to suffer damage. Also, due to increased temperatures and loss of balance during rotation, seal rings will become permanently damaged.

Figure 16. The most common types of damage [1]

Even in prolonged contact with lubricating oil, these rings will not be able to retain hot oil under pressure, and over time the oil will leave the lubrication area through them. Although damaged, the turbine can be reconditioned.

Any reconditioning operation after turbine disassembly involves the replacement of seal rings, bronze bearings and rubber seals. Well-equipped service providers use kits including the replacement components required during turbine disassembly. The turbine contains the so-called seal plate or housing cover, which is generally not replaced. In variable geometry turbines, the stator section should also be replaced in major overhauls. Undamaged components are reinstalled in the housing in reverse order.

Figure 17. Reconditioning of turbine parts [1]

When reinstalling the existing shaft and blades or installing new components, the assembly should be additionally balanced. It is only after this operation that the turbine can be assembled. Balancing is among the most sensitive processes during turbine reconditioning. It is performed only by trained service providers. Excess removal of the material during the balancing operation may cause permanent damage to the turbine.

Figure 18. Balancing of the shaft and blades [1]

4. CONCLUSION

Repair primarily serves to restore the operating performance of machine parts suffering surface damage (wear) and fracture. Rather than being disposed of as waste, worn-out and broken parts are repaired and reinstalled in mechanical structures instead of new spare parts. Repair has been widely applied for the following reasons: high competitiveness, struggle to make the maximum possible profit, and economic, energy-based and ecological crises. As repair of mechanical parts and structures requires expert knowledge in different fields (knowledge of materials, types of damage, mechanical engineering calculations, etc.), it cannot be performed by a single person, but by a well-balanced team of experts.

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