MAHLE

Driven by performance

TURBOCHARGER:
DAMAGE PROFILES, CAUSES, AND PREVENTION

Technical information

AFTERMARKET

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1 Preface

MAHLE is one of the most important development partners and manufacturers of engine components and systems as well as filter systems in the automotive industry. The engineers at MAHLE develop products of the highest quality throughout the world in conjunction with engine and vehicle manufacturers. The same high quality guidelines are also applied for the spare parts in the aftermarket.

Numerous checks during and after production ensure the high quality level of MAHLE products. If failures occur in practical operation, the causes are mostly found in the engine environment.

TURBOCHARGER—THE FUNCTION

Turbochargers are used to enhance the performance and optimise the combustion. To achieve good and complete combustion in the engine, a mixture ratio of 1 kg fuel and approximately 15 kg air is necessary (stoichiometric fuel ratio). This air volume corresponds to about 11 m^3. During turbocharging, the density of the intake air is elevated and the air volume increased.

The volumetric efficiency and thus the efficiency of the combustion engine are significantly improved by means of turbocharging. In addition, the torque can be increased considerably, which in turn serves to enhance the performance. The turbocharged engine with the same power output as a naturally aspirated engine can therefore be designed with a smaller displacement and hence lower weight (downsizing).

The core of the turbocharger is the rotating assembly, consisting of the turbine wheel with shaft and impeller. The turbine wheel is located on the exhaust side. It is firmly connected to the shaft, e.g. through friction welding or laser welding. The impeller is mounted on the other end of the rotor shaft, generally with a screw connection.

The exhaust flow from the engine is channelled through the turbine, which leads to a rapid rotational movement of the turbine wheel, subsequently driving the impeller. The turbine speed depends on the design and exhaust volume. In small turbochargers, the rotating assembly reaches speeds of up to 300,000 rpm. In order not to destroy the turbocharger and engine, the maximum charge air pressure is usually limited by boost pressure regulation.

TURBOCHARGER REPLACEMENT: THIS IS WHAT MATTERS

In terms of construction and function, a turbocharger is designed for the service life of the engine. In practice, however, the high-performance components in the exhaust gas system are subject to diverse risk factors that can lead to premature failure.

The analysis and rectification of the cause of the failure are the prerequisite for a successful repair. Otherwise, the new turbocharger might fail again after a short period of time.

This brochure summarises typical damage scenarios and sheds light on their possible causes. The information is supplemented by tips on how to avoid such damage in the future.

In this way, we aim to make it easier for repair shops and engine reconditioners to troubleshoot potential damage causes and ensure appropriate engine repair, which in turn is necessary for the long and reliable functioning of our products and hence the entire engine.

2 Inadequate lubrication

Inadequate lubrication is one of the most frequent causes for turbochargers to fail. If the turbocharger is not sufficiently supplied with oil, damage will occur within a very short time. This is due to the very high speeds of the turbocharger.

EFFECTS

- The impeller and turbine wheel can strike the turbocharger housing on account of bearing damage *(Fig. 1)*. This can be discerned from wear marks on the housing *(Fig. 2)*.
- If the turbocharger boost pressure is too low, the engine will not perform properly: the rotating assembly no longer reaches the maximum speed and can no longer build up the full boost pressure as a result. The reason for this is the mixed friction caused by the inadequate lubrication.
- The exhaust system emits black smoke. These are the effects of the engine not being supplied with enough air and a correspondingly too rich fuel-air mixture.
- The shaft shank exhibits clear discoloration *(Fig. 3)*, which arises from friction and the resultant high temperatures between the shaft and the bearings. The cause of this is inadequate lubrication. If the temperature exceeds a certain level, the bearing material will become deposited on the shaft *(Fig. 4)* or the bushing might even become completely fused to the shaft.
- A broken shaft shank *(Fig. 5)* is the result of operating the turbocharger for a prolonged time without enough oil. The shaft material can thus burn out and break.
- If bushings that are permanently incorporated in the bearing housing become fused to the shaft, the bushings might turn out of position in the bearing housing *(Fig. 6)*.
- The shaft might suddenly become blocked in the bearing housing due to the mixed friction. If the rotating assembly is suddenly blocked, the locking nut of the impeller can become loose.
- The rotating assembly can exhibit a large imbalance owing to the contact with the housing, which might result in the radial bearing breaking *(Fig. 7)*.
- Due to incorrect oil or heat soak, the bearing housing can become carbonised.
- The radial bearings have fretted.
- The axial bearing exhibits fretting marks or carbon deposits.
- Knocked-out bearings can cause too great a wobble of the shaft, whereby the bearing collar might also be damaged.

Fig. 1
Impeller after contact with housing

Fig. 2
Contact marks in the compressor housing

Fig. 3
Discoloration of the shaft shank

Fig. 4
Bearing material fused onto the shaft

Fig. 5
Broken shaft shank

Fig. 6
Twisted bushing

Fig. 7
Broken radial bearing

CAUSES

- The oil level in the engine is generally too low. As a result, not only the engine but also the turbocharger receives an inadequate oil lubrication and oil cooling.
- The oil used is not sufficiently temperature-resistant, leading to increased carbonisation. This might cause problems: the oil supply line of the turbocharger and the oil bores in the bearing housing of the turbocharger can become carbonised.
- If the engine was turned off while hot, the oil supply line can become carbonised, which means the turbocharger is no longer supplied with enough oil.
- If the cold engine was brought to high speeds immediately after the start, there is a risk that the oil supply in the turbocharger is not yet sufficient and hence the oil film in the turbocharger tears off.
- If foreign substances make it in the oil circuit, such as dirt or sealing residues, the oil supply line of the turbocharger and/or the bearing housing of the turbocharger might be clogged.
- If the viscosity of the oil is too high, the oil transport to the bearing points is delayed, which means that the timely oil supply of the turbocharger is not ensured. At too low a viscosity, the carrying capacity of the oil is too low, which can lead to mixed friction.
- If the engine is operated with biodiesel or vegetable oil, there is a risk of the engine oil gelling. This increases the viscosity of the oil and it can no longer be transported through the thin oil bores in the turbocharger.
- The cross section of the bearing housing supply bore might be reduced either through an incorrect flange seal or by a liquid sealant.

REMEDY/PREVENTION

- The engine must be warmed up and cooled down.
- The engine must be supplied with enough oil.
- Only engine oils specified by the vehicle or engine manufacturer may be used.
- Only driving short distances should be avoided.
- The maintenance intervals according to the manufacturer's recommendations should always be complied with.
- Only high-quality oil filters specified for the respective vehicle should be installed.
- The corresponding mounting kit for the turbocharger must always be used.
- When operating the engine with biodiesel or vegetable oil, the service intervals should at least be halved.

3 Contaminated oil

Dirt, soot, fuel, water, combustion residues, or metal abrasion can contaminate the oil. Even the smallest particles in the oil can cause serious damage to the turbocharger due to its extremely high speeds.

EFFECTS

- The smallest foreign substances in the oil cause grooves in the bushings *(Fig. 1)*. The piston rings in the turbocharger can undergo serious wear. As worn piston rings can no longer adequately seal the turbocharger, the oil enters the turbine side, which can be discerned by increased oil consumption.
- The bearing play of the rotating assembly increases due to the worn bushings. This leads to wobbling movements and causes the turbine wheel or impeller to come into contact with the housing *(Fig. 2)*. The shaft might subsequently break off.
- The bearing collar, i.e. the thrust washer of the axial bearing, exhibits grooves.
- Grooves or fretting marks are discernible in the axial bearing.
- Due to a blocked oil return line, the oil in the turbocharger can no longer flow off and is instead forced out to the compressor and turbine side. On the turbine side, the oil might then burn onto the shaft and coke *(Fig. 3)*. Owing to the oil carbon layer, the bearing housing and the piston rings might be significantly worn off as a consequence.
- The shaft of the turbocharger shows clear signs of wear at the bearing points *(Fig. 4)*.

CAUSES

- If the maintenance intervals are exceeded, the oil filter can no longer filter enough dirt out of the oil. In this case, the dirt particles penetrate through the open bypass valve of the oil filter into the engine circuit.
- If the engine is operated with a blocked oil filter, the small abrasive particles cannot be filtered out of the oil.
- If the cylinder head gasket or the oil cooler is leaking, water will enter the oil circuit and dilute the oil. Its carrying capacity is thus reduced.
- If the engine was repaired, but not properly cleaned before assembly, dirt will be in the engine even before putting it into operation for the first time.
- The charge air cooler was not replaced. Accumulated engine oil, chippings, or fragments from the prior damage usually find their way into the engine with a time delay.
- If the engine is subject to considerable wear, the mostly metallic wear debris also finds its way into the turbocharger via the oil circuit.
- If combustion faults occur in the engine, non-combusted fuel can end up in the oil. The carrying capacity of the oil is reduced by this dilution.

Fig. 1
Grooves in the radial bearing

Fig. 2
Turbine wheel after contact with housing

Fig. 3
Carbonised oil on the turbine side

Fig. 4
Clear signs of wear on the shaft at the bearing point

REMEDY/PREVENTION

- The maintenance intervals according to the manufacturer's recommendations should always be complied with.
- Only high-quality oil filters specified for the respective vehicle should be installed.
- Only engine oils specified by the vehicle or engine manufacturer may be used.
- A new charge air cooler and air filter should always be installed when replacing the turbocharger. In addition, an oil change including oil filter replacement must be carried out.
- The air filter housing and charge air line should be cleaned by suction.

4 Oil leakage at turbocharger

If the engine shows signs of increased oil consumption and emits blue smoke, it is imperative that the turbocharger is included in the cause analysis. Important: Oil is forced out of the housing from a turbocharger only if divergent operating conditions predominate in its environment.

Fig. 1
Carbonised oil return line

EFFECTS

- Oil is forced out of the turbine or compressor side of the turbocharger.
- Blue smoke is emitted from the exhaust system.
- Engine oil has accumulated in the intake section and charge air cooler.
- The engine experiences a power loss.
- Uncontrolled overspeeds resulting in the engine (so-called “rising”) due to the engine oil accumulating in the charge air cooler, which is blown into the intake of the engine and combusted.
- The guide vanes might be coked in a VTG turbocharger.

CAUSES

- If the oil return line of the turbocharger is clogged *(Fig. 1)* or constricted by a kink, the oil can no longer flow out of the turbocharger *(Fig. 2, diagram B)*. A possible cause for clogged oil return lines is the coking of the return line, which might be due to missing heat shields, a poorly routed return line, heat soak, inadequate oil quality, or the use of liquid sealants. As the turbocharger is still supplied with oil from the engine circuit, the oil then escapes to the turbine or compressor side.
- If the engine is supplied with too much oil, the oil can no longer flow back out of the oil return line into the oil pan *(Fig. 2, diagram C)*. The crankshaft also splashes up the oil. This results in the oil foaming, which forms an additional barrier for the returning oil from the turbocharger *(Fig. 2, diagram D)*.
- If the pressure in the crankcase is too high—either because of too high blow-by *(Fig. 2, diagram E)* or due to blocked crankcase ventilation *(Fig. 2, diagram F)*—, this pressure will also be transferred to the oil return line of the turbocharger. The oil drainage from the turbocharger is thus hindered, and the oil escapes from the turbine or compressor side.

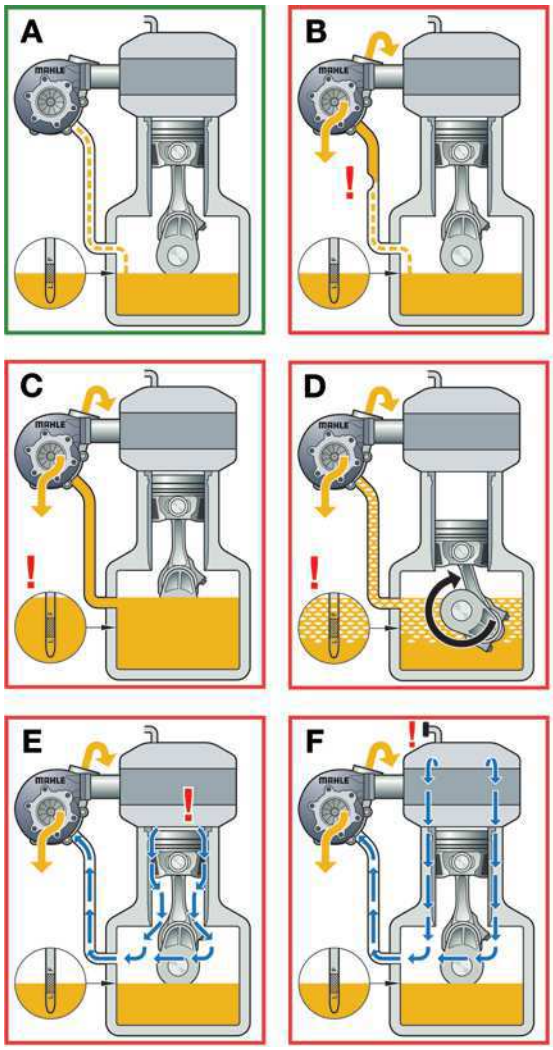

Fig. 2
Oil leakage at turbocharger. Diagram A shows the optimum state.

REMEDY/PREVENTION

- The engine must only be filled to the specified maximum oil level.
- Only engine oils specified by the vehicle or engine manufacturer may be used.
- The oil return line must be routed exactly as in the original state. In addition, it must be ensured that all heat shields are attached.
- The oil return line and the connections to the crankcase must be checked for continuity. We generally recommend replacing the line and the connecting piece.
- The crankcase ventilation must be checked and replaced, if necessary.
- The piston and piston rings must be checked for wear and replaced, if necessary.
- A new charge air cooler and air filter should always be installed when replacing the turbocharger. In addition, an oil change including oil filter replacement must be carried out.

5 Foreign object damage

If foreign substances, such as dust, sand, screws, parts of piston rings or valves, and sediments, enter on the intake or exhaust side, this will usually lead to total failure of the turbocharger due to the very high speeds. Damage to the charge air cooler might also be the consequence.

EFFECTS

- On account of previous damage, foreign substances from the engine or the exhaust manifold can damage the gas entry edges of the turbine wheel.
- The air guide plates of the VTG unit are damaged and bent *(Fig. 1)*, leading to a significant power loss.
- Foreign substances in the intake air result in damage to the impeller *(Fig. 2)*. The vanes might become completely worn as a result. In addition, the intake passage of the compressor housing might be damaged *(Fig. 3)*.
- The impeller might be damaged by condensation frozen in the intake section. Damage to just one vane is characteristic of this cause: owing to the high speeds, the ice particles burst when encountering the first vane, with no other vanes being damaged *(Fig. 4)*.

CAUSES

- If a valve is torn off or the piston rings fracture, for example, these parts come into contact with the guide vanes of the VTG unit and the turbine wheel via the exhaust manifold.
- Both a leakage in the intake section and a contaminated or defective air filter can be the cause of penetration by foreign substances in the intake section.
- In winter, ice can form through condensation in the intake section.

REMEDY/PREVENTION

- The leak tightness of the intake section must be guaranteed.
- After working on the intake section, it must always be ensured that no loose parts remain there.
- The air filter must be replaced as specified by the manufacturer, and the air filter housing as well as charge air line should be cleaned by suction.
- Only driving short distances should be avoided.

Fig. 1
Damaged air guide plates of the VTG unit

Fig. 2
Impeller damaged by foreign substances

Fig. 3
Foreign substance impact in the intake passage of the compressor housing

Fig. 4
Only one vane of the impeller damaged

6 Damage due to excessive exhaust temperatures

Fig. 1
Crack in the turbine housing

Each turbocharger is designed for only a defined temperature range. If this range is exceeded, the turbocharger can fail after just a few seconds.

EFFECTS

- Cracks in the housing of the turbocharger *(Fig. 1)*.
- Oil lines can become coked: If the supply line is carbonised, the turbocharger will not be sufficiently supplied with oil. If the return line becomes coked, the oil can no longer flow off and oil is forced out of the turbocharger (see also section “4 Oil leakage at turbocharger” on page 10).

CAUSES

- The temperature level has changed due to tuning.
- Combustion faults have occurred in the engine.
- The engine was turned off while still hot.

REMEDY/PREVENTION

- The turbocharger may only be installed in the specified vehicles.
- The turbocharger may only be installed and operated in the original state as supplied. Technical modifications are not permitted.
- The engine must always be cooled down at moderate speeds after high stress, such as driving at full load.

7 Overspeeding

The parts installed in the turbocharger are designed for a defined speed range. If this range is exceeded, major turbocharger damage can occur within seconds.

EFFECTS

- Small dents can be seen on the rear of the impeller *(Fig. 1)*. The material (mostly aluminium) has deformed plastically due to high centrifugal forces at overspeeds. It begins to flow and the outer diameter increases.
- If the speeds increase further, the impeller can come into contact with the housing and/or break apart *(Fig. 2)*.

CAUSES

- The maximum permissible speed of the turbocharger was exceeded due to tuning.
- The VTG air guide plates become blocked in the position for low speeds due to carbonisation. If the engine speeds are then increased, the turbocharger enters the overspeed range.
- The pneumatic or electric control is defective or leaking.

REMEDY/PREVENTION

- The turbocharger must always be left in the original state as supplied.
- The turbocharger may only be installed in the specified vehicles.
- The engine must always be cooled down at moderate speeds after high stress, such as driving at full load.
- Only engine oils specified by the vehicle or engine manufacturer may be used.
- The maintenance intervals according to the manufacturer's recommendations should always be complied with.

Fig. 1
Dents on the rear of the impeller

Fig. 2
Broken-apart impeller

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