MAHLE

Turbochargers

Damage scenarios, causes, remedies, and avoidance

Preface

MAHLE is one of the most important development partners and manufacturers of engine components and 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 to spare parts for the aftermarket.

Numerous checks during and after production ensure the consistently high quality of MAHLE products. If, however, unexpected failures occur in practical operation, the causes are usually to be found in the engine environment. Operating or assembly errors, or unsuitable operating media, may also be causes of failure.

In this brochure, we have summarized typical damage scenarios, described their causes, and provided tips for avoiding similar damage in the future. The aim is to make it easier to identify potential causes of damage. The advice provided in the brochure helps to ensure that our products continue to function reliably in the long term, thus prolonging engine service life.

Furthermore, our experts are also confronted with complex damage scenarios that go beyond the scope of this brochure. In cases where damage to our products cannot be readily diagnosed, we are more than willing to examine them at our premises and put together an expert damage report for you. To find out more, please contact your local sales partner.

Info available at:

www.mahle-aftermarket.com

Contents

Design and function of a turbocharger

Turbocharger: the unit

Turbochargers are used to increase performance and optimize combustion. Good and complete combustion in the engine requires a mixture ratio of 1 kg of fuel and approximately 15 kg of air (stoichiometric fuel ratio). This air volume is equivalent to about 11 m^3. During turbocharging, the density of the intake air is elevated, increasing the air volume.

Turbocharging significantly improves the volumetric efficiency and thus the efficiency of the combustion engine. In addition, the torque can be increased, thereby boosting performance. A 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).

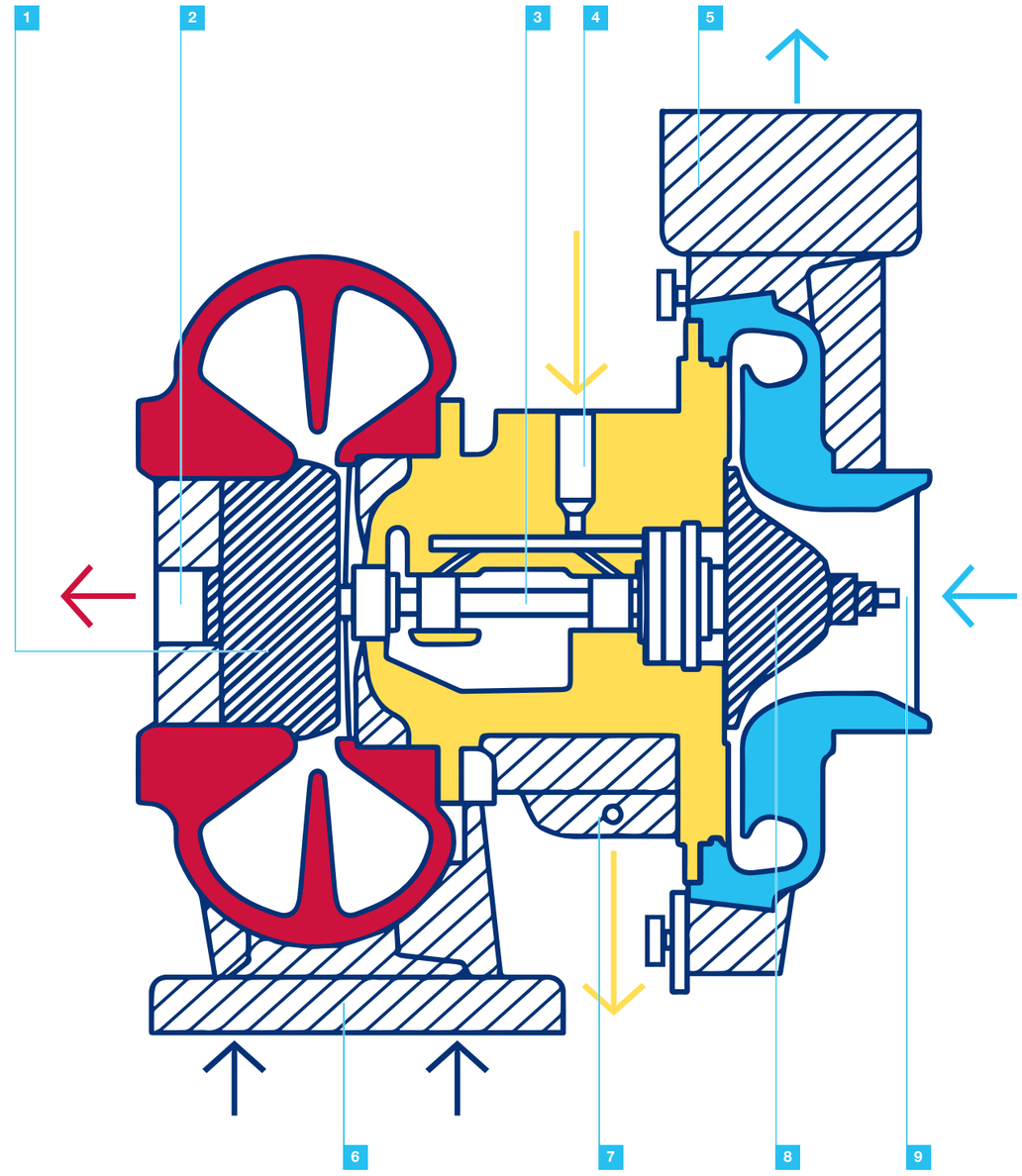
The core of the turbocharger is the rotating assembly, consisting of a turbine wheel with a shaft and impeller. The turbine wheel is located on the exhaust side. It is firmly connected to the shaft, for example, through friction welding or laser welding. The impeller is mounted on the other end of the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

The exhaust gas flow from the engine is channeled through the turbine, causing the turbine wheel to rotate rapidly, which drives the impeller. The turbine speed depends on the design and the amount of exhaust gas. 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: key points

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

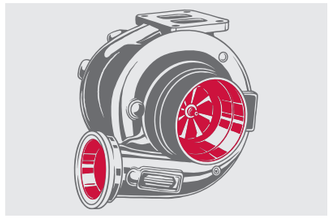
A successful repair depends on analyzing and eliminating the cause of the failure. Otherwise, the new turbocharger might fail again after a short period of time.



1 Turbine wheel
2 Turbine outlet
3 Rotor shaft
4 Oil inlet
5 Compressor outlet
6 Turbine inlet
7 Oil outlet
8 Impeller
9 Compressor inlet

1. Lack of lubrication

Lack of lubrication in the turbocharger



Lack of lubrication is one of the most common causes of turbocharger failure. If the turbocharger is supplied with too little oil, damage will occur within a very short time. This is due to the turbocharger's very high rotational speeds.

Fig. 1
Impeller after contact with housing

Fig. 2
Contact marks on the compressor housing

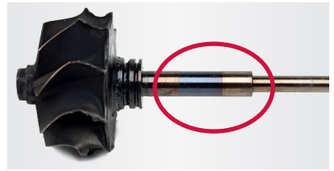


Fig. 3
Discoloration of the shaft shank

Fig. 4
Bearing material fused onto the shaft

Fig. 5
Broken shaft shank

Fig. 6
Twisted bushing

Fig. 7
Broken radial bearing

Effects

- Contact marks on the housing (*Fig. 2*). Due to bearing damage, the compressor and turbine wheel have struck the turbocharger housing (*Fig. 1*).
- If the 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 full pressure as a result. The reason for this is the mixed friction caused by the lack of lubrication.
- The exhaust system emits black smoke. The engine is not getting enough air; the fuel-air mixture is too rich.
- The shaft shank is clearly discolored (*Fig. 3*) due to friction and the resultant high temperatures between the shaft and the bearings. The cause of this is a lack of lubrication. If the temperature exceeds a certain level, the bearing material will become attached to 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 long time without enough oil. This can cause the shaft material to burn out and break.
- If bushings that are permanently mounted in the bearing housing become fused to the shaft, they 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 on the impeller can become loose.
- The rotating assembly can exhibit a severe imbalance owing to the contact with the housing, which might result in the radial bearing breaking (*Fig. 7*).
- Due to incorrect oil or hot soak, the bearing housing can become carbonized or coked.
- The radial bearings have fretted.
- Fretting marks or carbon deposits can be seen on the axial bearing.
- Knocked-out bearings can cause excessive wobbling of the shaft, which can also damage the bearing collar.

Causes

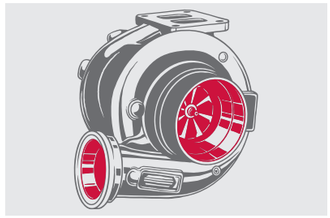
- The oil level in the engine is too low. As a result, the turbocharger also receives insufficient oil lubrication and cooling.
- The oil used is not sufficiently heat resistant. This increases the formation of oil carbon, which can carbonize the oil feed line and the oil feeder bores in the turbocharger bearing housing.
- If the engine was turned off while hot, the oil feed bore can become carbonized, restricting the supply of oil to the turbocharger.
- If the cold engine was brought up to high speeds immediately, the oil film in the turbocharger can tear off.
- If foreign objects are present in the oil circuit, the oil feed line and/or the bearing housing of the turbocharger might become clogged.
- If the oil viscosity is too high, the bearing points of the turbocharger are not supplied with oil quickly enough; if it is too low, the reduced load carrying capacity can lead to mixed friction.
- If the engine is operated using biodiesel or vegetable oil, the engine oil might gel. The higher viscosity of the oil prevents it being transported through the narrow oil feeder bores in the turbocharger.
- The cross section of the bearing housing feed bore might be reduced either by an incorrect flange seal or a liquid sealant.

Remedies/avoidance

- 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 manufacturer's specified maintenance intervals should always be complied with.
- Only high-quality oil filters specifically intended for the vehicle should be fitted.
- The appropriate mounting kit for the turbocharger must always be used.
- When operating the engine with biodiesel or vegetable oil, the service intervals must be reduced by at least half.

2. Contaminated oil

Contaminated oil in the turbocharger



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 rotational speeds.

Fig. 1
Grooves in the radial bearing

Fig. 2
Turbine wheel after contact with housing

Fig. 3
Carbonized oil on the turbine side

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

Effects

- The smallest foreign objects in the oil can cause grooves in the bushings (*Fig. 1*). The piston rings in the turbocharger can suffer serious wear. As worn piston rings can no longer adequately seal the turbocharger, the oil enters the turbine side, which can be detected 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.
- Grooves can be seen on the bearing collar, i.e., the thrust washer on the axial bearing.
- Grooves or fretting marks are visible in the axial bearing.
- Due to a blocked oil return line, the oil in the turbocharger can no longer drain out and is instead forced out to the compressor and turbine side. On the turbine side, the oil might then burn onto the shaft and carbonize (*Fig. 3*). The oil carbon film can cause the bearing housing and the piston rings to become heavily worn.
- The turbocharger shaft shows clear signs of wear at the bearing points (*Fig. 4*).

Causes

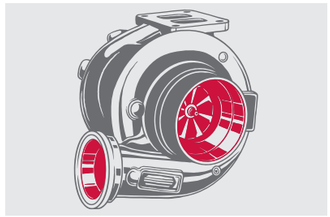
- If the maintenance intervals are exceeded, the oil filter can no longer filter enough dirt out of the oil. When this happens, dirt particles penetrate through the oil filter's open bypass valve into the engine circuit.
- If the engine operates with a clogged oil filter, the small abrasive particles cannot be filtered out of the oil.
- If the cylinder head gasket or the cooler is leaking, water will enter the oil circuit and dilute the oil, reducing its load carrying capacity.
- If the engine has been repaired but not properly cleaned before reassembly, the engine will contain dirt even before it is started up for the first time.
- The charge air cooler has not been replaced. Accumulated engine oil, chips, or fragments from previous 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, unburned fuel can end up in the oil. This dilution reduces the oil's loadccarrying capacity.

Remedies/avoidance

- The manufacturer's specified maintenance intervals should always be complied with.
- Only high-quality oil filters specifically intended for the vehicle should be fitted.
- 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.
- Only engine oils specified by the vehicle or engine manufacturer may be used.
- The air filter housing and charge air path should be vacuum-cleaned.

3. Oil leakage

Oil leaking from the turbocharger



If the engine shows signs of increased oil consumption and emits blue smoke, the turbocharger should definitely be included in the root cause analysis. Important: Oil from a turbocharger is only forced out of the housing if there are different operating conditions in its environment.

Fig. 1
Carbonized oil return line

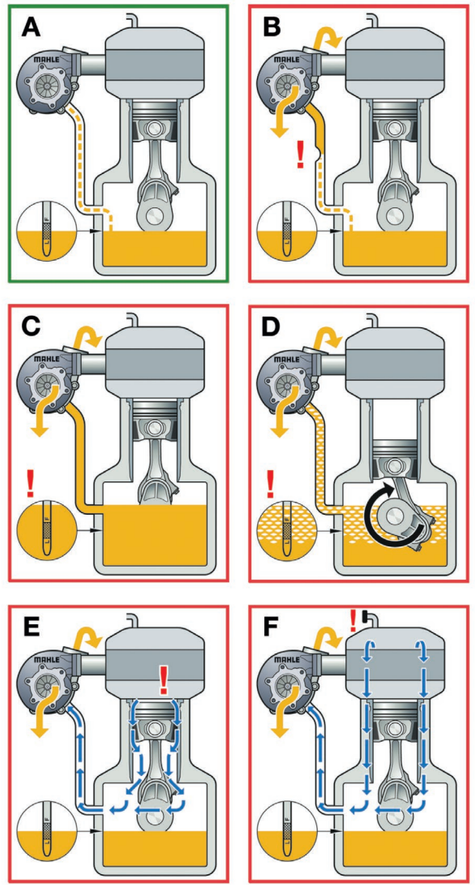


Fig. 2
Oil leaking from the turbocharger; diagram A shows the optimum state

Effects

- Oil is forced out from 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 power loss.
- Uncontrolled overspeeds occur in the engine due to engine oil accumulating in the charge air cooler and being blown into the engine air intake and burned.
- In a VTG turbocharger, the guide vanes might become coked.

Causes

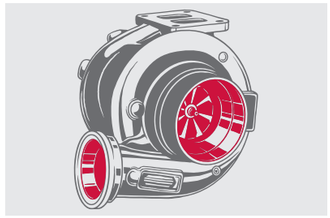
- If the turbocharger's oil return line is clogged (*Fig. 1*) or constricted by a kink, the oil can no longer flow out of the turbocharger (*Fig. 2, diagram B*). A possible cause of clogged oil return lines is a buildup of carbon in the return line, which might be due to missing heat shields, a poorly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

Remedies/avoidance

- 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 it was originally. 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 piston and piston rings must be checked for wear and replaced as required.
- The crankcase ventilation must be checked and replaced if necessary.
- A new charge air cooler and air filter should always be installed when replacing a turbocharger. An oil change including oil filter replacement must also be carried out.

4. Foreign object damage

Foreign object damage in the turbocharger



If foreign objects, such as dust, sand, screws, parts of piston rings or valves, and deposits, enter on the intake or exhaust side, this usually leads to total failure of the turbocharger due to the very high rotational speeds. Damage to the charge air cooler can also occur.

Fig. 1
Damaged air guide plates on a VTG unit

Effects

- On account of previous damage, foreign objects from the engine or the exhaust manifold can damage the gas entry edges of the turbine wheel.
- The air guide plates on the VTG unit are damaged and bent (*Fig. 1*), leading to significant power loss.
- Foreign objects in the intake air cause damage to the impeller (*Fig. 2*). The vanes might be completely worn away. In addition, the intake passage in 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 rotational 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 on the VTG unit and the turbine wheel via the exhaust manifold.
- Both a leak in the intake section and a clogged or defective air filter can be the cause of foreign objects penetrating the intake section.
- In winter, condensation can cause ice to form in the intake section.

Remedies/avoidance

- Care must be taken to ensure the leaktightness of the intake section.
- After working on the intake section, it's vital to make sure that no loose parts remain.
- The air filter must be replaced as specified by the manufacturer, and the air filter housing and charge air path should be vacuum-cleaned.
- Only driving short distances should be avoided.

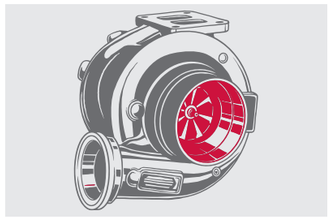
Fig. 2
Impeller damaged by foreign objects

Fig. 3
Foreign object impact in the compressor housing intake passage

Fig. 4
Only one vane of the impeller damaged

5. Excessive exhaust gas temperatures

Damage due to excessive exhaust gas temperatures



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

Fig. 1
Crack in the turbine housing

Effects

- Cracks appear in the turbocharger housing (*Fig. 1*).
- Oil lines can become coked: if the supply line carbonizes, the turbocharger won't receive enough oil. If the return line becomes coked, the oil can no longer drain out and oil is forced out of the turbocharger (see also section 3 "Oil leaking from the turbocharger" on page 10).

Causes

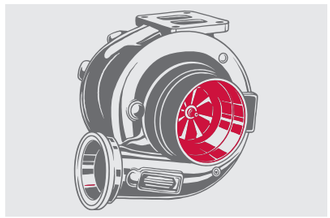
- Tuning has changed the temperature level.
- Combustion faults have occurred in the engine.
- The engine was turned off while hot.

Remedies/avoidance

- The turbocharger must only be installed in the vehicle for which it was intended.
- The turbocharger must only be installed and operated in its original as-received condition. Technical modifications are not permitted.
- The engine must always be cooled down at moderate speeds after high stress, such as driving at full load.

6. Overspeeds

Overspeeds in the turbocharger



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 (usually aluminum) has undergone plastic deformation due to high centrifugal forces at overspeeds. It begins to creep, 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

- As a result of tuning, the maximum permissible speed of the turbocharger has been exceeded.
- A buildup of carbon has caused the VTG air guide plates to jam in the position for low rotational speeds. If the engine speeds are then increased, this causes overspeeding in the turbocharger.
- The pneumatic or electronic control is defective or leaking.

Remedies/avoidance

- The turbocharger must always be left in the as-received condition.
- The turbocharger must only be installed in the vehicles for which it was intended.
- 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 manufacturer's specified maintenance intervals should always be complied with.

Fig. 1
Dents on the rear of the impeller

Fig. 2
Broken-apart impeller

Our product portfolio

Engine components

Quality built to last—precise fit and long life

- Pistons
- Piston rings
- Cylinder liners
- Bearings
- Valve train components
- Assemblies
- Turbochargers
- Controlled oil pump
- Intake modules with flap control
- Oil mist separators

Gaskets

Gasket range available worldwide for over one million applications

- Oil seals
- Head bolts
- Sealants

Filters

Our filter range—a clean solution

- Air filters
- Oil filters
- Fuel filters
- Cabin filters
- Air drier cartridges
- Transmission oil filters
- Urea filters
- CleanLine filters

Engine cooling & air conditioning

Comfort you can feel—now and in the future

- Radiators, charge air coolers
- Fans and clutches, condenser/radiator fans
- Expansion tanks, cabin heat exchangers
- Exhaust gas recirculation coolers, oil coolers
- E-water pumps
- Thermostats, thermal switches
- A/C compressors, A/C compressor oils
- A/C condensers, filter-driers, and accumulators
- Evaporators, expansion valves, and orifice tubes
- Interior blowers, A/C switches
- A/C blower control units and resistors, electric controls for blending flaps
- Sensors

Starter motors & alternators

Powerful and efficient—for the perfect start

- Starter motors
- Alternators

E-mobility & electronics

Innovative solutions—for the mobility of the future

- Actuators & switches
- High-performance electronics
- Various sensors
- Electric drive systems

Workshop equipment & diagnostics

Efficient solutions—for maintenance and service

- **TechPRO®** diagnostic kit
- **TechPRO®** Digital ADAS
- **ArcticPRO®** A/C service
- **FluidPRO®** automatic transmission flushing
- **NitroPRO®** nitrogen tire inflation
- **EmissionPRO®** exhaust emissions tester
- **LogiqPRO®** software tool
- **OzonePRO®** cleaning system
- **RemotePRO®** remote diagnostics
- **BatteryPRO®** electric vehicle battery diagnostics

Our information services

- **Technical Messenger:**
  Valuable technical information and the latest tips on all aspects of the maintenance and repair of MAHLE products
  mahle-aftermarket.com/technical-messenger
- **Technical posters**
- **Damage brochures**
- **Installation videos and animations**
- **A/C refrigerant and compressor oil filling quantities manual**
  mahle-aftermarket.com/filling-quantities
- **Training portal**
  training.mahle.com
- **TechTool**
  techtool.mahle.com
- **MAHLE Insider newsletter**
  mahle-aftermarket.com/mahle-insider
- **Aftermarket online catalog**
  catalog.mahle-aftermarket.com
- **CustomerCare Portal**
  customercare.mahle-aftermarket.com
- **Website**
  mahle-aftermarket.com
- **MAHLE e-shop**
  eshop.mahle-aftermarket.com
- **Digital customer magazine**
  mpulse.mahle.com
- **mahlempulse on Instagram**
- **MAHLE YouTube channel**
- **MAHLE Facebook page**

Do you have technical questions? We're happy to help.

Technical hotline UK: +44 190 235 7100*
Email: technical.uk@mahle.com
Monday to Thursday, 08:30–17:00 and Friday, 8:30–16:00

* Free calls from the UK. Charges from other countries may vary.

MAHLE Insider

MAHLE Aftermarket GmbH
Pragstraße 26–46
70376 Stuttgart/Germany
Phone: +49 711 501-0

www.mahle-aftermarket.com
www.mpulse.mahle.com

mahled-309/03.2024/EN