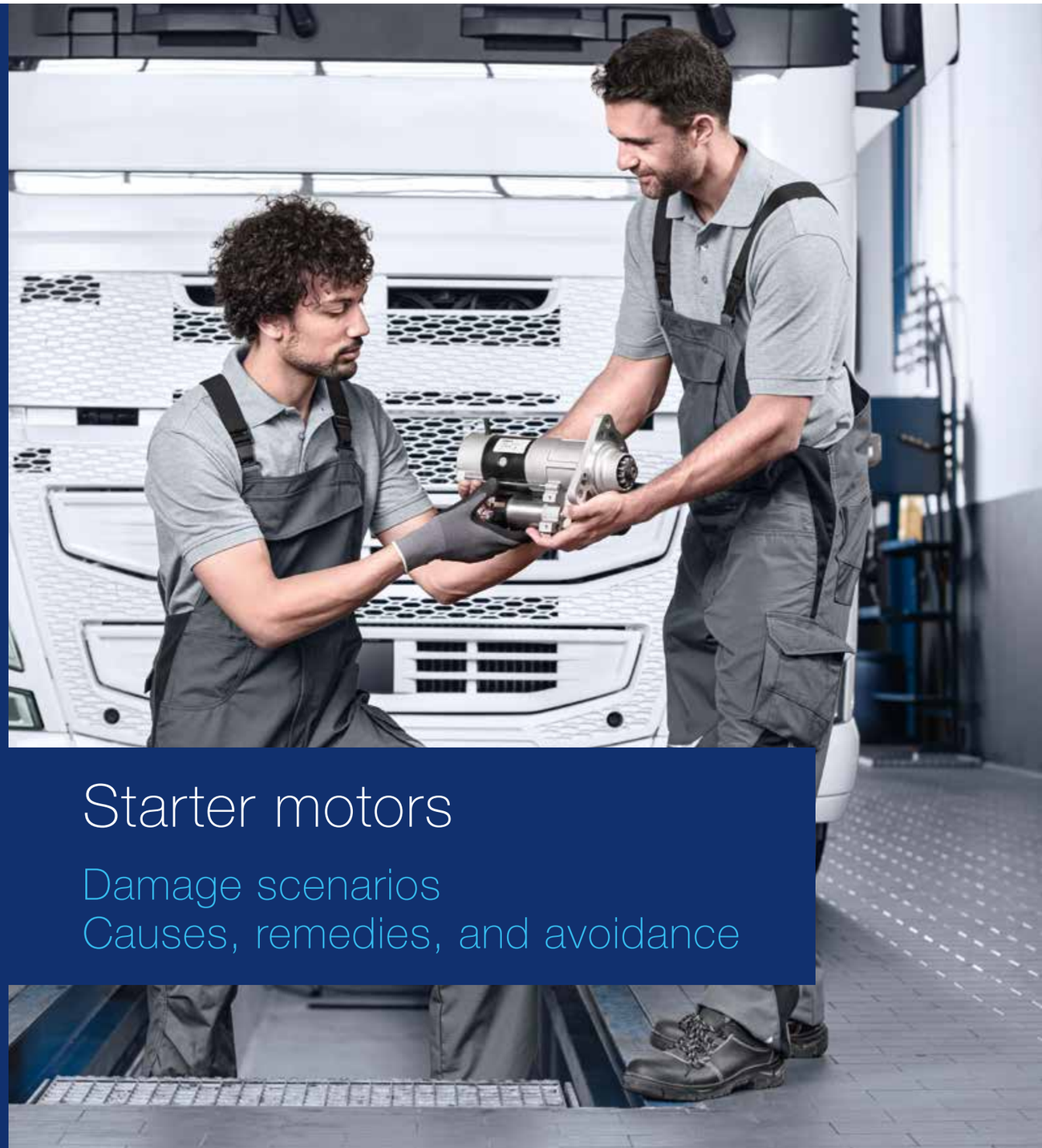
MAHLE Aftermarket GmbH
Pragstraße 26–46
70376 Stuttgart/Germany
Phone: +49 711 501-0

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

mahled-088/04.2020/EN



Starter motors

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 level 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.

This brochure summarizes typical damage scenarios, describes their causes, and provides tips for avoiding similar damage in the future. This makes it easier to troubleshoot potential causes of damage. The advice provided in the brochure helps to ensure that our products work reliably in the long term and thus prolongs the 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. Please contact your local sales partner.

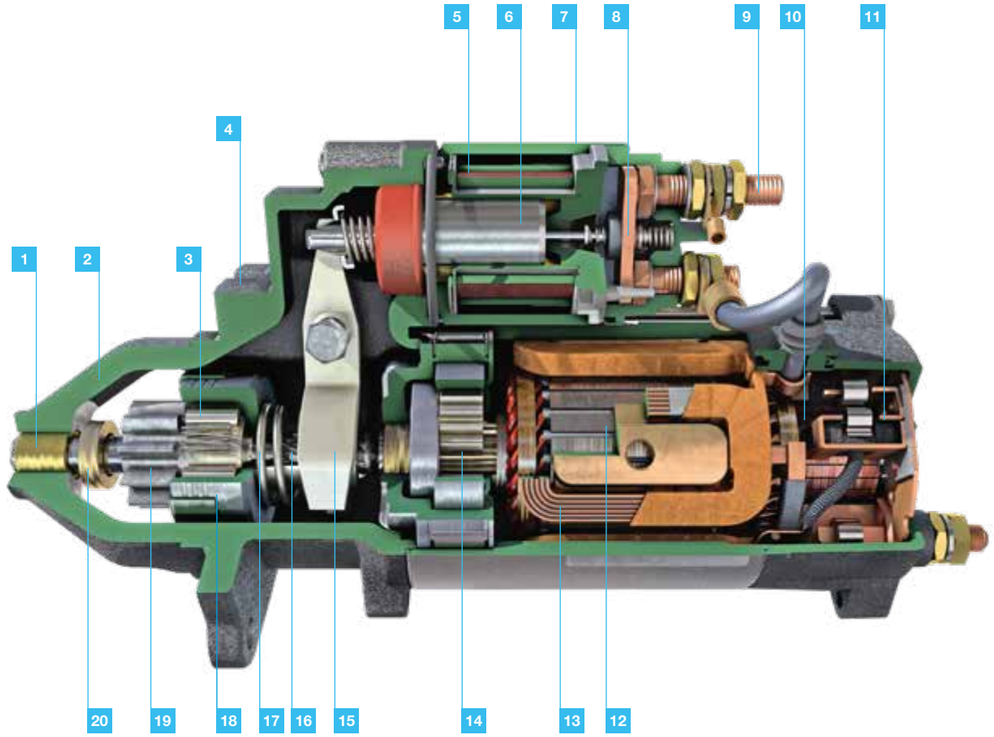
Info at:

www.mahle-aftermarket.com

Contents

Design and function of a starter motor

The starter motor has the task of starting the combustion engine. To do this, the ignition switch needs to feed current to the solenoid. The solenoid attracts an iron core (plunger), which mechanically (via a release fork) moves the starter pinion into engagement with the ring gear on the engine flywheel. At the end of its stroke movement, the iron core simultaneously closes the contact bridge, which switches the starter motor on. In most types of starter motors, the starter motor then uses a reduction gear to crank the engine. The starting process is complete as soon as the combustion engine reaches its cranking speed and starts. To do this, the ignition switch must stop feeding current to the solenoid. A spring then returns the iron core to its starting position. This opens the contact bridge and cuts off the supply of current to the starter motor. The starter pinion then also returns to its starting position. Because the engine speed increases to idle speed as the starting process ends, but the pinion is still engaged with the flywheel, a freewheel clutch between the starter motor's pinion and shaft prevents the starter motor from overspeeding.

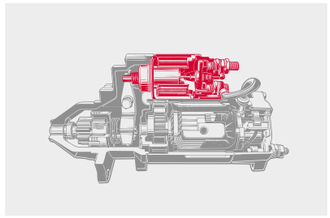


Technical data	
Speed required in the combustion engine to reach the point of self-sustained operation	approx. 70–120 rpm
Speed of the starter armature at the starting speed of the combustion engine	approx. 3,000–6,000 rpm
Idle-running speed of the combustion engine	approx. 700–1,200 rpm
Current consumption of the solenoid	approx. 50–250 A
Current consumption of the solenoid holding coil	approx. 20–80 A
Current consumption of the starter motor	approx. 200–2,500 A
Starter motor output	0.8–9.0 kW

1 Location of pinion shaft
2 Flange
3 Rolling element of freewheel clutch
4 Mounting flange
5 Solenoid coil
6 Plunger
7 Solenoid
8 Contact bridge
9 T30 battery connection
10 Commutator
11 Carbon brush
12 Armature
13 Pole winding
14 Reduction gear
15 Engaging fork
16 Helix
17 Meshing spring
18 Freewheel clutch
19 Pinion
20 Stop ring

1.1 Solenoid

Malfunction I



Contacts burnt

Findings:

- No overheating of the coil in the solenoid
- Solenoid is energized momentarily but the starter motor does not turn
- The solenoid is partially energized and then released again immedi-ately; a clicking noise can be heard
- The solenoid does not respond when supplied with current

Cause(s):

- Combustion engine or auxiliary aggregate is stuck
- Starter battery too weak: when the starter motor is switched on, the voltage fails
- Contact bridge in solenoid burnt
- Contact bridge corroded
- Poor contact of the connecting cable with the starter motor and battery
- Defective earth cable or corrosion on one of the screw connections

Remedies/avoidance:

- Charge battery or replace if necessary.
- Check whether the combustion engine and auxiliary aggregates can be turned mechanically.
- Check all cables for damage and connections for corrosion.
- If the solenoid has burnt through: check ignition switch and cable to starter motor.
- In case of corrosion, check at what point water has entered the starter motor.
- In case of a defective solenoid: replace starter motor.
- Never aim jet of high-pressure cleaner directly onto starter motor and cables.
- Only use starter motor to move the vehicle in an emergency.

Contact screw overheated and melted into cover

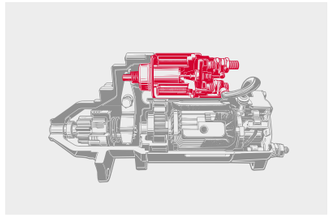
Corrosion on the contacts

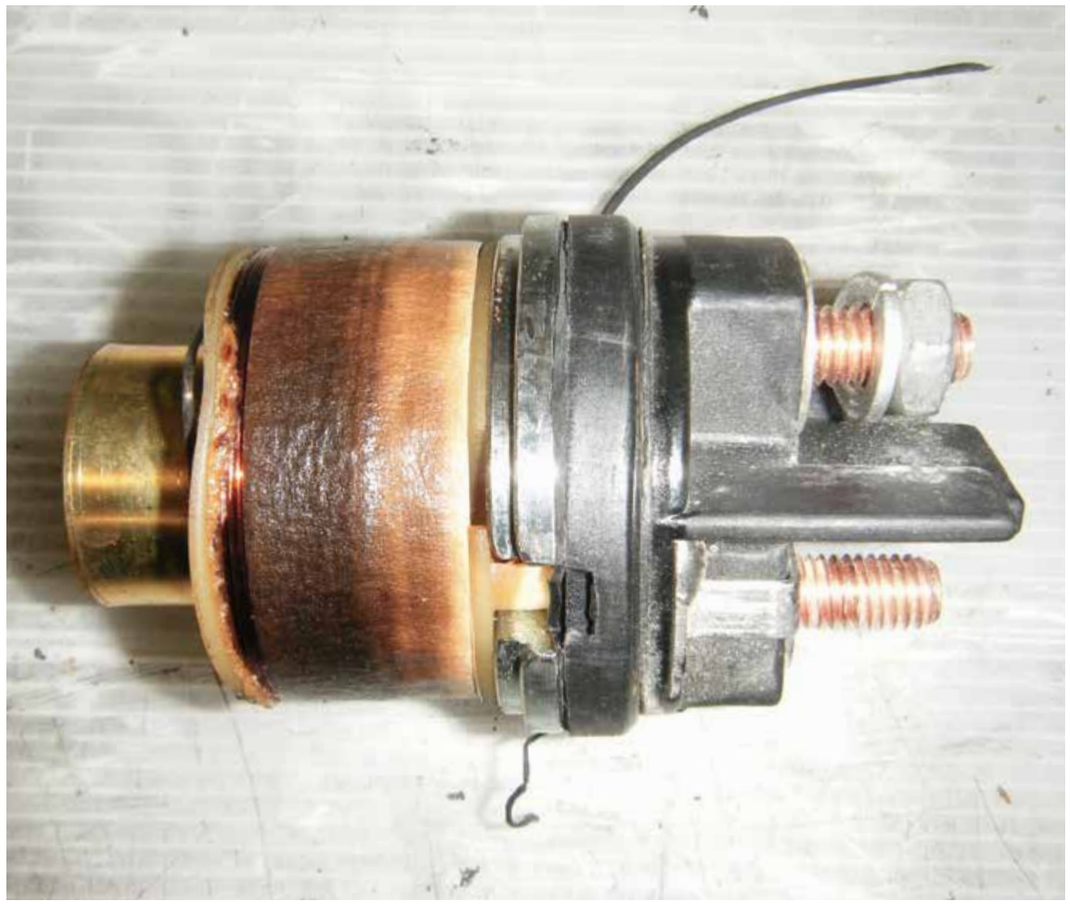
Corroded ground strap

Solenoid (opened) not overheated

1.2 Solenoid

Malfunction II





Solenoid overheated, indicator band heavily discolored

Findings:

- Indicator band discolored
- Coil in solenoid overheated
- No response from solenoid when supplied with current
- Indicator band inside solenoid is blackened
- Burning smell in the vicinity of the solenoid

Cause(s):

- Coil in solenoid burnt through or short circuit in the windings.
- Starter motor actuated for too long.
- Starter motor jammed (engine or auxiliary aggregates jammed).
- Starter motor overloaded (vehicle moved using starter motor).
- In larger starter motors, the motor is already set into rotation with reduced power via the solenoid connected in series. In tooth-to-tooth position, the solenoid does not engage, which soon leads to overheating.

Remedies/avoidance:

- Actuate starter motor for a maximum of 30 seconds, then allow it to cool for at least two minutes before the next starting attempt.
- For example, after changing the fuel filter, do not bleed the system by running the starter motor for a long time. It makes more sense to bleed the system using a pump to ensure that all bubbles are removed.
- Only use the starter motor to move the vehicle in an emergency (e.g., if the vehicle is stuck on a crossing).
- With heavier starter motors, stop the starting process immediately if the motor does not turn (tooth-to-tooth position).

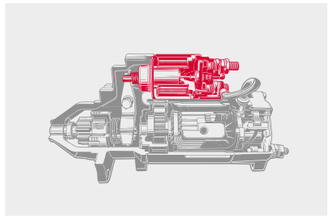
Solenoid overheated, indicator band slightly discolored

Solenoid significantly overheated and burnt

Fixing bolt of the solenoid with burning marks from overheated solenoid coil

1.3 Solenoid

Malfunction III



Dirt inside the solenoid

Findings:

- Starter motor is not working
- Solenoid pulls the pinion out, but does not engage in the starter motor
- Solenoid does not pull the pinion out

Cause(s):

- Heavy contamination in the solenoid was compacted in the rear of the solenoid by the plunger. Thick dirt deposits prevent the plunger from moving right to the end. The distance is no longer sufficient, contact bridge is not closed.

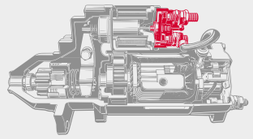
- Heavy contamination in the solenoid prevents movement of the plunger. This means that the pinion does not engage and the starter motor does not switch on.

Remedies/avoidance:

- Install new starter motor.
- Clean drive end housing thoroughly.
- Clarify cause of contamination (heavy contamination in the drive end housing may indicate a worn vehicle clutch).

1.4 Solenoid

Electrical connections charred



Loose connection has caused screw to overheat (housing melted)

Findings:

- Solenoid cover melted
- Connection bolt in cover charred
- Burning marks on connection cable and bolt

Cause(s):

- Connection cable loose. Increased contact resistance and arcing on connecting line produce local overheating.
- Connection bolt used incorrectly as a “power distributor” for other consumers.
- Excessive current consumption due to ground terminal on starter motor.
- Connection cables not fastened securely enough to vehicle. If electrical cables start to vibrate, the nut at the connection may begin to loosen.

Remedies/avoidance:

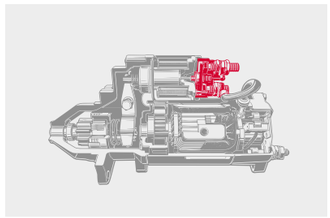
- Tighten connecting nut of the electrical connections with the prescribed torque.
- Ensure the connections are correctly positioned.
- Ensure that the cables are laid according to the specifications and the insulation cannot fray.
- Fasten electric cable according to manufacturer specifications in order to prevent cable from vibrating. A vibrating cable can damage the insulation and result in the nut becoming loose. A loose nut increases the electrical contact resistance, resulting in excessive temperatures and arcing.
- Do not misuse the connections of the starter motor as a node for other electric components. Additional cables on terminal 30 of the starter motor can lead to electrical contact resistances.

Loose connection has caused screw to overheat (housing melted)

Short circuit on solenoid

1.5 Solenoid

Housing melted



Short circuit (burning marks on housing)

Short circuit (burning marks on housing)

Findings:

- Burning marks and melted points on the housing of the solenoid or starter motor
- Connection bolt on positive pole (T30) of solenoid discolored
- Burning marks and plastic cover of the solenoid melted
- Insulation on supply line to starter motor charred
- Solenoid not working, pinion does not engage, but starter motor turns
- Solenoid not working, pinion does not engage, and starter motor only turns momentarily

Cause(s):

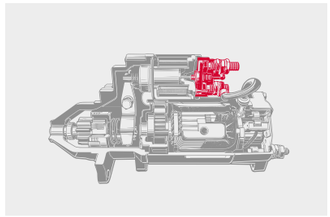
- Insulation of the positive pole (T30) supply line frayed. Short circuit to the ground of the solenoid housing.
- Connecting nut of terminal 30 connection loosened. Either the nut was not correctly tightened or the nut has become loose.
- Positive pole (T30) supply line not fastened according to manufacturer specifications. The connecting nut has become loose as a result of the heavy copper cable vibrating.
- Terminal 50 connection cable (coming from the ignition switch) inadvertently connected to the supply line to the starter motor (T30).
- Missing earth cable (T31) to the engine and/or transmission.
- Corrosion on the earth cable. When the engine is not running, there is an electrical ground connection from the engine block to the pinion of the starter motor via the bearings, crankshaft, flywheel, and ring gear. If an oil film builds up in the crankshaft bearings during the starting process, the ground connection is broken. The starter motor speed drops significantly, possibly causing a heavy break spark, which may also damage the bearings.

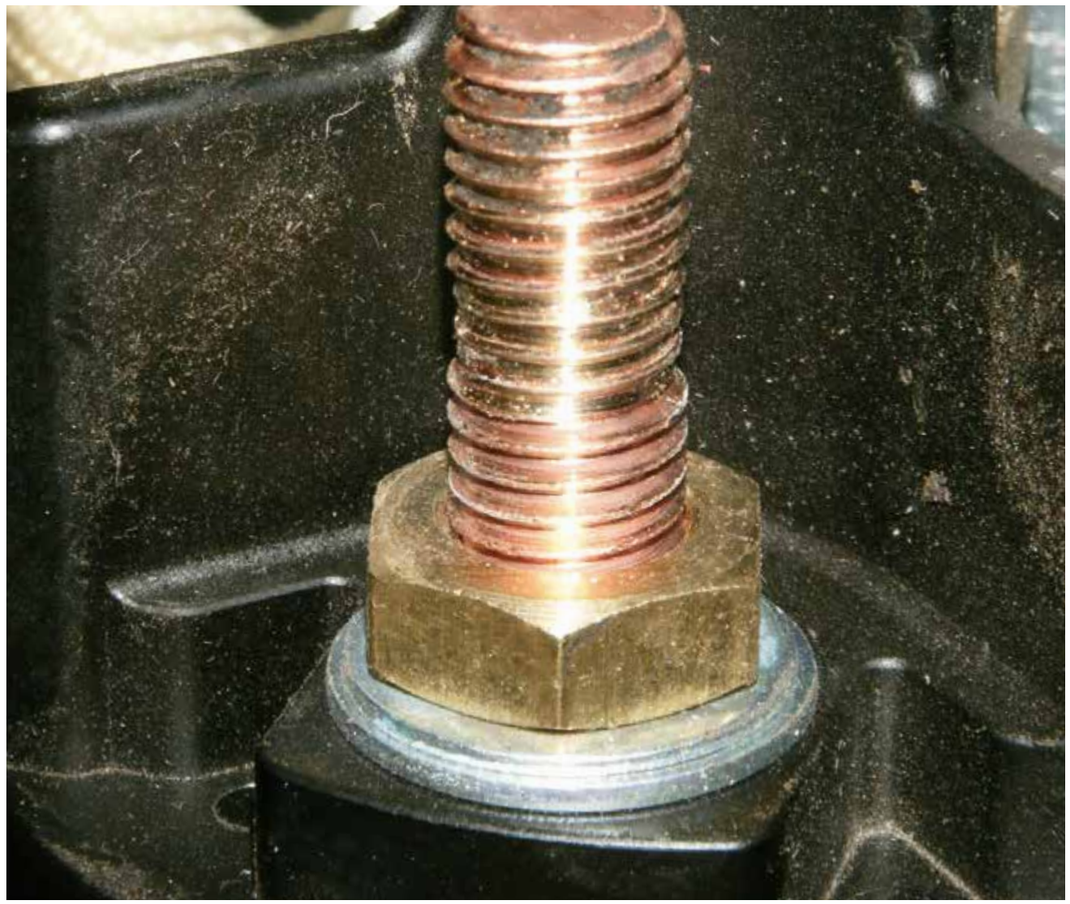
Remedies/avoidance:

- Check all electric cables, insulation, cable grips, and connections for damage.
- When removing the starter motor, mark the cables and connections.
- Remove corrosion from connections.
- Check that all earth cables on the vehicle and on the drive unit are connected correctly. Carefully remove corrosion from the connections.
- Tighten connecting nuts of the electrical connections with the prescribed torque.
- Ensure the connections are correctly positioned.
- Ensure that the cables are laid according to the specifications. Do not misuse the connections of the starter motor as a node for other electric components.

1.6 Solenoid

Copper bolt damaged





Nut on connection tightened too much and thread damaged

Findings:

- Thread on connection bolt damaged
- Connection bolt stretched, in some cases with visible necking in the thread
- Connection bolt torn off

Cause(s):

- Connecting nut tightened too much

Remedies/avoidance:

- Only tighten the nut on the copper bolt with the permitted torque:

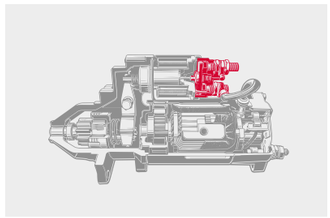
M8: 10 Nm ±2 Nm
M10: 15 Nm ±3 Nm
M12: 21 Nm ±3 Nm

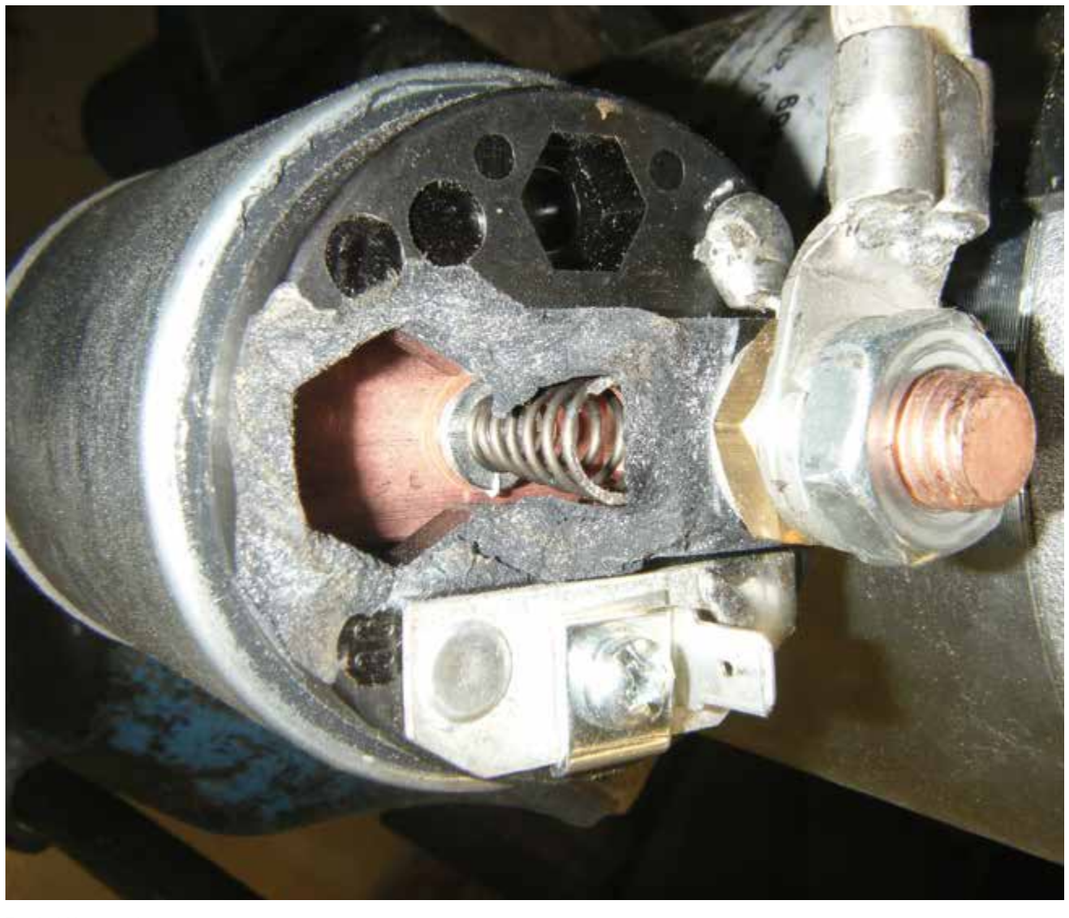
Nut on connection tightened too much and bolt torn off

Bolt thread overtightened

1.7 Solenoid

Electrical connections broken





Terminal 30 connection torn out

Findings:

- Solenoid cover torn off
- Solenoid cover broken
- Connection bolt completely torn out

Cause(s):

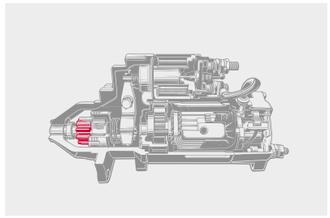
- Transport damage.
- Connection bolt knocked during installation of starter motor.
- If the starter motor still worked a few times, the plastic housing was only cracked. Actuating the starter motor has increased the size of the crack.
- Battery cable not secured firmly enough, in conjunction with strong vibrations.

Remedies/avoidance:

- Do not drop or throw the starter motor.
- When installing the starter motor, do not knock any components in the engine compartment.
- Replace starter motor.
- Secure cables to eliminate/ prevent vibrations.

2.1 Starter pinion

All teeth abraded on the front face



All teeth on front face of pinion worn

Findings:

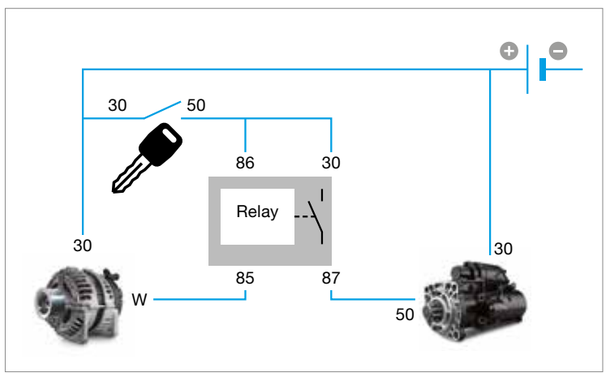
- All teeth on front face of the pinion worn or abraded
- Heavy contamination on starter shaft and pinion
- All teeth on front face of the pinion are worn or abraded and the solenoid is thermally damaged

Cause(s):

- Starter motor was started while the engine was running. Pinion cannot engage in the ring gear. As a result, the front faces of all the pinion teeth are damaged by the ring gear (operating error).
- Starter motor engages automatically in the running engine. In case of heavy contamination, the pinion may remain in the extended position and is slowly pushed back to the starting position by the rotating combustion engine.
- If the solenoid is activated for too long via terminal 50 (T50), the temperature increases, along with the internal resistance. This causes the solenoid to lose power, resulting in the pinion being pushed back to the starting position by the rotating combustion engine.

Remedies/avoidance:

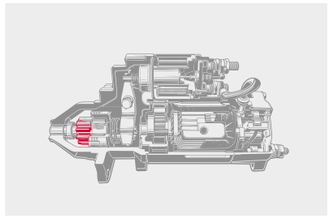
- Check starter pinion and ring gear for damage and replace if necessary.
- Check that ignition switch works correctly, replace if necessary.
- Check connection cable from ignition switch for damage to insulation.
- If the starter motor is switched via a relay, the relay must be replaced.
- Install a start-locking relay to prevent unintentional starting while engine is running.



Additional start-locking relay prevents starting while engine is running

2.2 Starter pinion

Partially abraded on the front face



Individual pinion teeth are worn

Findings:

- One or more pinion teeth are abraded on the front face
- The damaged areas often have a blue discoloration
- Starter motor is usually jammed (cannot turn in any direction)

Cause(s):

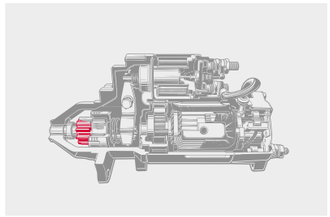
- Starter motor and freewheel clutch are jammed—as a result, pinion is also stuck. When pinion is disengaged, only one or two pinion teeth are worn.

Remedies/avoidance:

- Clarify cause of starter motor failure (see damage scenario “Starter motor spun out of control”) and replace starter motor.
- Check ring gear on flywheel for damage along entire circumference and replace if necessary.
- Clean drive end housing and remove all foreign objects.
- Check key switch and supply lines.

2.3 Starter pinion

Teeth broken off



Tooth broken off on starter pinion (mechanical overload)

Findings:

- Cracks on one or more pinion teeth (forced rupture)
- One or more teeth completely broken off (forced rupture)
- Pinion broken
- In some cases, the shaft and/or flange are also broken

Cause(s):

- Mechanical overload as a result of engine misfiring
- Mechanical overload due to starting when the engine is coming to a stop
- Mechanical overload as a result of using a battery that is too large or a second battery

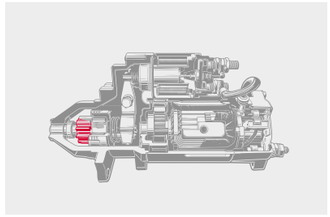
Remedies/avoidance:

- Check valve timing and carburetion and correct if necessary.
- After a failed starting attempt, wait until the engine has come to a complete stop.
- Install a start-locking relay with a time delay adjusted to the specific application.
- Use correct battery size according to vehicle manufacturer's specifications.

Broken starter pinion (mechanical overload)

2.4 Starter pinion

Tooth broken off



Foreign object damage on pinion

Findings:

- One or more pinion teeth are damaged in the center (forced rupture)
- Starter shaft broken (forced rupture)
- Ring gear mechanically damaged

Cause(s):

- Foreign objects (bolt, spring, parts of the clutch) have become loose and ended up between the ring gear and the pinion during the starting process. This has caused the starter motor and ring gear to become mechanically overloaded.

Remedies/avoidance:

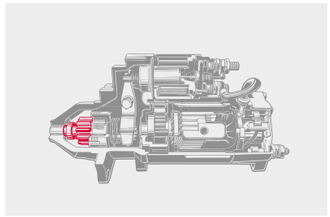
- Replace starter motor.
- Replace ring gear, as there will be severe damage to at least two teeth.
- Remedy cause (replace vehicle clutch, pressure plate, and/or thrust bearing).

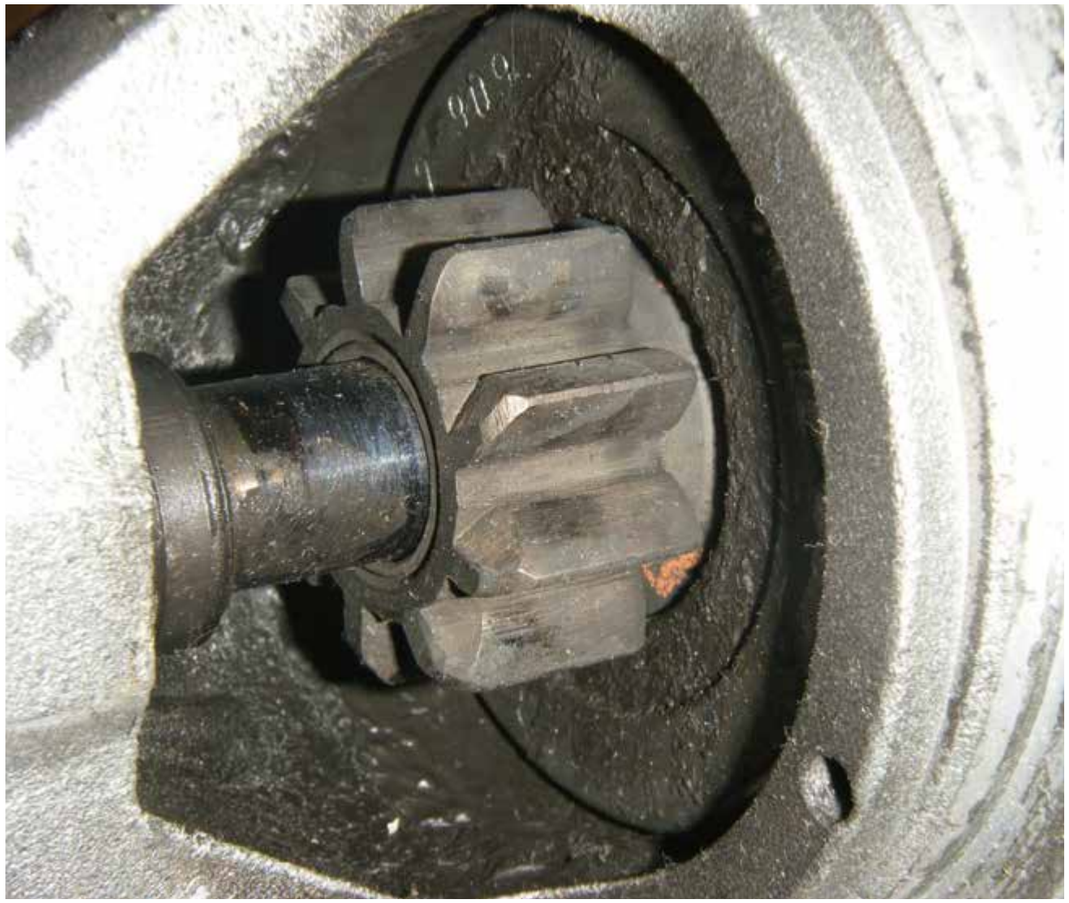
Pinion broken off

Foreign object damage on pinion, starter shaft broken

2.5 Starter pinion

Starter pinion and shaft discolored





Blue thermal discoloration on starter shaft

Findings:

- Blue discoloration on starter shaft and pinion
- Significant run marks on the front and back of the tooth flanks
- Bearing bush of the pinion worn
- Heavy contamination in the vicinity of the starter jaw
- Freewheel clutch sluggish, jammed, or without power

Cause(s):

- Pinion not disengaged after starting, causing it to run along the ring gear
- Heavy dirt and dust contamination on the starter shaft, pinion, and/or helix
- Electrical defect in the solenoid actuation
- Starter motor actuated for too long (starting problems, improper ventilation of the fuel system, etc.)
- Freewheel clutch damaged as a result of starting when the engine was coming to a stop
- Freewheel clutch clogged or overheated (grease leaked)

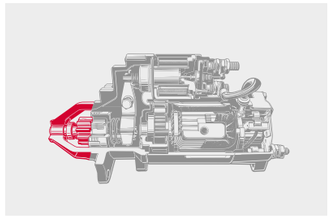
Remedies/avoidance:

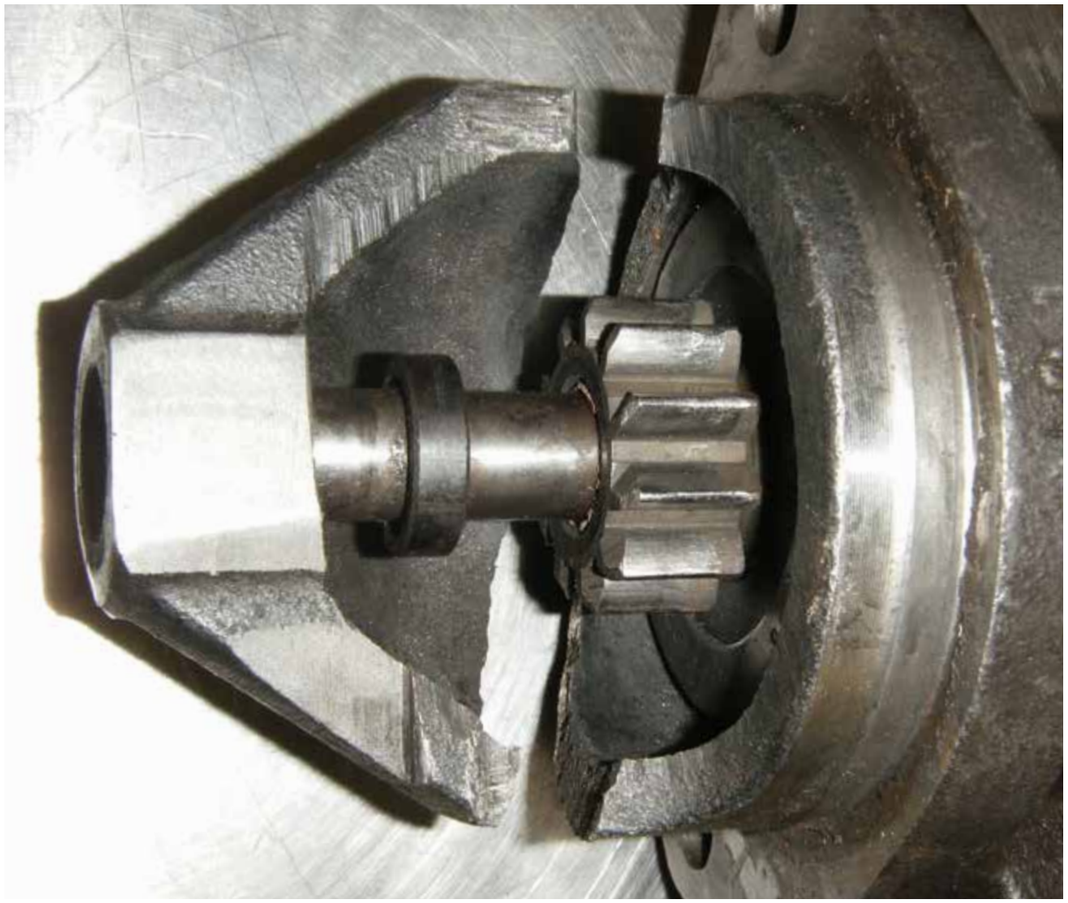
- Install new starter motor; check ring gear for wear and replace if necessary.
- Check electric actuation of the starter motor (key switch, cables, relay).
- Ensure that the starter motor is only actuated for a short period of time. It is advisable to engage the starter motor for no more than 30 seconds and to then let it cool for 2 minutes.
- Clean drive end housing thoroughly.
- Clarify cause of contamination (heavy contamination in the drive end housing may indicate a worn vehicle clutch).

Significant run marks on pinion (front and back)

3.1 Starter housing

Starter housing broken





Bearing cap on starter motor broken as a result of mechanical overload

Findings:

- Starter motor flange broken (forced rupture)
- Shaft broken (forced rupture)
- Cracks on one or more pinion teeth (forced rupture)

Cause(s):

- Mechanical overload as a result of engine misfiring
- Starting when engine was coming to a stop

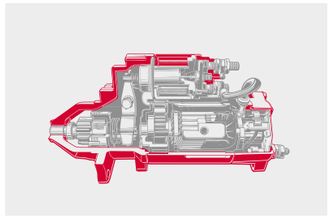
Remedies/avoidance:

- Check valve timing and carburetion and correct if necessary.
- After a failed starting attempt, wait until the engine has come to a complete stop.
- Install a start-locking relay with a time delay adjusted to the specific application.

Starter shaft broken as a result of mechanical overload

3.2 Starter housing

Starter housing broken or deformed



Transport damage to starter housing

Findings:

- Mechanical damage to housing
- Mechanical damage to the rear bearing cap

Cause(s):

- Transport damage
- Starter motor damaged during installation
- Starter motor tilted during assembly
- Starter motor dropped

Remedies/avoidance:

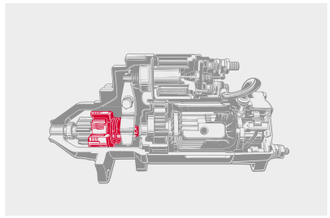
- Do not drop or throw starter motor (even when still in the packaging).
- Install starter motor carefully and do not try to pull it into position with the fixing bolts.

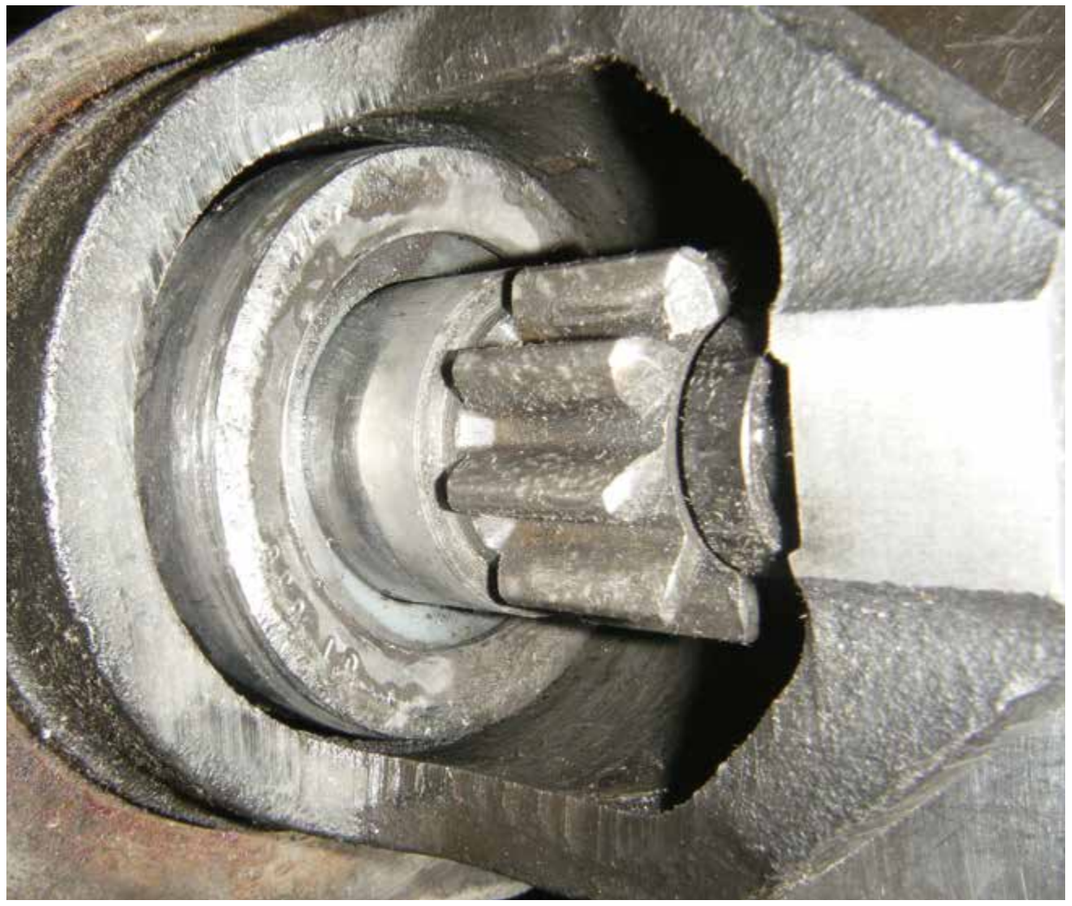
Transport damage to the flange

Transport damage to the flange

4.1 Freewheel clutch

Grinding marks on the lock plate





Grinding marks from the flywheel on the guard plate of the freewheel clutch

Findings:

- Grinding noises during starting process
- Contact marks from the flywheel/ gear wheel on the front face of the freewheel clutch
- The lock plate is abraded, causing the rollers and springs to fall out of the freewheel clutch

Cause(s):

- Starter motor is not suitable for the vehicle. Starter motor pinion extends too far for this engine. Freewheel clutch comes into contact with the ring gear of the flywheel.
- Ring gear has come free of the flywheel or was incorrectly mounted on the flywheel.
- Flywheel is severely crooked or wobbly (assembly defect).

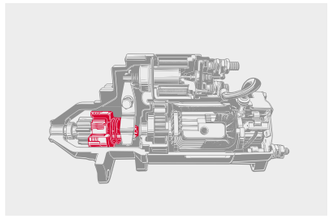
Remedies/avoidance:

- Only use the appropriate starter motor for the application.
- Check that the ring gear is positioned correctly on the flywheel.
- If it is unclear which starter motor is right for the application, compare all dimensions of the old starter motor and the stroke of the freewheel clutch (with pinion) with the new starter motor.

Grinding marks from the flywheel on the guard plate of the freewheel clutch

4.2 Freewheel clutch

Overrunning force uneven



Impressions on the cylindrical part of the pinion from the rollers of the freewheel clutch

Findings:

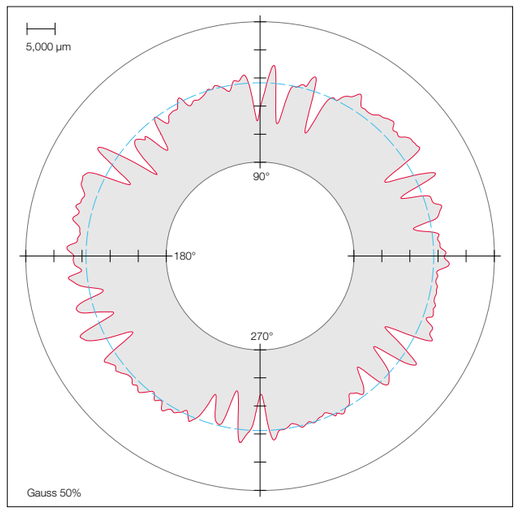
- Cracks on one or more pinion teeth (forced rupture)
- One or more teeth completely broken off (forced rupture)
- Pinion broken
- Overrunning force uneven

Cause(s):

- Mechanical overload as a result of engine misfiring.
- Mechanical overload due to starting when the engine is coming to a stop.

Remedies/avoidance:

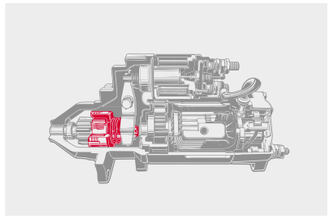
- Check valve timing and carburetion and correct if necessary.
- After a failed starting attempt, wait until the engine has come to a complete stop.
- Install a start-locking relay with a time delay adjusted to the specific application.



Roundness measurement on the cylindrical part of the pinion

4.3 Freewheel clutch

Freewheel clutch sluggish or jammed



Pinion with freewheel clutch overheated, rolling element cage melted

Findings:

- Freewheel clutch is jammed
- Significant wear marks on the front and back of the pinion tooth flanks
- Heavy contamination in the freewheel clutch
- Grease in the freewheel clutch has become resinous and mixed with dirt and dust

Cause(s):

- Contamination and dust thicken the grease in the clutch. Rolling elements and springs are wedged and jammed.
- Freewheel clutch was thermally overloaded, for example, because the pinion was engaged for too long. As a result, the grease filling has become resinous and the rolling elements and springs are sticky.
- Freewheel clutch was thermally overloaded. As a result, the plastic rolling element cage has melted and bonded with the springs and rolling elements as it cooled down.

Remedies/avoidance:

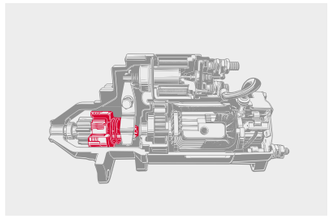
- Replace starter motor.
- Prevent the pinion from running along the ring gear for too long.
- Also install a start-locking relay.
- Clean drive end housing thoroughly.
- Clarify cause of contamination (heavy contamination in the drive end housing may indicate a worn vehicle clutch).

Significant run marks on pinion (front and back)

Freewheel clutch heavily contaminated

4.4 Freewheel clutch

Freewheel clutch no longer frictionally connected I



Housing of freewheel clutch overloaded and cracked

Findings:

- Combustion engine does not turn during the starting process, although the pinion engages and the starter motor turns
- Pinion can be twisted in both directions
- Lock plate of the freewheel clutch is loose or has fallen off
- Rolling elements and springs are completely or partially missing

Cause(s):

- Mechanical overload as a result of engine misfiring.
- Freewheel clutch mechanically overloaded as a result of starting when the engine was coming to a stop.
- If the starter motor is actuated when the engine is coming to a stop, the radial force generated by the rolling elements in the guide tracks can be so large that the housing of the freewheel clutch bursts. As a result, the rolling elements can no longer transfer sufficient force. At the same time, the compressed lock plate is dilated and comes free of the housing. Eventually, the rolling elements and springs fall out.

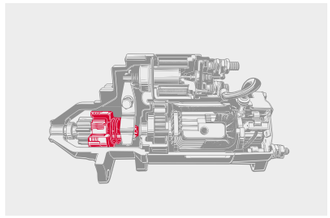
Remedies/avoidance:

- Install new starter motor; check ring gear for wear and replace if necessary.
- Check valve timing and carburetion and correct if necessary.
- After a failed starting attempt, it is very important to wait until the engine has come to a complete stop before attempting to start the engine again.
- Install a start-locking relay with a time delay adjusted to the specific application.
- Check electric actuation of the starter motor (key switch, cables, relay).

Housing of freewheel clutch overloaded and cracked

4.5 Freewheel clutch

Freewheel clutch no longer frictionally connected II



Starter motor and freewheel clutch heavily contaminated

Findings:

- Combustion engine does not turn during every starting process, although the pinion engages and the starter motor turns
- Pinion can be twisted in both directions.
- Heavy contamination in the vicinity of the pinion, freewheel clutch, and helix
- Dust, clutch abrasion particles, oil, and grease form a sticky paste in the vicinity of the pinion, shaft, and freewheel clutch
- Pinion remains engaged for a long time even though the starting process has ended

Cause(s):

- Leaking engine or transmission oil combines with contamination to form a sticky paste. This hinders the axial movement of the pinion on the shaft. The spring of the de-energized solenoid pulls the mechanism back more slowly or not at all. The pinion remains engaged for a long period of time and rotates along the flywheel of the combustion engine.
- The release fork mechanism is sluggish.
- Freewheel clutch is overloaded as a result of the pinion being engaged in the ring gear for a long time.
- Grease leaks from the freewheel clutch as a result of thermal load. From time to time, rolling elements and springs become wedged, jammed, or worn.

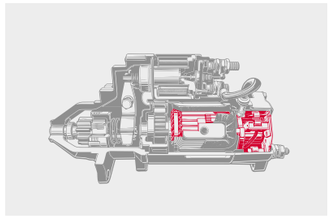
Remedies/avoidance:

- Install new starter motor; check ring gear for wear and replace if necessary.
- Locate and rectify cause of oil leakage (shaft seal rings on engine and transmission, crankcase ventilation on engine clogged).
- Clean drive end housing thoroughly.
- Clarify cause of contamination (heavy contamination in the drive end housing may indicate a worn vehicle clutch).

Freewheel clutch and helix heavily contaminated

5.1 Starter motor

Starter motor spun out of control I



Rear bearing cap opposite the flange twisted

View into the drain hole

Rear bearing cap broken; rotor and commutator spun out of control

Commutator has started to break apart

Findings:

- Rear bearing cap on the front flange of the starter motor twisted (can be easily identified by the two housing screws)
- View through the bore of the drainage tube: fibers and destroyed components visible inside the starter motor
- Rear bearing cap destroyed
- Fiberglass ring to reinforce the armature windings has been destroyed (rear bearing cap is full of glass fibers)
- Some copper elements of the commutator have come free of the assembly; brushes are heavily worn
- Commutator has broken down into its individual components
- Brush holders and carbons have been crushed
- If the starter motor is shaken, rattling noises can be heard in the rear section

Cause(s):

- Overspeeds on the starter motor armature due to damage to the freewheel clutch. If the freewheel clutch is jammed and the engine goes from the starting speed to idle speed, the starter motor speed also increases tenfold. If the combustion engine is then brought to operating speed, the armature speeds increase to well over 100,000 rpm (instead of 5,000 rpm). This creates such strong centrifugal forces that the armature and commutator are broken down into their individual components.
- Freewheel clutch jammed. Mechanical damage due to starting when the engine was coming to a stop.
- Freewheel clutch jammed. Mechanical damage due to the pinion running along the ring gear for too long.
- Heavy contamination in the vicinity of the pinion and shaft.

Remedies/avoidance:

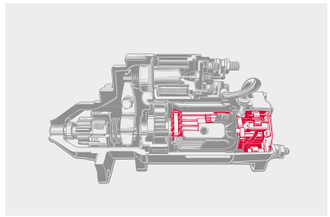
- Install new starter motor; check ring gear for wear and replace if necessary.
- After a failed starting attempt, it is very important to wait until the engine has come to a complete stop before attempting to start the engine again.
- Check electric actuation of the starter motor (key switch, cables, relay).
- Ensure that the starter motor is only actuated for a short period of time. It is advisable to engage the starter motor for no more than 30 seconds and to then let it cool for 2 minutes.
- Install a start-locking relay to prevent inadvertent actuation of the starter motor.

Armature winding and fiberglass ring of the armature spun out of control; commutator and brushes destroyed

New starter motor for comparison

5.2 Starter motor

Starter motor spun out of control II



Rear bearing cap of the starter motor broken as a result of spinning out of control and melted after coming into contact with the brush

Brush holder destroyed as a result of the armature spinning out of control (overspeed)

Commutator totally destroyed (extreme overspeed)

Rear bearing cap of the starter motor melted after coming into contact with brush

Findings:

- Rear bearing cap on the front flange twisted (can be easily identified by the two inclined housing screws)
- Melted areas on the bearing cap as a result of arcing (short circuit between brushes and bearing cap)
- Fiberglass ring to reinforce the armature windings has been destroyed (rear bearing cap is full of glass fibers)
- Brush holders and carbons have been crushed
- Commutator has broken down into its individual components
- Rear bearing cap destroyed
- Armature windings heavily thermally discolored
- Heavy thermal discoloration on the commutator
- Overspeeds on the starter motor armature due to damage to the freewheel clutch.
- Freewheel clutch jammed. Mechanical damage due to starting when the engine was coming to a stop.
- Freewheel clutch jammed. Mechanical damage due to an excessively long starting process.
- At the time of the overspeeds resulting in damage, the starter motor was still being supplied with current. As a result, there may have been a short circuit between the brush holder and housing cover.

Cause(s):

- Defect on the key switch or supply line, resulting in the starter motor being permanently supplied with current.

Remedies/avoidance:

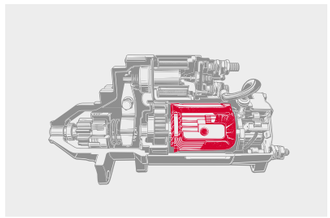
- Install new starter motor; check ring gear for wear and replace if necessary.
- Check electric actuation of the starter motor (key switch, cables, relay).
- Ensure that the starter motor is only actuated for a short period of time.

It is advisable to engage the starter motor for no more than 30 seconds and to then let it cool for 2 minutes.

- Use the starter motor with the output indicated in the manufacturer specifications.
- Check whether the engine and all connected units can be turned easily.
- Install a start-locking relay to prevent inadvertent and excessively long actuation of the starter motor.

Rear bearing cap opposite the flange twisted

6. Pole windings and armature burnt



Brown discoloration on the pole winding insulation (pole windings overheated)

Findings:

- Pole winding insulation burnt or shows a dark discoloration
- Armature discolored (annealing colors)
- Enamel insulation of the copper windings in the armature burnt or shows a dark discoloration
- Commutator thermally discolored
- Burning marks on the surface of the commutator

Cause(s):

- Starter motor actuated for too long (starting problems, improper ventilation of the fuel system).
- No or far too little rotation of the starter motor during the starting process (engine jammed or sluggish).
- Vehicle was moved using the starter motor.
- With excessive power takeoff at the starter motor, the starter motor speeds fall, while the current consumption of the starter motor increases to several times its normal value. This results in extreme heat being generated within the component.
- Damage process: starter motor overheats, enamel insulation burnt, short circuit in the windings, and short circuit to ground.

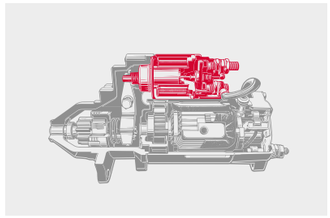
Remedies/avoidance:

- Replace starter motor.
- Clarify and eliminate the cause of the sluggishness of the combustion engine and connected units.
- Check whether key switch, relay, and cables were also affected.
- Ensure that the starter motor is only operated for a short period of time. It is advisable to engage the starter motor for no more than 30 seconds and to then let it cool for 2 minutes. After the third unsuccessful attempt at starting, the starter motor requires a cooling period of 30 minutes.
- Only use the starter motor to move the vehicle in an emergency (e.g., if the vehicle is stuck on a crossing).
- After changing the fuel filter, do not bleed the system by running the starter motor for a long time; instead, bleed the system with a pump to ensure that all bubbles are removed.

Starter motor armature thermally overloaded (discoloration)

Burning marks on the commutator of the starter motor

7. Corrosion in the starter motor



Findings:

- Solenoid is not being energized
- Solenoid is energized but the main current for the starter motor is not applied
- Reduced starter motor speed
- Insufficient starter motor output
- Corrosion in the solenoid, in the retaining spring and plunger, and on the contact bridge
- Corrosion in the starter motor (armature, commutator, brush holder, etc.)
- Drain hose is missing or defective

Cause(s):

- Starter motor was under water. (Starter motors are only splash-proof!)
- Starter motor was actuated under water. Movement of the solenoid and pinion causes a pump movement.
- Starter motor installed in the wrong direction (drain hose facing up).
- Water ingress as a result of the engine being cleaned incorrectly with a high-pressure cleaner.
- Damage to starter motor gaskets.

Remedies/avoidance:

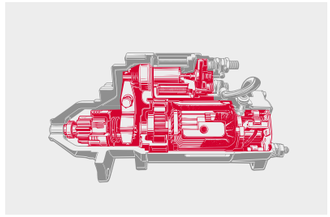
- Replace starter motor.
- When cleaning the vehicle or engine, do not direct the water jet straight onto electric components.
- Ensure that the correct installation orientation is observed (drain hoses must always point downward).
- Ensure that the drain hose is seated properly.
- Avoid driving through deep pools of water.
- Never start the engine if the starter motor is below the water line.
- If the starter motor fails sporadically, install a new starter motor.

Corrosion on the solenoid

Corrosion on the starter motor

Corrosion inside the starter motor

8. Fuel or oil in the starter motor



Abrasion particles from the carbon brushes on the commutator

Findings:

- Insufficient starter motor output
- Reduced starter motor speed
- Bridged copper segments of the commutator (carbon dust)
- Burning marks and discoloration on the commutator
- Brushes soaked with fuel or oil
- Abrasion particles from the carbon brushes are visibly adhered to the sides of the brushes and brush holders
- Despite a low mileage, carbon brushes are very heavily worn

Cause(s):

- Ingress of fuel or engine oil in the starter motor
- Brushes are saturated with fuel or oil, leading to increased brush sparking and heavy abrasion
- Abrasion becomes paste-like (rather than dusty) and causes bridges and short circuits in the commutator
- Abrasion becomes paste-like (rather than dusty) and can cause a short circuit to ground at the brush holders
- Leaks in the fuel filters and lines
- Oil loss in the engine or transmission
- Oil loss in the hydraulic system

Remedies/avoidance:

- Replace starter motor.
- Locate and repair leaks in the engine.
- Clean engine and transmission thoroughly.
- Check hydraulic pump, lines, and cylinders and replace or seal.

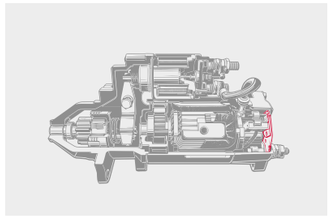
Oil in the starter motor

Sticky abrasion particles from the carbon brushes all around the brushes

Mixture of oil and graphite dust in the bearing cap

9. Malfunctioning of the starter motor

Direct drive starter motor (without reduction gear)



Support plate in the bearing cap heavily tarnished

Findings:

- Combustion engine does not start
- Starter motor turns too slowly
- Starter motor turns sluggishly
- Grease escaping at the protection cap on the rear bearing cap
- Axial bearing disc on the rear bearing cap jammed
- Significant grinding marks on the front face of the commutator
- Significant grinding marks on the rear bearing cap

Cause(s):

- The battery installed was too powerful.
- An additional battery was subsequently installed in the vehicle.
- Connection cable from battery to starter was replaced by a cable that was too large.
- Support plate wedged
- Wear marks on the support plate and washer
- Large burr/ridge on the shaft groove

- The consequences:
  Solenoid disengages the pinion too forcefully.
  If the pinion hits the stop ring too powerfully, the shaft and commutator are pulled out of the armature piece by piece.
  Axial bearing disc at the back end of the shaft is wedged and inhibits the starter motor.

Remedies/avoidance:

- Replace starter motor.
- Use starter battery in accordance with the engine manufacturer's instructions.
- Never use a starter battery that is too powerful.
- Use a cross section of the connection cable in accordance with the specification.
- If possible, replace the direct drive starter motor with a starter motor with reduction gear. In a starter motor of this type, the pinion shaft and armature shaft are separated mechanically by the reduction gear.

Support plate in the bearing cap heavily tarnished

Support plate in the bearing cap heavily tarnished

Glossary

Term	Explanation
Armature	Rotor of the starter motor.
Bearing cap	Rear cover of the starter motor. This cap contains the starter shaft and protects the starter motor against ingress of dust and liquids.
Burning marks	Melting of metallic components due to arcing.
Carbon brush	Transfers the currents to the sliding contacts (commutator) of the rotating armature.
Commutator	Sliding contacts on the armature that conduct the current from the carbon brushes to the corresponding armature windings (coils).
Contact bridge	Electrical switch in the solenoid. As very high working currents of several hundred amps need to be conducted in the starter motor, the contact bridge consists of a thick copper plate.
Current consumption	The amount of current that a starter motor takes from the battery. The current consumption is dependent on the required torque, starter motor speed, and capacity of the battery.
Direct drive starter motor	Starter motor without reduction gear—the shaft is made from one continuous piece.
Dust-proof	Design that does not allow any contaminants to enter the starter motor in very dusty environments.
Dust-protected	Design that allows very few contaminants to enter the starter motor in dusty environments.
Enamel insulation	Insulation made of synthetic resin for copper wires. Copper wires for coils usually come with enamel insulation. As the insulation is very thin, more windings can be fitted into a small installation space.
Engaging	The pinion teeth mesh with the teeth of the ring gear.
Engaging lever	Rotatable lever via which the solenoid moves the pinion into engagement with the ring gear of the flywheel.
Fiberglass ring	The copper coils in the armature are also fixed in place using a ring made of glass fiber-reinforced plastic. The fiberglass ring prevents the windings from being flung out of the armature by centrifugal forces.
Flange	Special starter motor design in which the pinion shaft is additionally fastened and mounted on the front end.
Flywheel	The flywheel (also known as the flywheel mass) is used to store the rotational energy of the combustion engine. The flywheel compensates for the uneven acceleration of the crankshaft. The ring gear, via which the starter motor starts the engine, is fastened to the flywheel.
Freewheel clutch	The starter motor drives the pinion using a frictional connection. As soon as the engine reaches the point of self-sustained operation, the engine speeds increase. The freewheel clutch interrupts the transmission of power in a backward direction from the engine to the starter motor.
Ground terminal	The starter motor is generally grounded via the housing. In some applications (e.g., boat engines), the starter motor has a separate ground terminal.
Helix	Helix thread on the pinion shaft. Its task is to cause the pinion to rotate slightly when it engages, allowing it to engage more easily. This prevents “tooth-to-tooth” positioning as far as possible.
Hold-in winding	Coil in the solenoid that pulls the plunger into the solenoid during the starting process and holds it there throughout the process.
Ignition switch	The ignition switch is used to actuate the starter motor at terminal 50 on the solenoid.
Indicator band	A special paper band wound around the coils of the solenoid. If the solenoid is thermally overloaded (actuated for too long), the indicator band becomes discolored. This makes it possible to verify that overloading has occurred.
Meshing spring	The pinion is flexibly mounted with the meshing spring. This acts as a protection in case the pinion and ring gear are positioned tooth to tooth.
Mounting flange	Front housing with which the starter motor is fastened to the combustion engine or transmission.

Glossary

Term	Explanation
Operating time	A starter motor is designed to be actuated for a maximum of 30 seconds per start. If actuated for longer, there is a risk of overheating.
Permanent magnet	Most starter motors have electromagnetic coils that form a stator. In some applications, permanent magnets are installed in the stator housing instead of coils.
Pinion	The pinion is a small gear wheel on the starter motor. During the starting process, it engages in the ring gear of the combustion engine and turns it.
Plunger	The plunger is the iron core of the solenoid. When the solenoid coils are supplied with current, the iron core moves both the pinion and the spring-mounted contact bridge via the engaging lever.
Pole winding	Electromagnetic coils in the stator housing of the starter motor.
Power output	In the case of direct current, the real power P is the product of the voltage U and the current I.
Pull-in winding	Coil in the solenoid that pulls the plunger into the solenoid during the starting process.
Reduction gear	The reduction gear (planetary gear) reduces the pinion speed, increasing the torque accordingly. Thanks to the transmission ratio, the starter motor has a smaller design than a direct drive starter motor, with the same power output.
Relay	Electromagnetic switch that can turn large working currents on or off using small control currents.
Ring gear	The ring gear is part of the flywheel. During the starting process, the pinion engages in the ring gear.
Sealed noseless starter motor	Starter motor without a flange. The starter shaft is not countersupported at the front.
Self-sustaining speed	The speed necessary to bring a combustion engine to the point of self-sustained operation. Generally, it is approximately one tenth of the idle-running speed.
Solenoid	Electromagnet that moves the pinion into engagement with the ring gear during the starting process and then energizes the starter motor.
Start-locking relay	A relay that prevents the starting process from being initiated when the combustion engine is running.
Starter motor performance curve	Performance curve (torque, rotational speed) and current consumption of a starter motor.
Starter motor with flange	Starter motor design in which the pinion shaft is additionally fastened and mounted on the front end.
Stop ring	Metal ring at the front end of the starter shaft, designed to restrict the pinion’s path of contact.
Torque of copper bolt	M8: 10 Nm ±2 Nm, M10: 15 Nm ±3 Nm, M12: 21 Nm ±3 Nm
Transport damage	External damage to the component caused by improper handling.
Water drain	On the bearing cap, there is a bore at the lowest position (ensure correct installation position). If condensation water collects in the starter motor, it can drain here.
Water drain, drain hose	To prevent the water spray from getting into the starter motor via the water drain, the drain hose bends when water is spraying out.

Our product portfolio

Engine components

Quality built to last—precise fit and long life

- Pistons
- Piston rings
- Cylinder liners
- Bearings
- Valve train components
- Cylinder kits
- Turbocharger & retrofit/special kits

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

Engine cooling & A/C

Comfort you can feel—now and in the future

- Radiators, charge air coolers
- Fans & clutches, condenser/radiator fans
- Expansion tanks, cabin heat exchangers
- Exhaust gas recirculation coolers, oil coolers
- Water pumps & kits
- Thermostats, thermal switches
- A/C compressors, A/C condensers
- Filter-driers & accumulators, A/C compressor oils
- Evaporators, expansion valves, orifice tubes
- Interior blowers, A/C switches
- A/C blower control units & resistors, electric control for blending flap
- 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
- **OzonePRO** professional hygienic cleaning
- **EmissionPRO®** emissions testing measuring instrument
- **LogiqPRO®** software tool

Our information services

- **Technical Messenger**
  Valuable technical information and the latest tips on all aspects of the maintenance and repair of MAHLE products (see under “Services” on our website)
- **Technical posters**
- **Damage brochures**
- **Installation videos and animations**
- **A/C refrigerant charge and A/C compressor oil filling quantities manual**
- **MPULSE customer magazine**

- **CustomerCare Portal**
  customercare.mahle-aftermarket.com
- **Website**
  www.mahle-aftermarket.com
- **Online catalog**
  catalog.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**