



Alternators

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

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Design and function of an alternator

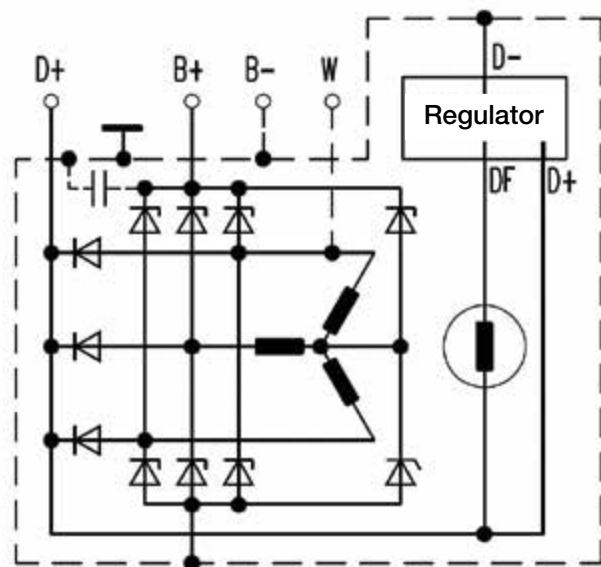
Many of the functions in a vehicle require electrical power. When the combustion engine is running, this is generated by the alternator. In contrast, the car battery serves as a power store and buffer.

The construction of the alternator must be designed to ensure that sufficient power is available for all electric components that are operated over a long period of time. It is also important to take into account the customary engine speeds.

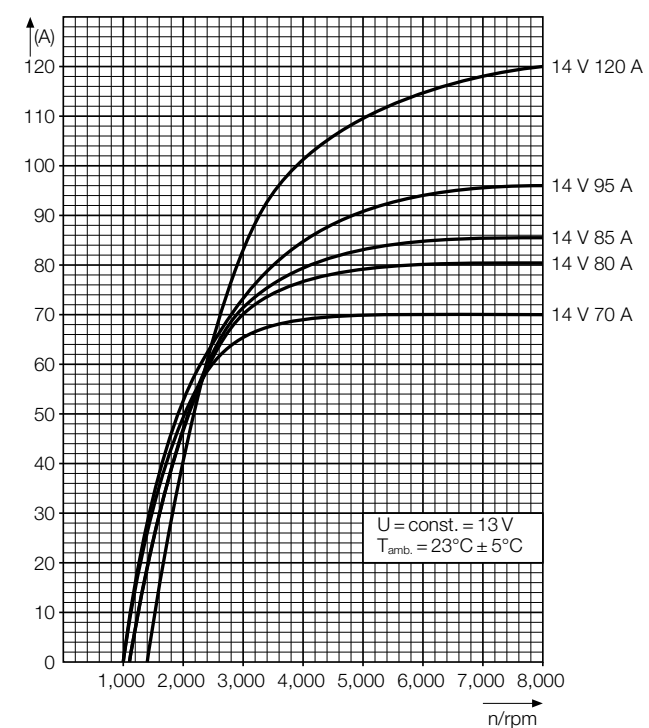
The alternator is usually driven by the vehicle engine via a belt. In the alternator, the turning of the rotor in the stationary stator generates electrical current inductively. Most alternators are three-phase alternating current generators.

A bridge rectifier with high-power diodes is used to convert the alternating current. The exciter coil in the rotor receives the necessary power from the regulator, depending on the vehicle's current power requirements. The regulator supplies the rotor via carbon brushes that press against the slip rings on the rotor.

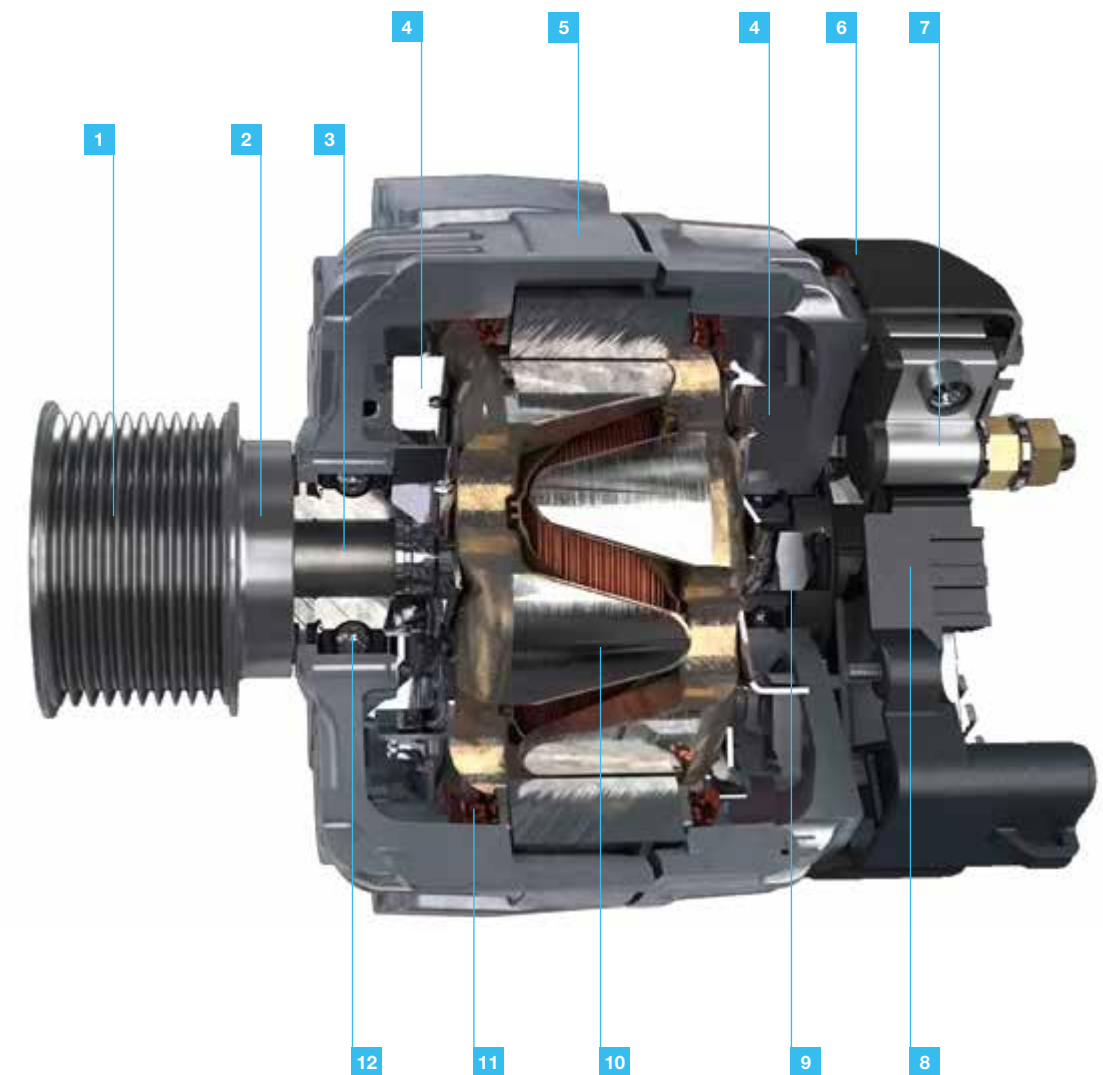
As a result of electromagnetic losses and the electrical resistances of the components, heat is generated in the alternator in addition to electrical output. Depending on the design, one or two fans are therefore installed on the rotor shaft to dissipate heat.



Example connection diagram



Alternator characteristic curves

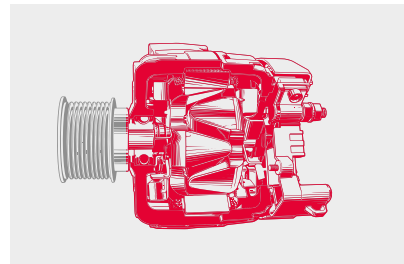


- 1 Belt pulley
- 2 Distance washer
- 3 Shaft
- 4 Fan
- 5 Housing
- 6 Protective cover

- 7 Rectifier/excitation diodes
- 8 Regulator/carbon brushes/slip rings
- 9 Rear bearing
- 10 Rotor
- 11 Stator
- 12 Front bearing

1.1 Ingress of liquid

In the alternator



Very oily slip rings



Oily regulator



Very oily alternator



Very oily alternator

Findings:

- Alternator oily on the outside (engine/hydraulic oil or diesel fuel)
- Alternator provides little or no output
- Increased brush wear
- Heavily worn slip rings

- Brush abrasion as a paste in the vicinity of the regulator

- Brush holder charred

Cause(s):

- Ingress of liquid in the alternator (engine/hydraulic oil or diesel fuel)

- Leak in the engine, hydraulic system, or fuel system

- Alternator contaminated during filter change

- Contamination occurred when filling the engine with oil

- Thermal overload of the alternator, grease leak from the alternator bearings

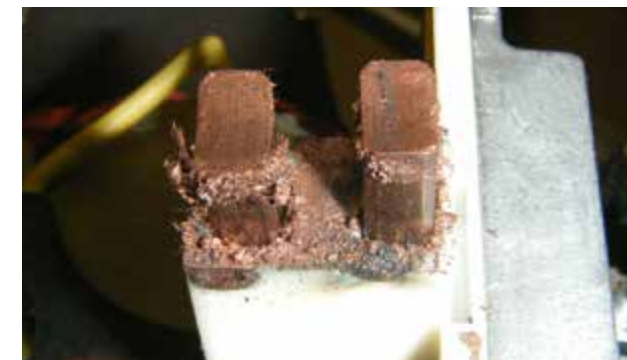
Remedies/avoidance:

- Replace alternator.
- Find and remedy cause of leaks in the oil, hydraulic, or fuel system.
- In the case of heavy exposure to dust and dirt: clean air inlet, fan, and alternator regularly.
- Connected electric components must match the alternator output voltage. If additional electric components are connected, choose an alternator that is identical in construction but with a higher output level, if required.



Caution!

If there is leakage oil in the engine compartment, do not use flammable liquids to clean the alternator: this poses a fire hazard!



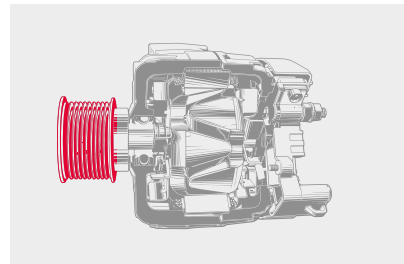
Oily regulator with sticky carbon abrasion



Oil in the alternator

2.1 Assembly errors

Belt pulley I



Thread on generator shaft heavily damaged

Findings:

- Thread of shaft damaged/torn off

Cause(s):

- Belt pulley nut tightened with an excessively high tightening torque (shaft overloaded at thread)
- Belt pulley nut tightened in an uncontrolled manner with an impact wrench

Remedies/avoidance:

- Replace alternator.
- Fasten shaft with a suitable hex key or polygon head wrench.
- Tighten belt pulley nut with the prescribed torque:
M16 × 1.5: 95 Nm ± 5 Nm,
M27 × 1.5: 152 Nm ± 17.5 Nm



Caution!

Never use an impact wrench to tighten the belt pulley nut. An impact wrench may only be used to loosen the nut. Before adjusting the nut, check the direction of rotation!



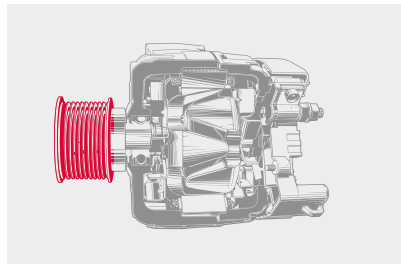
Remnants of the torn-off shaft in the nut



Generator shaft torn off as a result of an excessively high tightening torque (impact wrench)

2.2 Assembly errors

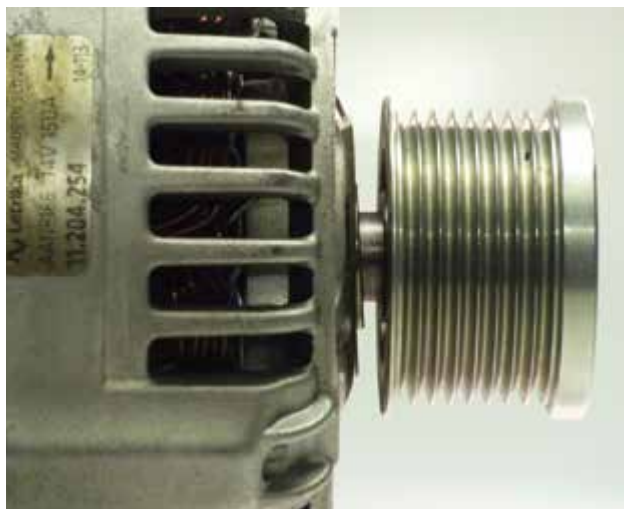
Belt pulley II



Clearly visible wear of the shaft in the vicinity of the ball bearing (nut was loose). As a result of the increased play, the rotor has ground against the stator.



Clearly visible wear of the shaft in the vicinity of the bearing (nut was loose).



Overrunning alternator pulley assembled without distance washer



Alternator with overrunning alternator pulley assembled by customer

Findings:

- Alternator provides no output after a certain mileage
- Noise in the alternator
- Battery charge indicator lights up
- Belt pulley loose
- Traces of wear on the belt pulley
- Thread on the shaft heavily worn/abraded
- Rotor has significant radial clearance on the belt pulley side

- Shaft heavily worn in the vicinity of the front ball bearing
- Rotor has touched the stator
- Grinding marks on the rotor
- Some of the stator laminations have shifted circumferentially, causing a short circuit in the windings

Cause(s):

- Nut was not fastened tightly enough on the shaft. As a result, the belt pulley was loose and was spinning on the shaft.

- The mechanic screwed the over-running alternator pulley onto the shaft without the necessary distance washers. As a result, the inner ring of the roller bearing was not fastened tightly enough to the shaft. The shaft rotated in the inner bearing ring, causing it to become worn. Because of the increased play between the bearing ring and shaft, the rotor was not guided cleanly and was grinding against the stator. The laminations in the stator were displaced from one another, causing short circuits in the windings.

Remedies/avoidance:

- Replace alternator.
- Fasten shaft with a suitable hex key or polygon head wrench.
- When assembling a belt pulley, place the appropriate distance washers underneath.
- Tighten belt pulley nut with the prescribed torque:
M16 × 1.5: 95 Nm ± 5 Nm,
M27 × 1.5: 152 Nm ± 17.5 Nm



Grinding marks on the stator caused by the rotor as a result of shaft wear



Shaft end heavily worn by belt pulley (nut was loose)



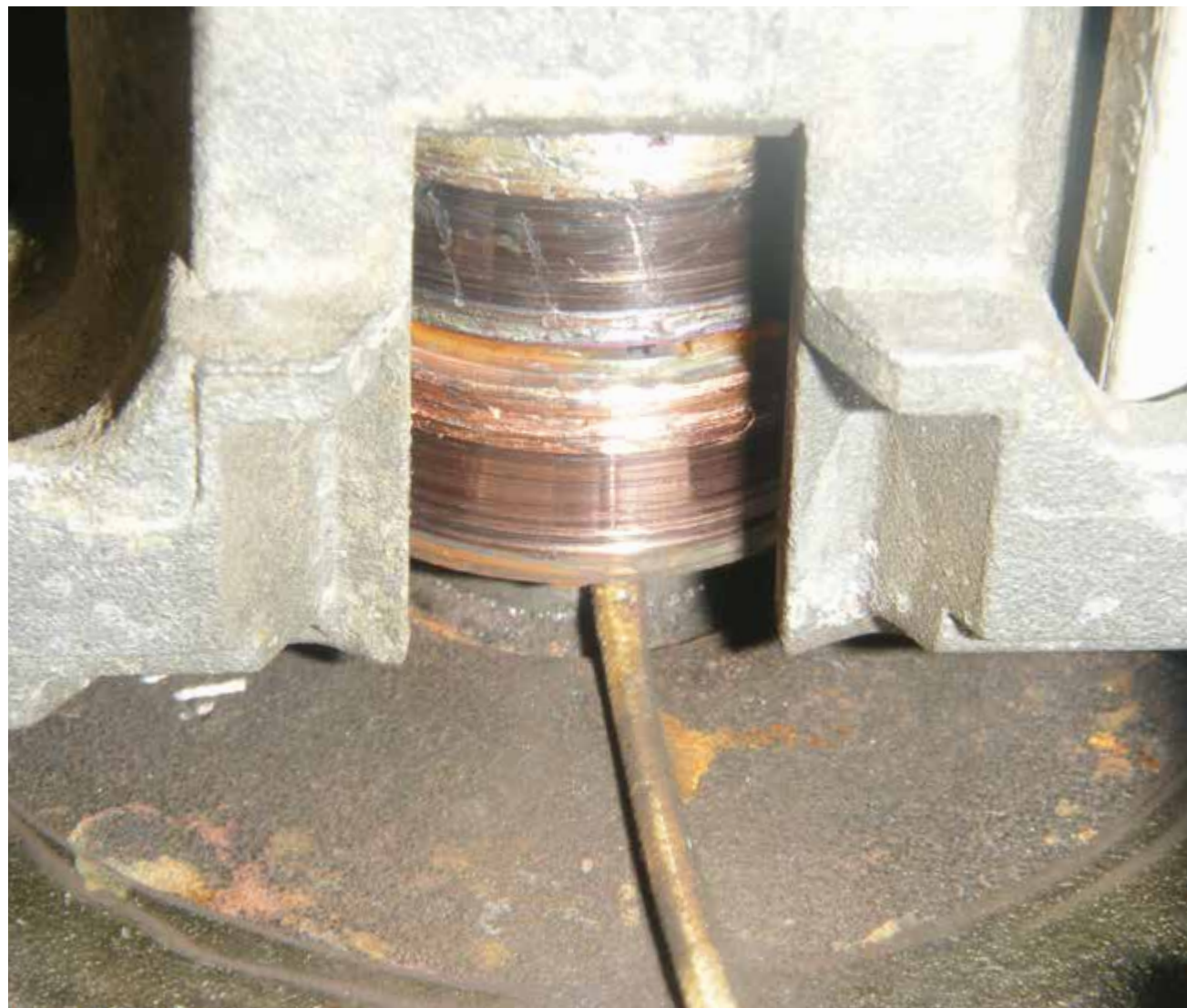
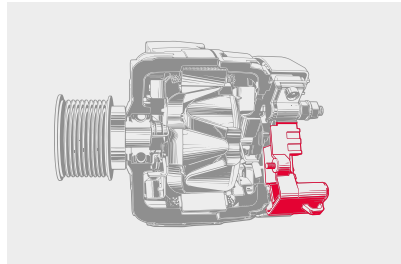
Shaft end heavily worn by belt pulley (nut was loose)



Shaft heavily worn in the vicinity of the front ball bearing (nut was loose)

2.3 Assembly errors

Regulator



Slip rings damaged by broken carbon

Findings:

- Immediately or a short time after a new regulator is installed: battery charge indicator lights up (no output)
- Immediately after a new regulator is installed: low alternator output
- Coarse fracture structure on carbon (forced rupture), some light run marks from the slip ring in the center of the broken carbon

- Score marks and burning marks on a slip ring

Cause(s):

- When the regulator is dismantled or assembled: carbon has caught and broken off
- Broken carbon transmits only a low excitation current: alternator provides little or no output

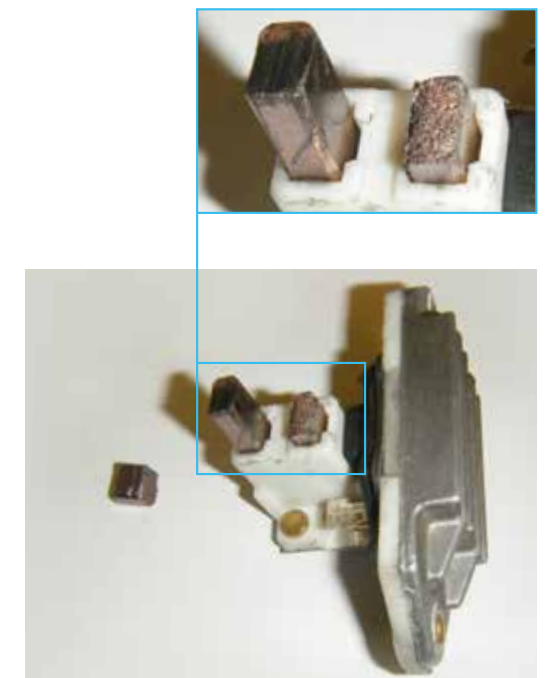
- Because the contact surface of the broken-off carbon is too small and there is too little contact pressure: heavy sparking occurs on the affected slip ring

Remedies/avoidance:

- Replace alternator.
- When dismantling or assembling the regulator, press carbons against the spring force into the regulator to prevent the carbons from catching.
- If the carbons catch, do not use force.



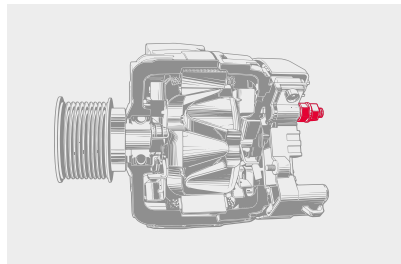
Carbon broken off during dismantling/assembly of the regulator



Carbon broken off during dismantling/assembly of the regulator

2.4 Assembly errors

Electrical connection



Nut not fastened tightly at connection B+



Burning marks on washers and nuts



Cable grip with burning marks

Findings:

- Vehicle battery not sufficiently charged
- Nut of connection B+ loose
- Terminal stud B+ thermally discolored
- Terminal stud B+ partially burned
- Nut and washer show burning marks and melting

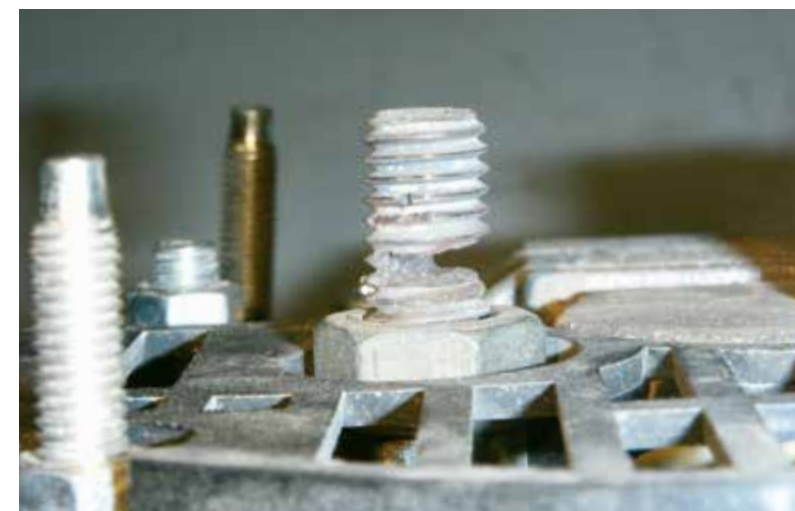
Cause(s):

- Nut not fastened tightly enough at B+
- Connection cable not fastened according to manufacturer specifications; freely swinging cables can lead to loosening of the nut

- If nuts are not correctly tightened or become loose, contact resistances will lead to increased component temperatures and electric arcs resulting from the charging currents

Remedies/avoidance:

- Replace alternator.
- Examine connection cable and cable grip for damage and replace if necessary.
- Fasten connection cable according to the vehicle manufacturer specifications in order to prevent the cable from swinging freely.
- Tighten nut with the correct torque:
 - M5: 3.3 Nm \pm 0.6 Nm
 - M6: 5.1 Nm \pm 0.9 Nm
 - M8: 11 Nm \pm 2 Nm
 - M10: 11.8 Nm \pm 2.3 Nm



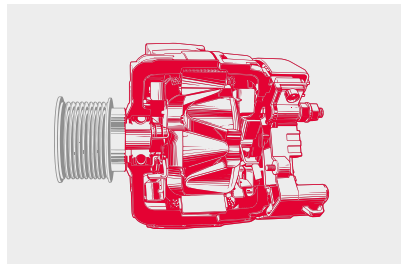
Burnt connection B+



(enlarged)

3.1 Contamination

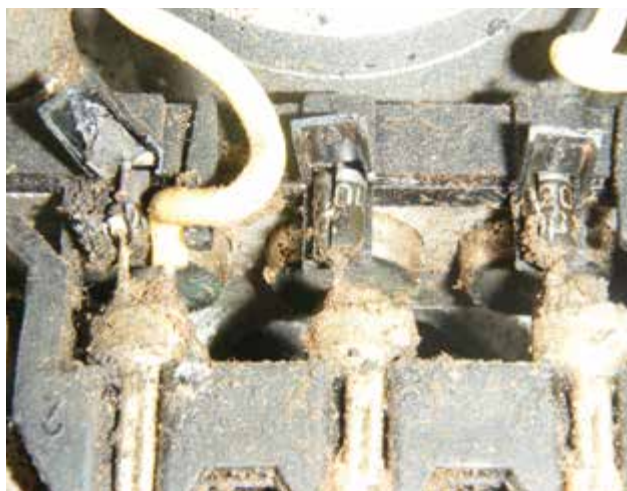
Heavy contamination in the alternator



Badly clogged alternator



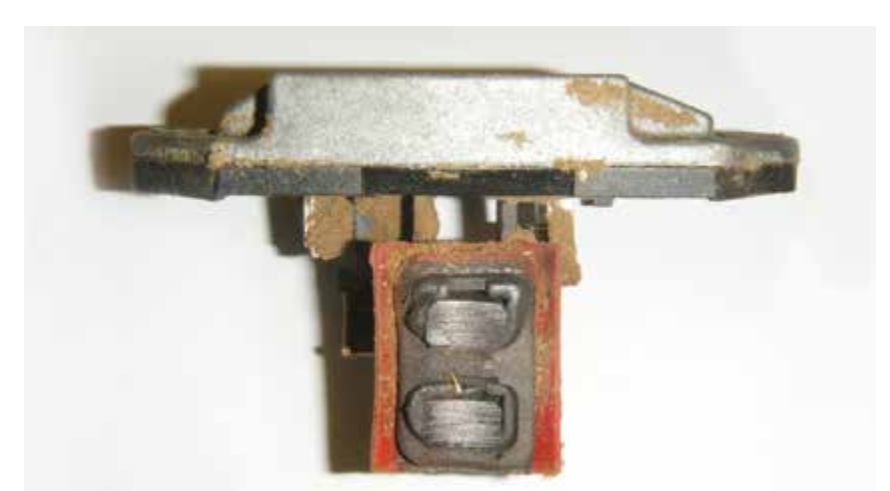
Dirt in the stator windings



Badly clogged rectifier and excitation diodes



Discolorations and score marks resulting from dirt on the slip rings of the alternator



Heavy contamination on the regulator Carbon overheated and blocked in the melted guide

Findings:

- Alternator provides insufficient or no output
- Alternator is making noises
- Ball bearing is running rough
- Insulation on the copper windings and cables in the alternator are thermally discolored
- Carbon brushes and slip rings are heavily worn for the mileage

- Alternator is heavily contaminated on the outside
- Heavy contamination and incrustations, including on the inside of the alternator
- Diodes are damaged

Cause(s):

- Heavy contamination from dust or contaminants from the environment

- Alternator is contaminated with liquids (oils, fuel, coolant, leaked bearing grease), which also means increased adhesion of dust
- Reduced heat dissipation as a result of adhesion of dust and contaminants: thermal overload and damage to the components in the alternator
- Thermal overload of the ball bearing: reduced load-bearing capacity of the lubricating film; leaking grease can damage the ball tracks

Remedies/avoidance:

- Replace alternator.
- In the case of heavy accumulation of dirt during operation: clean alternator and engine compartment thoroughly at appropriately short intervals.
- In the case of contamination from liquids: determine cause and remedy leaks.

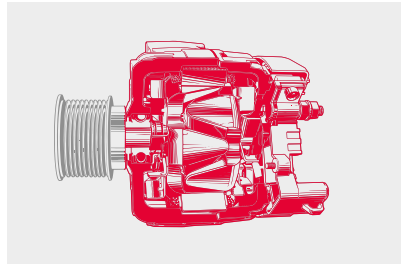


Caution!

If there is leakage oil in the engine compartment, do not use flammable liquids to clean the alternator: this poses a fire hazard!

4.1 Mechanics

Mechanical damage to the alternator



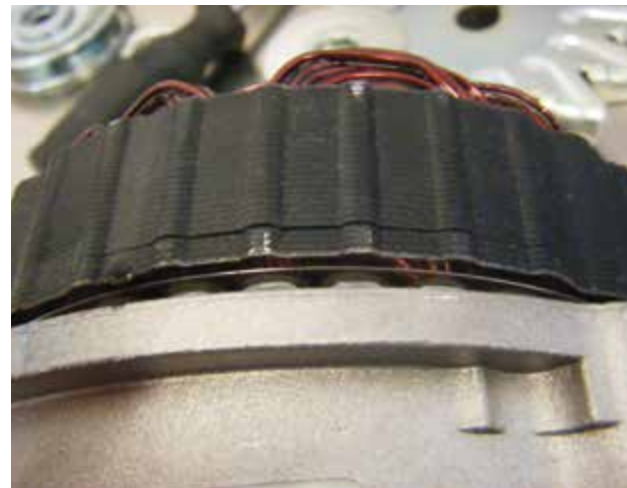
Alternator housing cover broken



Mechanical damage to the power diode and plastic holder



Laminations inside the stator displaced



Deformation (dent) in the stator (e.g., due to alternator being dropped)

Findings:

- No function
- Damage to plastic cover
- Bent electrical connections
- Electrical connections broken off
- Defective parts and components inside a damaged plastic cover

- Alternator provides little or no output or voltage
- Regulator housing broken
- Grinding noises when the belt pulley is rotated manually
- Alternator doesn't run smoothly
- Alternator is blocked

Cause(s):

- Alternator was damaged during transport
- Alternator was dropped during installation
- Alternator has knocked against other components in the engine compartment

Remedies/avoidance:

- Do not throw or drop the alternator.
- Always check the packaging and alternator for damage prior to fitting.
- Rotate alternator shaft manually and check for noises or stiffness.
- If the alternator is damaged, do not install it; otherwise, follow-up costs may be incurred.
- When fitting the alternator, avoid knocking it against other components in the engine compartment.
- When fitting the alternator, secure it initially with at least one bolt so that it cannot fall during installation.



Condenser connection broken off (e.g., as a result of alternator being dropped)



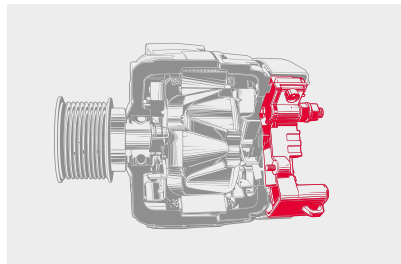
Regulator housing deformed and cracked (mechanical overload)



Housing cracked as a result of mechanical overload

5.1 Function

No alternator function (defective excitation diodes)



Traces of arcing on alternator housing



Burnt excitation diode (short circuit)



Burning marks on alternator housing due to short circuit



Live wire causes short circuit in regulator

Findings:

- Alternator provides no output
- Battery charge indicator lights up
- Excitation diodes melted and/or cracked
- Melting and erosion marks resulting from electrical sparking on the regulator housing, alternator, or connections

Cause(s):

- Short circuit in the cable connection
- Connection polarity reversed
- Short circuit with other components in the engine compartment
- Short circuit with tools
- Battery disconnected while engine is running

Remedies/avoidance:

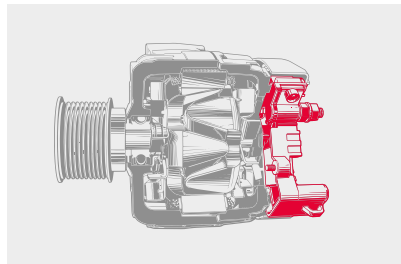
- Replace alternator.
- Always disconnect the battery before working on the alternator.
- Ensure connection cables have correct polarity.
- Before working on a car body using electric welding equipment, always disconnect the battery.
- Disconnect the battery when connecting fast charger.
- Always ensure correct polarity when using starting aids.
- Never disconnect the battery while the engine is running (overvoltage).



Signs of short circuit on the ground terminal and on the regulator housing

5.2 Function

No alternator function (defective rectifier diodes)



Power diode connection melted as a result of short circuit

Findings:

- Alternator provides insufficient or no output
- Connections on one or more rectifier diodes are burnt
- Rectifier diodes allow no flow in either direction
- Rectifier diodes allow flow in both directions

Cause(s):

- Battery connection polarity reversed
- Reverse polarity at connections B+ and B- on alternator (if B- is designed as a screw connection)
- Fast charging unit incorrectly connected or voltage spikes
- Reverse polarity when using starting aids

- Diodes overloaded by excessive current

Remedies/avoidance:

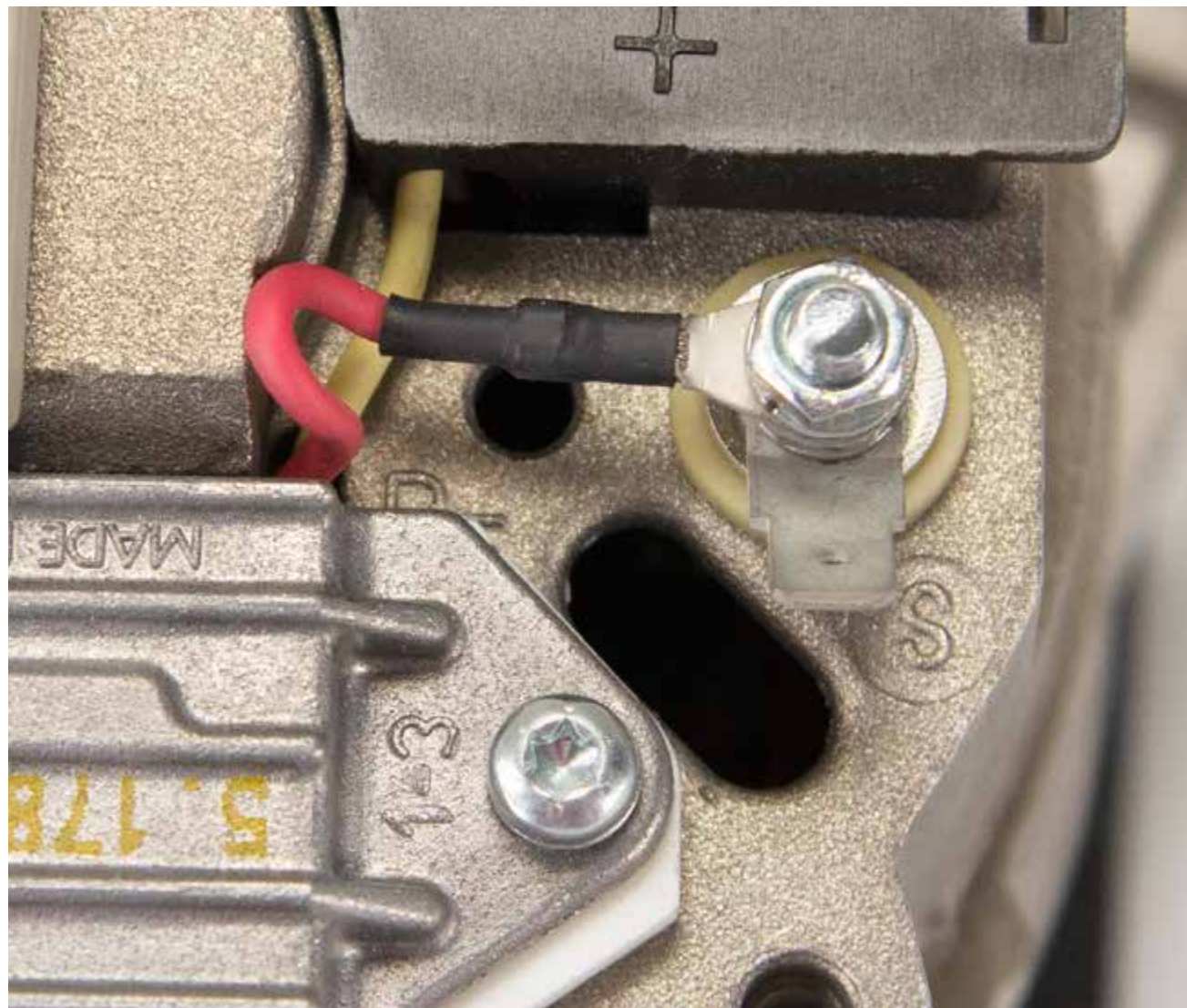
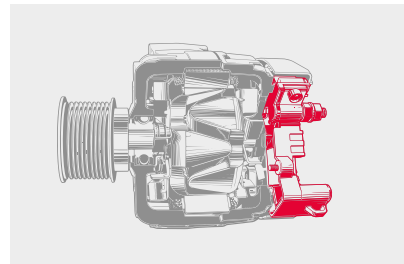
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- Before working on a car body using electric welding equipment, always disconnect the battery.
- Disconnect the battery when connecting fast charger.
- Always ensure correct polarity when using starting aids.
- Never disconnect the battery while the engine is running (overvoltage).



Burnt copper power rail

5.3 Function

No alternator function with connection for battery sensor



Alternator with S terminal for battery sensor

Findings:

- Alternator provides no output
- Battery charge indicator lights up

Cause(s):

- Sensor cable for battery monitoring was not connected to the alternator (S terminal)
- Battery sensor defective
- Break in sensor cable
- Short circuit on sensor cable
- Alternator is not intended for this application

Remedies/avoidance:

In certain applications, a sensor monitors the battery temperature. If the battery temperature is too high, the alternator output is throttled to prevent damage. If the electric resistance value of the sensor is too high or the sensor is not

connected at all, the output of the alternator is reduced to zero by the regulator.

- Connect battery sensor.
- Check battery sensor.

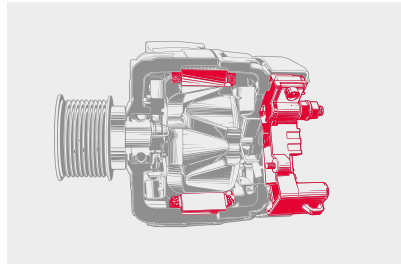
- Check battery sensor cable.
- If there is no battery sensor in the vehicle, install another suitable alternator (correct alternator for vehicle/engine according to MAHLE catalog).



Battery temperature sensor

5.4 Function

No alternator function after a certain mileage



Broken solder joint on alternator as a result of heavy vibrations

Findings:

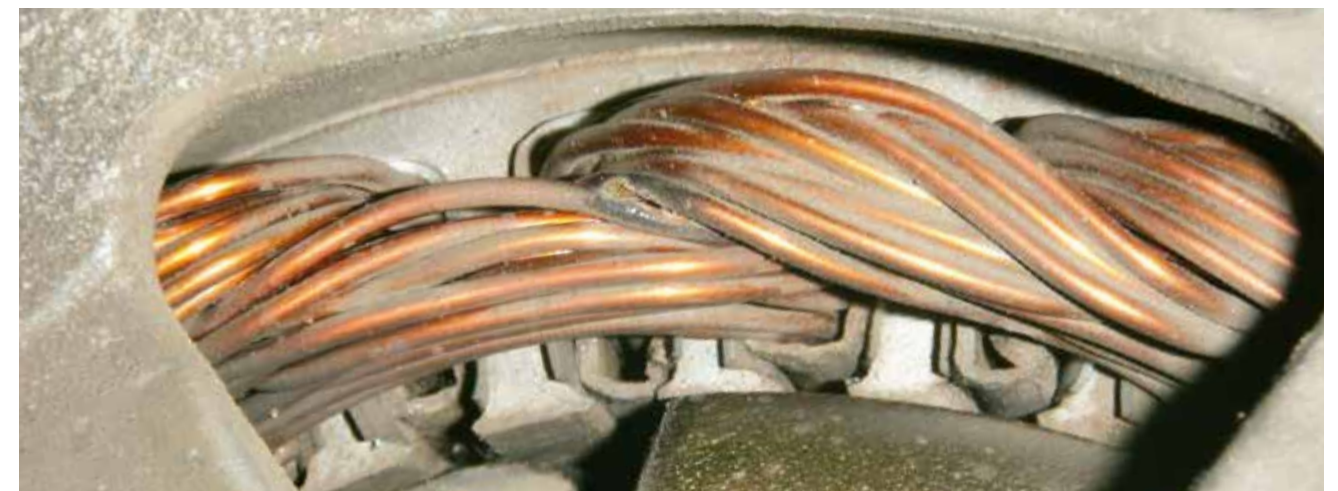
- Battery charge indicator lights up
- Alternator provides no output
- Solder joint cracked inside the alternator
- Cable break inside the alternator
- Short circuit in stator windings

Cause(s):

- Heavy vibrations in alternator due to loose fixing bolt
- Heavy vibrations due to broken alternator mount
- Vibrations throughout the engine due to defective vibration damper or engine mounting
- Heavy vibrations in the engine due to a defect in the injection area
- Defective overrunning alternator pulley also causes heavy vibrations
- Effects of vibrations: solder joints damaged, cable breaks, frayed electrical insulation

Remedies/avoidance:

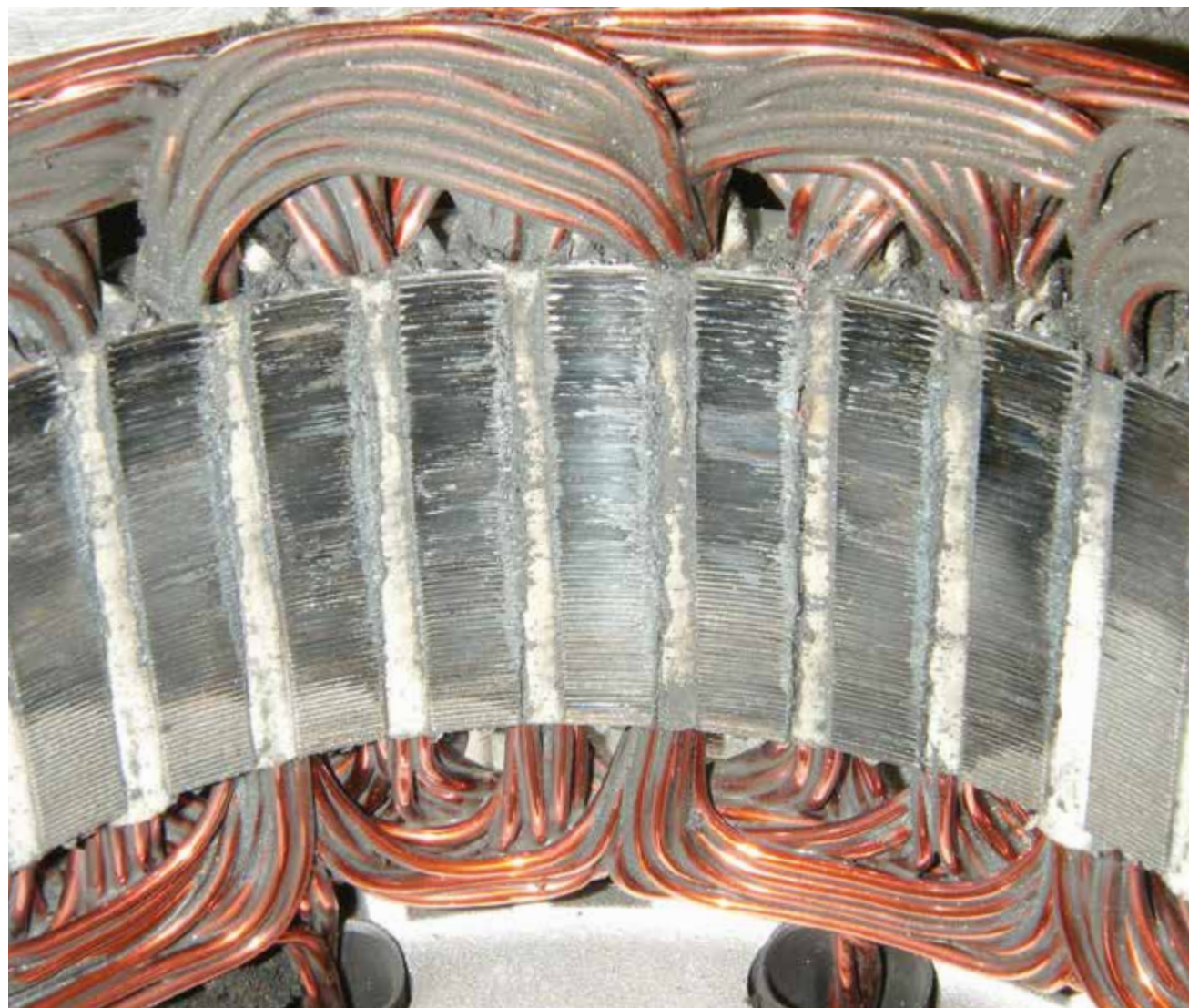
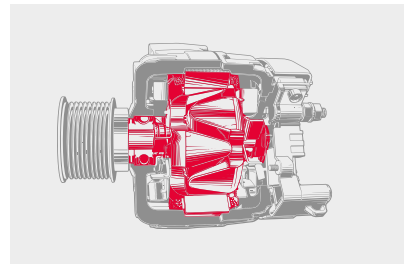
- Replace alternator.
- Always identify and remedy causes of vibrations.
- Check function of overrunning alternator pulley and replace if necessary.



Frayed winding insulation

6.1 Performance

No alternator output, rotor makes grinding noise



Grinding marks on the stator caused by the rotor

Findings:

- Alternator provides no output
- Battery charge indicator lights up
- Alternator makes strange noise during operation
- Rotor shaft has a large radial clearance
- Metallic abrasion inside the alternator
- Rotor makes grinding noise when rotated manually

Cause(s):

- Bearing damage due to excessive belt tension
- Heavy vibrations on the belt tensioner
- Engine running unevenly as a result of defect in injection system
- Bearing damage in the combustion engine
- Water ingress in roller bearing
- Bearing damage due to thermal overload of the alternator; grease leaked from ball bearing, raceways and balls extremely worn
- Alternator speed too high as a result of belt pulley being too small (gear ratio)

Remedies/avoidance:

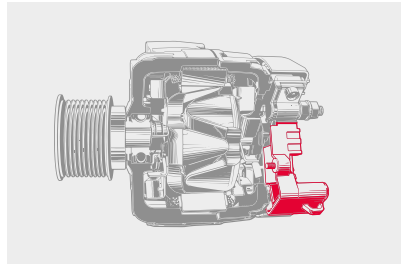
- Replace alternator.
- Use new belt and new clamping device.
- Set belt tension according to manufacturer specifications.
- Check combustion engine (running smoothness, bearing play in the crankshaft).
- When washing the engine, do not hold the jet of the high-pressure cleaner directly on the alternator.
- Identify and remedy cause of thermal load (entry of dirt, check total connected load).
- If the power requirements increase because additional components are connected: choose an alternator with a correspondingly higher output.



Overheated roller bearing; grease leak

6.2 Performance

No alternator output, battery charge indicator does not go off



Cable from D+ trapped under regulator housing

Findings:

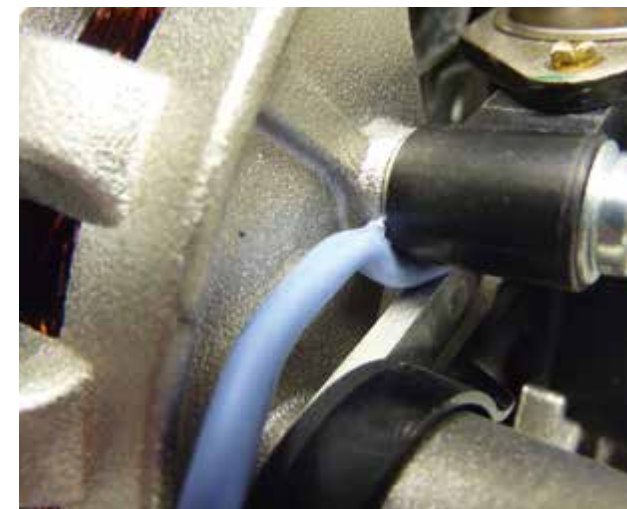
- Alternator provides no output
- Battery charge indicator does not go off when engine is running
- Cable from D+ is pinched
- Cable insulation damaged

Cause(s):

- Cable became trapped when replacing regulator
- Short circuit on cable D+

Remedies/avoidance:

- Replace alternator.
- When fitting the alternator and replacing the regulator, ensure that no electric cables become trapped.



Cable from D+ trapped under regulator housing



Pinched cable








Glossary

Term	Explanation
Belt pulley	The belt pulley drives the alternator. It is important to ensure that the belt pulley is aligned with the alternator and the crankshaft.
Burning marks	Discoloration of insulation or melting of metallic components due to arcing.
Capacitor	The capacitor stores energy. It can temporarily absorb current and discharge it again. In this way, a capacitor can smooth out fluctuations in voltage.
Carbon brushes	The carbon brushes transfer the field voltage from the regulator to the rotor's slip rings. In the rotor there is a coil that generates the excitation magnetic field. Both ends of this coil are connected to a slip ring.
Central nut	The central nut is used to screw the belt pulley onto the shaft. The nut must always be tightened with the correct torque.
Charging current	Amount of current produced by the alternator. The greater the charging current, the greater the mechanical energy required to drive the alternator. The regulator therefore adjusts the field voltage so that the alternator only produces the amount of current required by the components.
Diode	Diodes are semiconductors that allow current to flow in one direction only. They can be used in a circuit to create a rectifier that converts alternating current into direct current.
Distance washer	To ensure the correct axial position of the belt pulley, distance washers must be placed behind the belt pulley. It is important that the belt pulley is tensioned tightly to the shaft and the inner bearing ring of the ball bearing with the central nut.
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.
Excitation diode	Excitation diodes make supply voltage from all three phases available to the regulator.
Fan (external)	In compact-diode assembly alternators, there is an external fan between the belt pulley and the alternator housing. The fan draws cooling air from the rear housing through the alternator. The advantage of this is that, if necessary, the direction of rotation of the alternator can be changed when using a different fan.
Fan (internal)	In compact alternators, there are two fans, one at the front on the rotor and one at the back end of the rotor. The cooling air is drawn in at the front and guided radially to the stator winding.
Field voltage	The field voltage is controlled by the regulator. The regulator supplies the voltage to the rotor that is needed to generate a certain excitation magnetic field strength.
Housing	The alternator housing is important for dissipating heat. Air diffusers and ventilation slots conduct the cooling air to thermally critical components in a targeted manner.
Power diode	Diodes designed to handle high currents. Certain power losses cause the diodes to heat up. Power diodes often have aluminum housing, which is pressed into a heat sink.
Protective cover	For compact-diode assembly alternators, there are special protective covers with a very fine mesh that keeps out larger foreign objects.
Rectifier	A group of connected diodes (power diodes) for converting three-phase alternating current into direct current.
Regulator	Adjusts the field voltage so that the alternator only produces the amount of current required by the components.
Rotor	The rotor has an electromagnetic coil inside it. Both ends of the rotor are bent over the coil like claws. This creates a magnetic field with rapidly flipping north and south poles.
Shaft	The shaft connects the belt pulley, fan, and rotor. High precision is required in order to ensure the durability of the roller bearings. However, this also allows the alternator to be designed with a small gap between the rotor and stator, significantly increasing its efficiency.
Slip ring	The two slip rings provide the solenoid coil inside the rotor with the excitation current. The regulator sends the excitation current to the slip rings via carbon brushes.
Stator	The stator consists of three coils with an iron core. The rotor spins inside the stator. The changing magnetic fields generate the three-phase current in the stator.

Glossary

Term	Explanation
Voltage	In principle, an alternator supplies a somewhat higher voltage than the vehicle system voltage. This is the only way the battery in the vehicle can be charged. With a 12 V electrical system, the alternator supplies 14 V. A 24 V electrical system is provided with 28 V.



Our product portfolio

<div>Engine components</div> <div></div>	<div>Quality built to last—precise fit and long life</div> <div><div><div>Pistons</div><div>Piston rings</div><div>Cylinder liners</div><div>Bearings</div></div><div><div>Valve train components</div><div>Cylinder kits</div><div>Turbocharger & retrofit/special kits</div></div></div>
<div>Gaskets</div> <div></div>	<div>Gasket range available worldwide for over one million applications</div> <div><div><div>Oil seals</div><div>Head bolts</div></div><div><div>Sealants</div></div></div>
<div>Filters</div> <div></div>	<div>Our filter range—a clean solution</div> <div><div><div>Air filters</div><div>Oil filters</div><div>Fuel filters</div><div>Cabin filters</div></div><div><div>Air drier cartridges</div><div>Transmission oil filters</div><div>Urea filters</div></div></div>
<div>Engine cooling & A/C</div> <div></div>	<div>Comfort you can feel—now and in the future</div> <div><div><div>Radiators, charge air coolers</div><div>Fans & clutches, condenser/radiator fans</div><div>Expansion tanks, cabin heat exchangers</div><div>Exhaust gas recirculation coolers, oil coolers</div><div>Water pumps & kits</div><div>Thermostats, thermal switches</div></div><div><div>A/C compressors, A/C condensers</div><div>Filter-driers & accumulators, A/C compressor oils</div><div>Evaporators, expansion valves, orifice tubes</div><div>Interior blowers, A/C switches</div><div>A/C blower control units & resistors, electric control for blending flap</div><div>Sensors</div></div></div>
<div>Starter motors & alternators</div> <div></div>	<div>Powerful and efficient—for the perfect start</div> <div><div><div>Starter motors</div><div>Alternators</div></div></div>
<div>E-mobility & electronics</div> <div></div>	<div>Innovative solutions—for the mobility of the future</div> <div><div><div>Actuators & switches</div><div>High-performance electronics</div></div><div><div>Various sensors</div><div>Electric drive systems</div></div></div>
<div>Workshop equipment & diagnostics</div> <div></div>	<div>Efficient solutions—for maintenance and service</div> <div><div><div>TechPRO® diagnostic kit</div><div>TechPRO® Digital ADAS</div><div>ArcticPRO® A/C service</div><div>FluidPRO® automatic transmission flushing</div></div><div><div>OzonePRO professional hygienic cleaning</div><div>EmissionPRO® emissions testing measuring instrument</div><div>LogiqPRO® software tool</div></div></div>

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** 