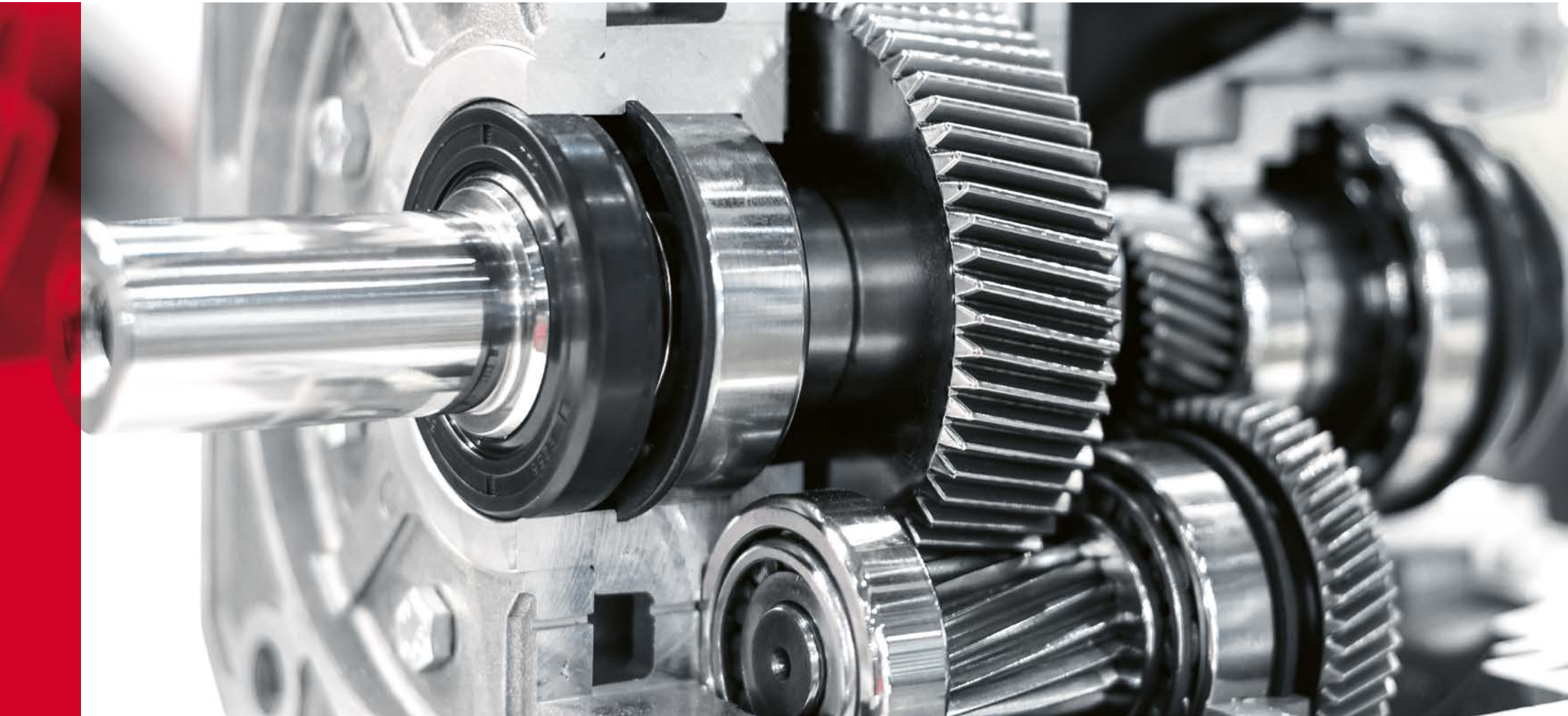
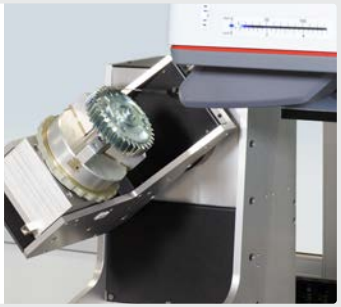
# Measuring solutions for electromobility: **Roughness testing on gears**



# Contents





# **Executive Summary**
# Gear roughness

Roughness of gears plays a fundamental role in electromobility. Gear wheels in transmissions and rotor shafts, especially in electric motors – but more recently also in aircraft turbines – require extremely fine surfaces to meet functional requirements, because their quality has a direct impact on efficiency, torque and power throughput as well as noise emissions.

With the measuring solutions available on the market, it was previously not possible to test the surface condition of gears with high precision and repeatability at the required measuring points. Mahr Engineered Solutions has therefore developed a technology that can measure

- a high-quality surface finish of Rz < 1 µm
- down to the ground tooth root and
- fine waviness on gears

in accordance with standards. Three different machine configurations based on the MarSurf series are available, depending on the workpiece size, weight and desired measurement characteristics.

# Gear roughness:
# **Focus on transmissions**

The roughness measurement feature plays a particularly important role in electric cars' transmission gears, both for manufacturers and end customers. The surface quality of gears has a decisive effect on three aspects:

## 1. Efficiency

The correlation between the surface quality of transmission gears and energy efficiency has always been a concern for the automotive industry. For example, an internal combustion engine has an average efficiency of 20 percent[1], i.e., around 80 percent of the energy it generates is lost as wasted heat. One possible approach to save fuel and reduce emissions is to minimize gear roughness in complex transmissions.

On the other hand, electric car transmissions are much less complex: As a rule, they are single-stage transmissions. Regardless of lower complexity, surface quality of the gear teeth plays a central role because an electric motor has at least 80 percent[2] efficiency, i.e., it uses more than three-quarters of the energy generated. Manufacturers' most important goal and generally the most pressing challenges in electromobility is to prevent efficiency loss that would reduce vehicle range. To maintain or even increase the range, gear surfaces must be ground with high precision to minimize friction losses from the first mile traveled.

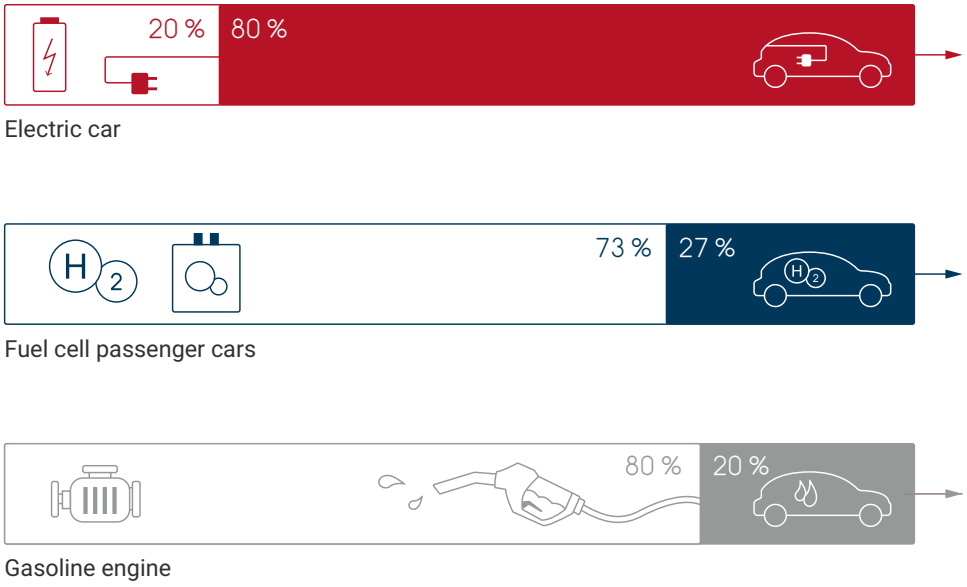
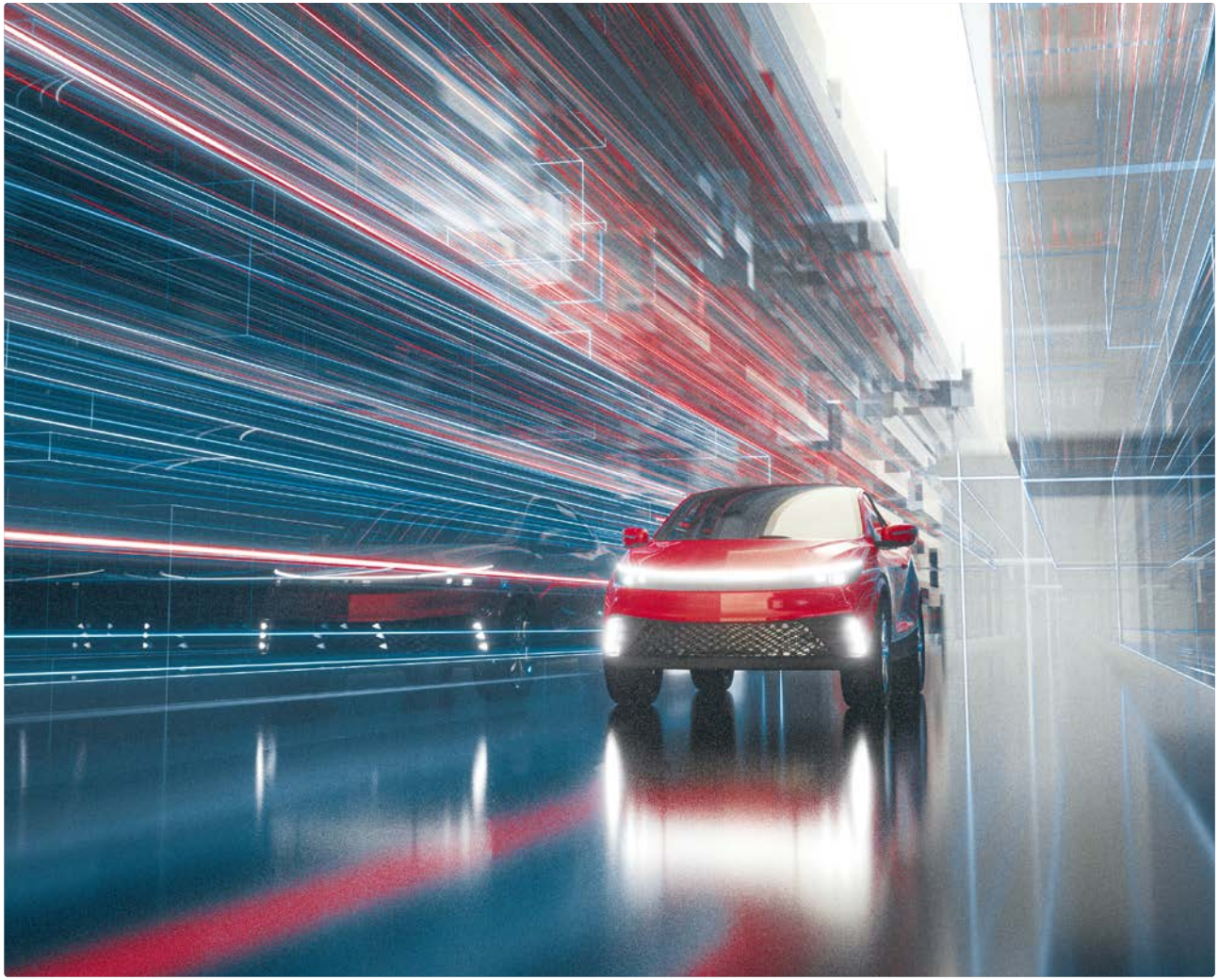



Figure 1: The efficiency shows how much of the energy supplied by the vehicle converts during movement.

[1] Source: https://www.bmuv.de/themen/verkehr/elektromobilitaet/effizienz-und-kosten

[2] Source: https://www.bmuv.de/themen/verkehr/elektromobilitaet/effizienz-und-kosten



## 2. Torque and power throughput

The classic transmissions of combustion engines and the gears installed in them are designed for comparatively low torques. The situation is different with electric motors: Even normal stationary operation places extreme demands on the drivetrain; the load is comparable to that of a combustion engine under maximum load. This is because it reaches its highest torque and therefore its highest power throughput immediately after starting[3]. The gears in electric motors must be able to cope with these extreme loads even in normal operation, which means that the demands on their surface quality are also very high.

## 3. Noise emissions

Every manufacturer strives to ensure its automobiles emit as little noise as possible. In combustion engines, noise comes mainly from the engine, not the transmission. In contrast, electric motor transmissions do cause undesirable noises, such as whistling[4]. High roughness on gear surfaces increases this noise, whereas smoother surfaces minimize it. Ultra-fine surfaces on gear tooth flanks is therefore a key noise-reducing factor for an electric motor.

[3] Source: https://e-auto-journal.de/elektromotor-vs-verbrennungsmotor/

[4] Source: https://www.ingenieur.de/fachmedien/vdi-z/automobilindustrie/wie-klingt-und-schwingt-ein-e-fahrzeug/



# **Excursus: Polish grinding** for ultra-fine surfaces

Ultra-fine surfaces on the tooth flanks are the decisive quality feature for gears in electric motors and transmissions. However, gears are produced before they are tested. Grinding machine manufacturers have already worked intensively with their machining equipment and production processes to ensure the required ultra-fine gear surfaces. Reishauer, for example, has further developed continuous gear grinding and has integrated polish grinding as an innovative process step. This reduces the roughness of a gear manufactured with continuous gear grinding "without negatively affecting the macro-geometry, flank topography or edge zone properties of the active tooth flanks."[5] The corresponding processing machines create surfaces with unprecedented quality, currently between Rz 0.2 and 1 µm. Mahr predicts the standard gearing of the future will be Rz 0.4 to Rz 0.5 µm.



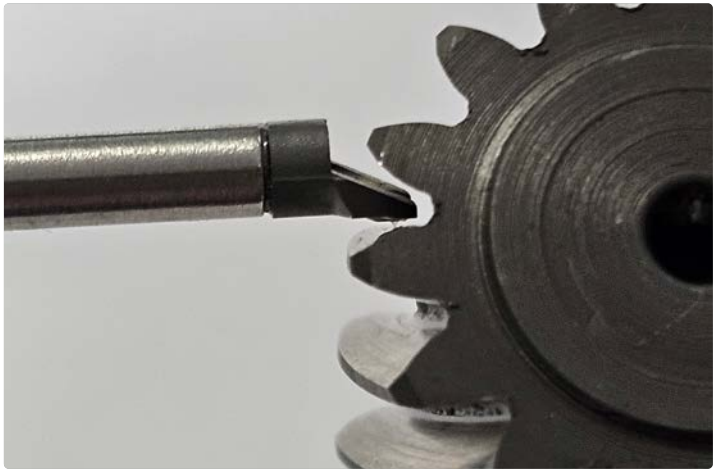
[5] Source: Walter Graf: Optionen des Verzahnungswälzschleifens zur gezielten Beeinflussung von Werkstückoberflächen. [Generating gear grinding options for the targeted influencing of workpiece surfaces.] Pg. 7. Offprint. Originally in: Jahrbuch Schleifen, Honen, Läppen und Polieren. Verfahren und Maschinen. [Yearbook grinding, honing, lapping and polishing. Processes and machines.].68th edition, published by Hans-Werner Hoffmeister and Berend Denkena.

# Gear roughness
# **A metrological challenge**

High-precision metrology for testing gear roughness is rare. Until now, common practice has been to determine gears' surface finish using geometric gear measuring systems. However, these systems are designed for measuring coordinates, not roughness, which allow for roughness measurements by means of optional sensor technology in addition to the actual geometric measurement sequence.

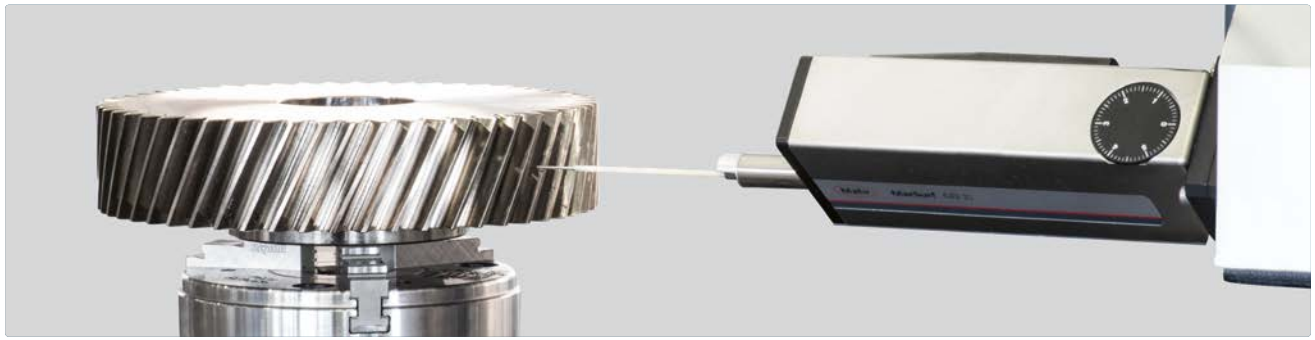
Commercially available gear measuring systems also face a number of metrological problems, as their design has so far led to inaccuracies when measuring roughness on gears:

1. They operate with a skidded probe system. This is too large to allow measurement down to the root of the tooth even with small gears, where too much roughness can lead to hairline cracks and, as a result, to the complete rupture of a tooth. In addition, they can only detect roughness and cannot measure waviness.
2. A large number of moving axes influence the measurement result, so that Rz < 1 µm cannot be measured reliably.
3. Optical methods are also currently unsuitable for achieving the desired measurement results: Firstly, access to the measurement location is difficult or even impossible due to the size of the sensor system and secondly, traceability to two-dimensional, classic roughness parameters can lead to a need for discussion between the manufacturer and customer.



A skidded probe is too large to be able to measure down to the root of the tooth.

# Testing roughness on gears with **solutions from Mahr**



Mahr Engineered Solutions (MES) has risen to the challenge and developed a technology for surface measurement that reliably checks roughness on gears.

This makes Mahr the only metrology company to offer a system that can measure the following in accordance with standards:

- a high-quality surface finish of Rz < 1 µm
- the ground tooth root by means of a skidless probing system
- fine waviness on gears

Depending on the workpiece size, weight and desired measuring features (with contour or not), the customer can choose between three different configurations based on the MarSurf series:

1. MarSurf Engineered S1300 for roughness on small gears in the drive train of an electric car
2. MarSurf Engineered S2000 for roughness on the gearing in aircraft engines and large electric drives
3. MarSurf Engineered S1400 for roughness and contour on gears in the drivetrain of an electric car






MarSurf LD 130

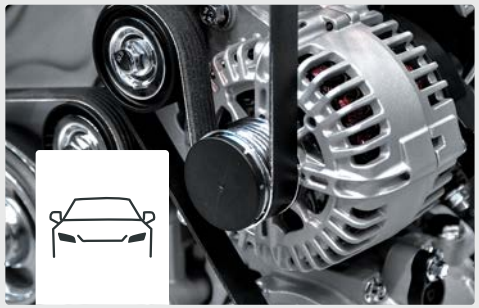
# Roughness testing on gears with **solutions from Mahr**

**Mahr solutions offer many advantages:**

- Measuring in the direction of profile and flank line (or even crosswise)
- Standard-compliant measurement due to free tracing system
- Stable testing without moving auxiliary axes during measurement, thanks to measuring machine construction
- No programming knowledge required: The software was developed specifically for surface measurement and evaluation. The operator enters the geometric gear data and the program then automatically calculates all positioning.
- Further simulation tools for correct filter selection or for collision testing of the selected probe arm in the tooth gap
- Evaluation of all standardized roughness parameters and special parameters
- Fully automatic, flexible tooth search
- No single operator is bound to the machine, since the measuring run is fully automatic
- Standard clamping devices, with special jaws also available on request

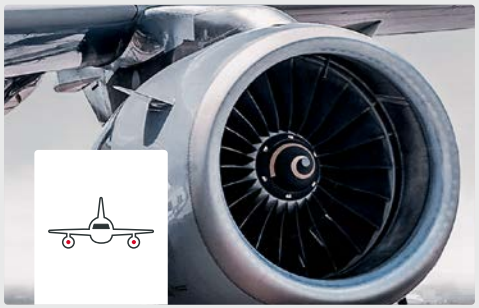
# Industries that most **benefit from our special solutions**

Roughness on gears is a topic that is especially relevant to e-mobility and drives it. Mahr's special solutions for surface measurement can add particular value in the following industries:



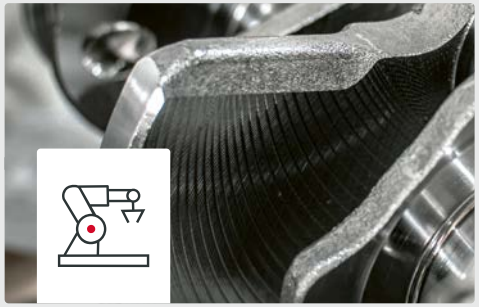
## Automotive

High-precision gears in the electric drive



## Aviation

High-precision gears in engines



## Mechanical Engineering

Grinding machine manufacturers
Gear manufacturers


**In electromobility, roughness plays a decisive role.**
We support you in ensuring your quality with high precision.

**Axel Binder**
Director Global Engineered Solutions



# **Contact the specialists** at Mahr Engineered Solutions

If you are concerned about gear roughness, please contact us. Our specialists can provide intensive expertise and guidance, and will work with you to implement the right solution for your needs.

**Mahr Engineered Solutions**

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For more information on special solutions, visit http://www.mahr.com/engineered-solutions.

# Sources and images

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