PAMENSKY

What mechanical engineers and plant operators need to know about gears

Technical Guide

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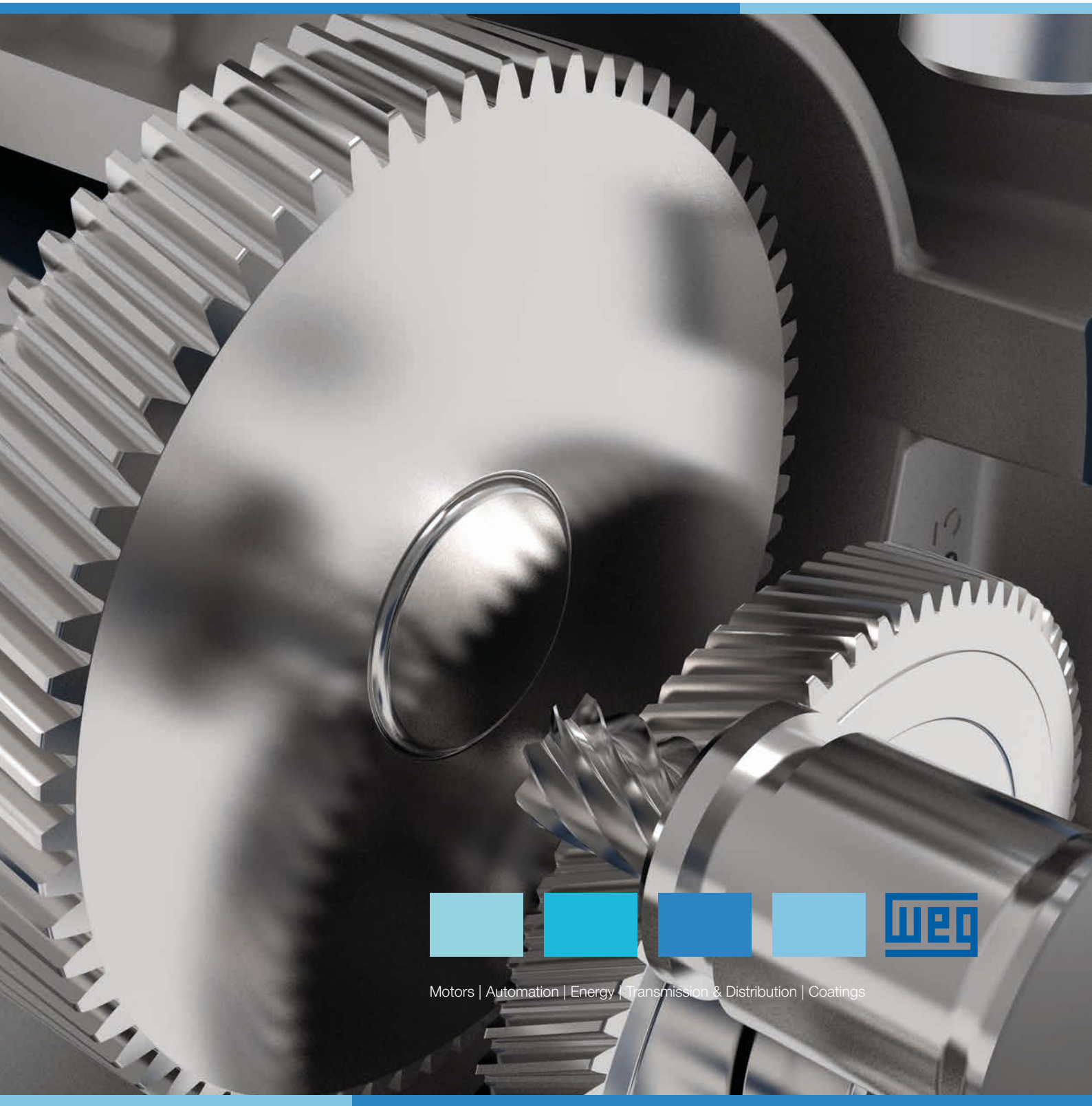

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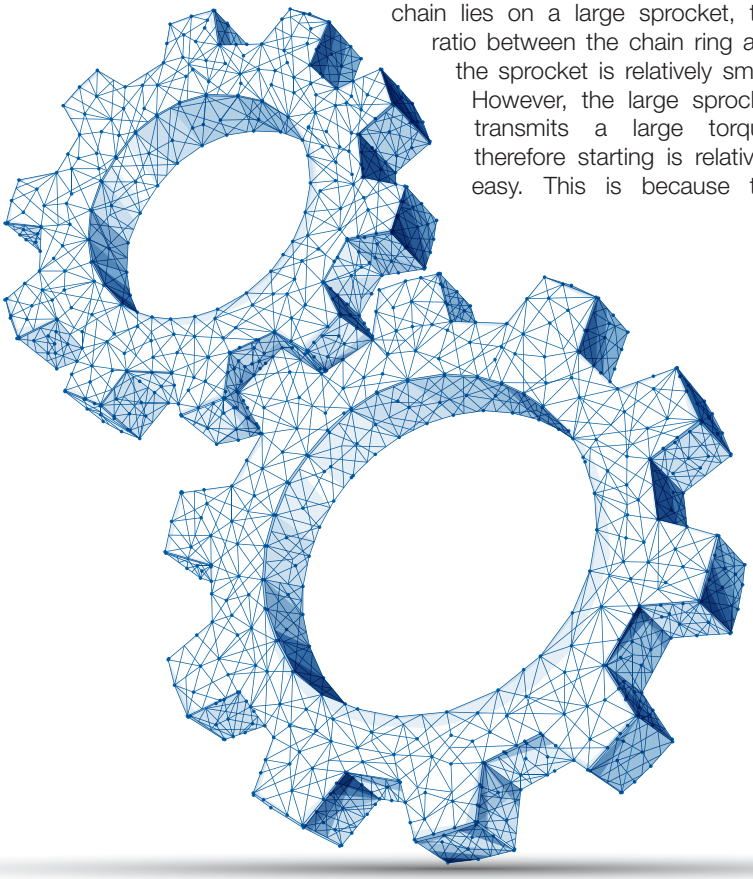
Gears are among the most important components in a wide variety of drive trains. For example, in industry in particular, they ensure the smooth running of a production line – often in conjunction with an electric motor. They transmit the right amount of movement and force to where it is needed.

Why is a gear unit needed and how does it work?

Electric motors have their ideal operating point in a certain speed range, depending on the type. This varies depending on the motor type, but also, for example, on whether the highest possible torque or operation at maximum speed or energy efficiency is required. As a rule, an electric motor's optimum speed does not necessarily correspond to that required by the user in an application. The same applies to a combustion engine or other drives. Gears are used to adapt the speed or torque of a drive to the requirements of the application. A simple and intuitive example of how gears work is a rear derailleur bicycle. If the chain lies on a large sprocket, the ratio between the chain ring and the sprocket is relatively small. However, the large sprocket transmits a large torque, therefore starting is relatively easy. This is because the gear wheel has a large radius and consequently transmits a large amount of torque to the wheel according to the equation $M = F \times r$ (since the force acts perpendicular to the axis). In this case, the speed is low. Later, the cyclist can switch to a smaller sprocket, which means that with the same force, a lower torque acts at a higher speed.



A pedal-chain rear wheel or chain-ring-chain sprocket system is a simple example of a gear unit and illustrates the significance of the transmission ratio, i.e. the ratio between input and output speed. The gear basically regulates the ratio between speed n and torque M, or speed and force, with the same mechanical power; their ratio is inversely proportional: $M \sim 1/n$. The side of the power input to the gear – via the pedal crank in the example or an electric motor – is called the input side. The side that delivers the required speed or torque is called the output side.

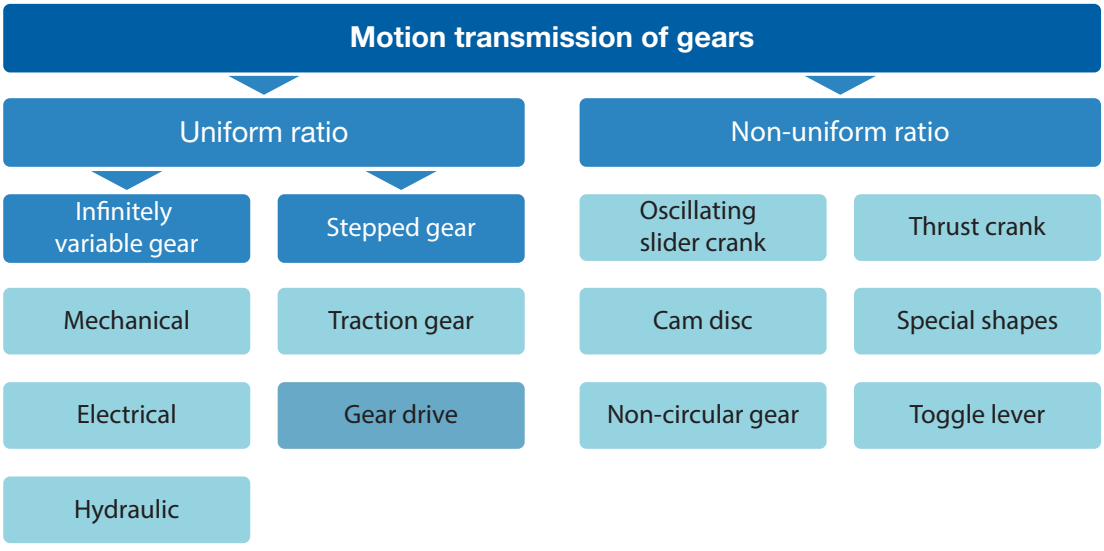
Types of gear and their classification

Gears – i.e. components for converting speed and torque or speed and force – are available in countless designs and versions. The type of power transmission is a distinguishing feature. In addition to mechanical gears, there are also hydraulic and electric gears, for example. However, gears can also be classified according to the type of motion transmission. A distinction is made between a uniform and a non-uniform ratio. A non-uniform ratio is when a gear transmits irregular movements. This is the case when linear movements are converted into rotational movements. Typical examples are a toggle lever or a thrust crank gear.

Gear units with a uniform ratio usually convert a rotary motion into a rotary motion with the relationships between speed and torque described above. Once again, a distinction is made between fixed or stepped and continuously variable gears. With continuously variable gear units, the transmission ratio can be set freely and continuously during operation. This type of gear includes hydraulic and electric gear units as well as some mechanical designs, such as continuously variable chain gears, which can be found, for example, in motor vehicles with automatic gearboxes. In turn, fixed and stepped mechanical gear units operate according to the same principle. Stepped gears comprise only several power or torque transmission stages. This enables a correspondingly wide speed range. The following section will only describe mechanical gear units.

Mechanical gears include the coupling gear group. Among them are, for example, crank gears, which convert linear movements into rotary motions, or cardan joints. Another well-known type of mechanical gears is the cam gear. As with the crank gear, it is a non-uniformly transmitting gear. With a cam gear, almost any motion can be implemented. They are mainly used as transmission gears, in which a uniformly rotating drive movement is usually converted into an uneven output movement. This allows continuous movements as well as latching movements. Rotating or straight components are used to move a cam body, which either rotates or is guided straight. The best-known example of a cam gear is the valve control of a combustion engine: The rounded cams on the rotating camshaft drive the valves via tappets, which in turn perform a linear movement. There are countless other types of mechanical gears. These include step gears, belt and chain drives, friction and rolling element drives as well as gear drives.

In industry, gear drives are primarily used. The above-mentioned targets of speed and torque conversion or speed and force conversion can be achieved with an assembly of gears, bearings, shafts and a housing. Due to their design with intermeshing gear wheels, gear drives also belong to the group of positive-locking gears. As a rule, the required conversion should be as low-friction and low-noise as possible. Significant differences between the various types of gear units relate to the type of gearing and the angle between the force input axis and the force output axis.



Technical features of a gear unit

As mentioned above, the most important technical features of a gear unit are the torque, the power, the reduction and transmission ratio and the speed range. The connection dimensions and the housing material also play a role for the respective application. Modern gear units are ultra-efficient. Only about 1.5 % of mechanical efficiency is lost per gear stage. In the case of a two-stage gear unit, this corresponds to a mechanical efficiency of approximately 97 %. With worm gear units, the level of efficiency is much lower, depending on the ratio.

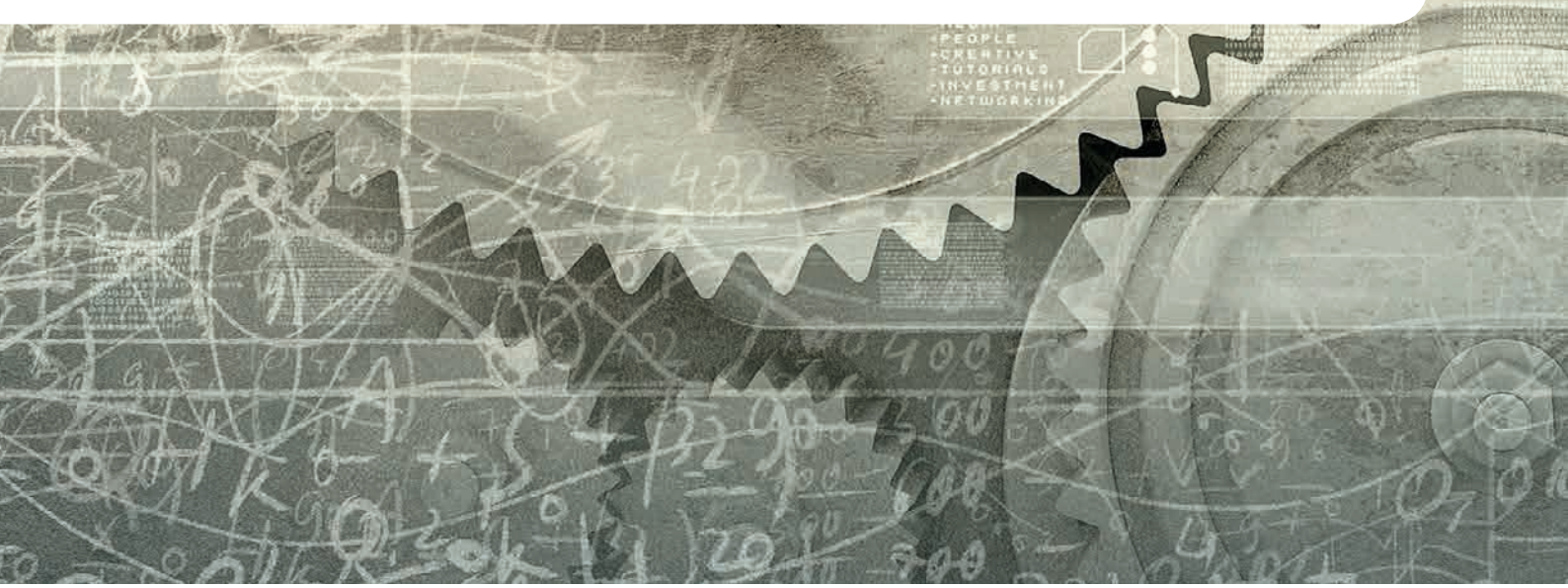
Apart from the power data, other factors play a far more significant role in practice than, for example, the already very high degree of efficiency. In day-to-day use, key factors are the reliability of a gear unit, its robustness and durability as well as the maintenance effort. This means that high-quality components (e.g. lubricants) are an important aspect of a low-maintenance gear unit.

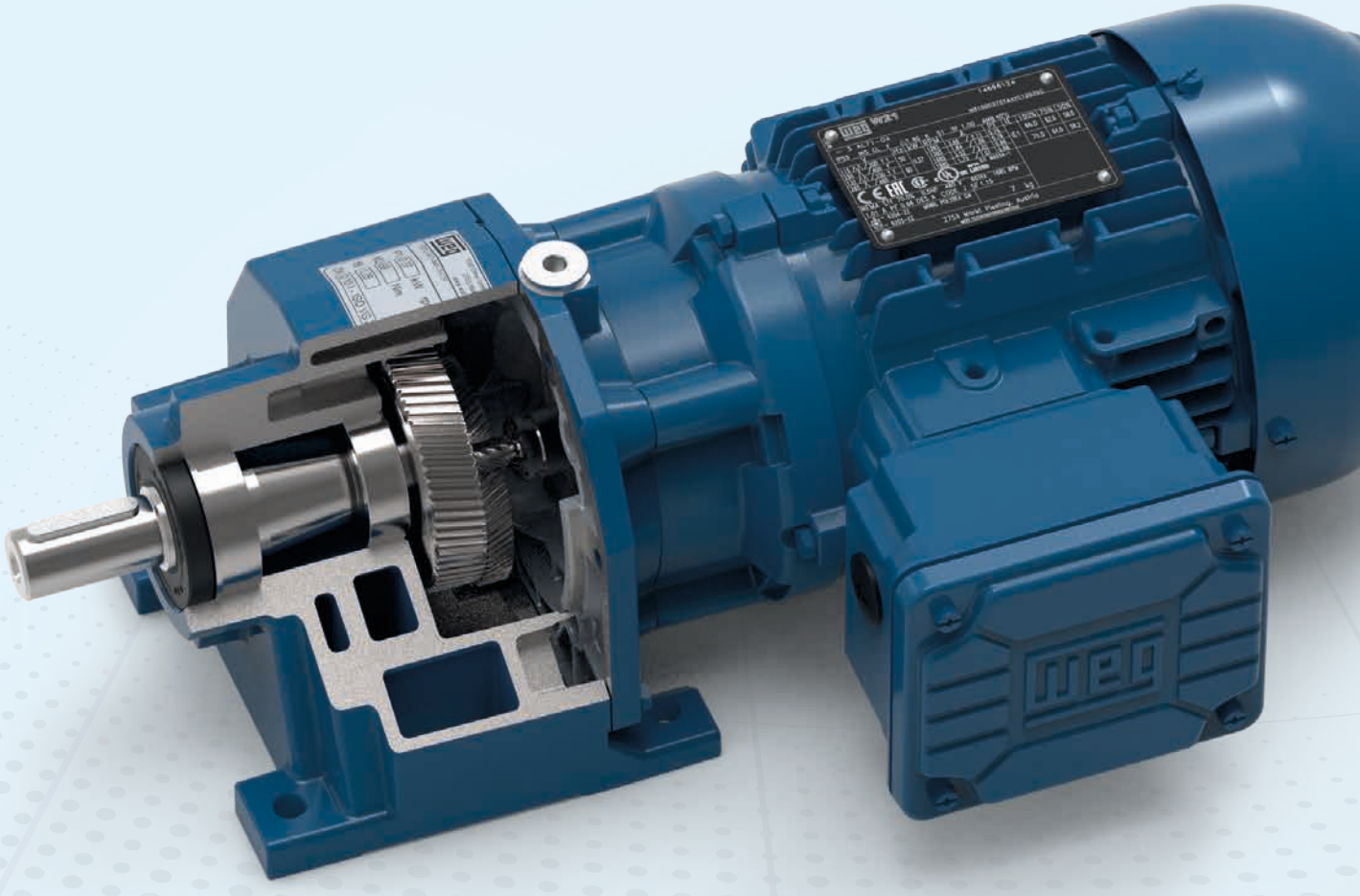
The selection of a gear unit is primarily determined by the application data including, for example, the power requirement, speed, ambient temperature and space conditions. The durability of a gear unit also depends on the loads it is exposed to, e.g. shock loads such as when driving a conveyor belt. Therefore, when designing a machine or system, it is important to avoid exposing the gear unit to frequent shock loads.

The above-mentioned housing material comes into its own when it comes to the rigidity and weight of the overall design. An aluminium housing, for example, is much lighter than a grey cast iron housing with similar strength. For higher torques, grey cast iron is the better choice, as the material is particularly torsion-resistant and has improved vibration-damping. In general the following applies: The smoother the housing surface, the easier it is to clean a gear unit, which enables it to be used in industries requiring intensive cleaning, such as the food industry.

Helical gears, bevel gears, parallel shaft gears and worm gears each have a share of around 20 percent of the global industrial market. This means that these four gear types account for the majority of all gear units installed. Planetary gears are also used in the industry.

The types of gears used in industry, particularly in combination with an electric motor, i.e. as a geared motor, include helical, parallel shaft and helical bevel gears. The WG20 geared motor from WEG, one of the leading global suppliers of drive technology, is available, for example, in these three gear types. The most important gear types are described below.





Helical gear units

Helical gears (cylindrical gears) are the best known types of gear wheels. The teeth are arranged on the circumference of a cylinder. This also means that the input and output shafts of helical gears are always arranged parallel and coaxial to each other. Single-stage helical gears consist of two gears meshing on two parallel axes. Depending on the required transmission ratio, helical gear units can also be designed with several stages. A special type of helical gear is the rack-and-pinion gear unit. A helical gear rolls over a rack. This can be imagined as an unwound gear wheel.

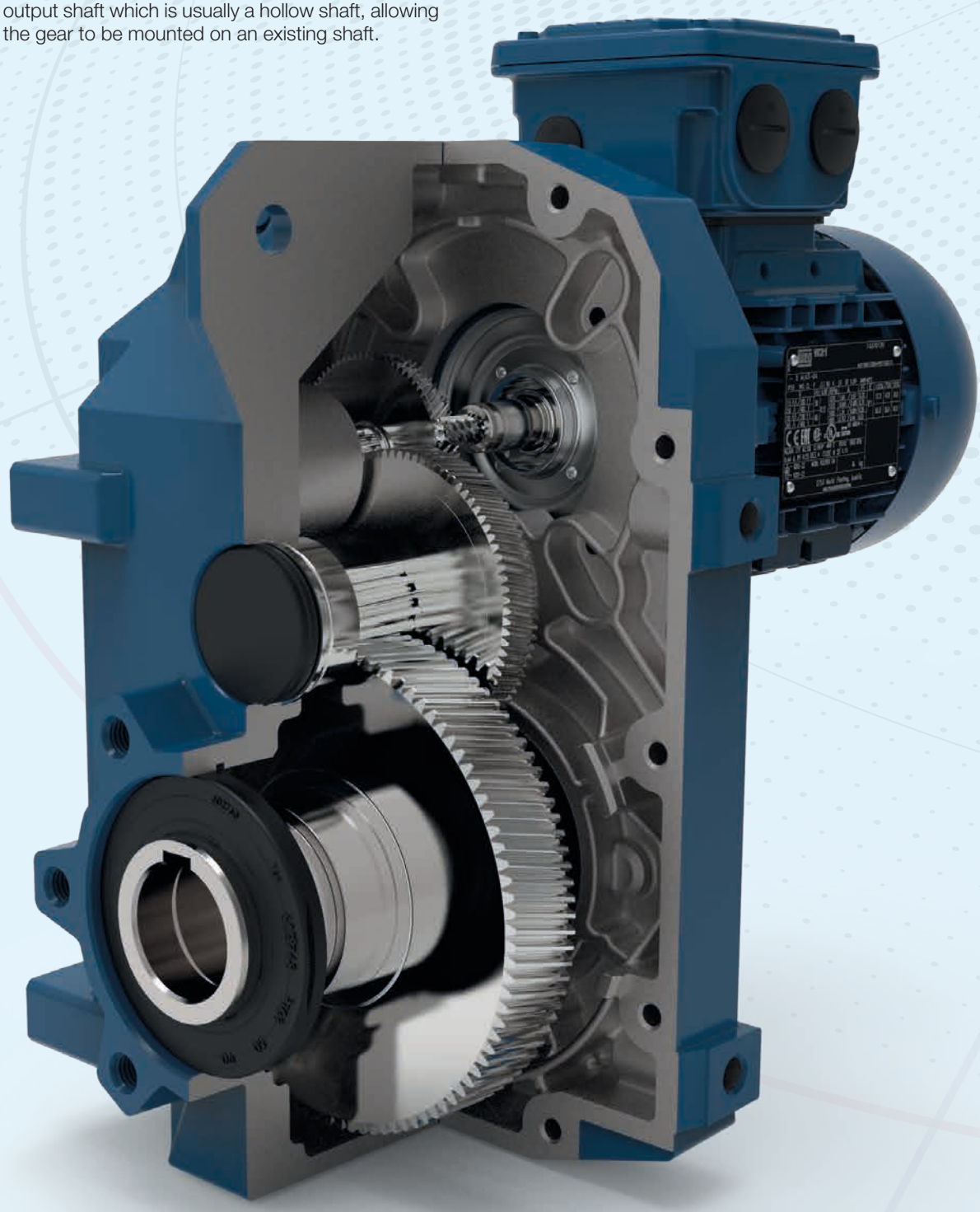
With helical gears or helical gear units, a distinction is made between different types of gearing. The simplest is straight cut gears. As a rule, this type of gearing uses involute gearing. If larger torques are to be transmitted, helical cut gears are used for the gear unit design. These run more smoothly on each other, thus enabling quieter running gears. The disadvantage of helical cut gears is that they generate axial forces, which in turn must be absorbed by the bearings of the gear unit. This requires bearings that can absorb both radial and axial forces.

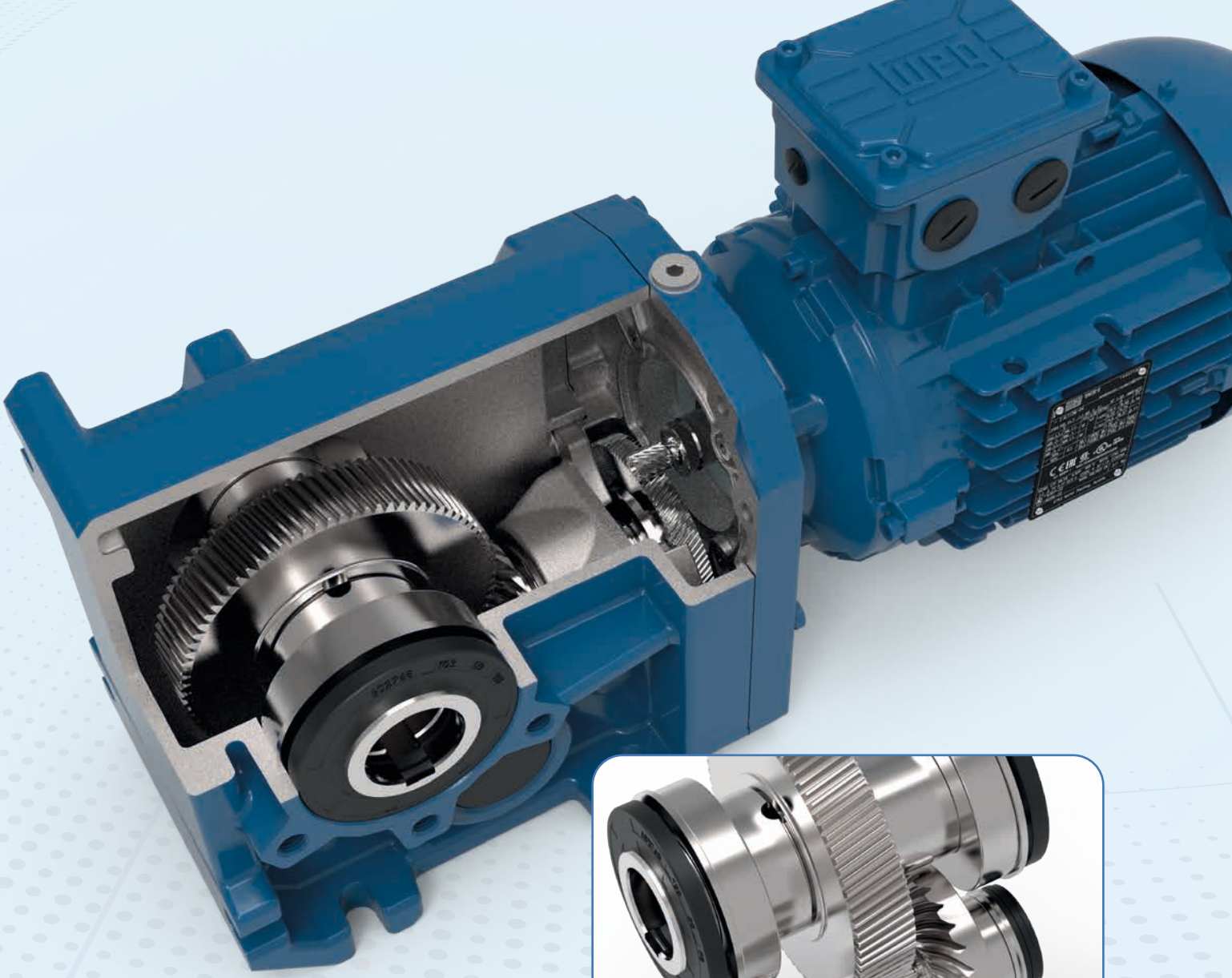
This disadvantage can be compensated for by using herringbone or double helical gears. These have the advantages of helical cut gear wheels, but do not generate any elements of axial force. However, the production of these gear types is complex and expensive such that these gear types are only used in gear units with special requirements.

Due to the small number of moving components, helical gears have a high degree of efficiency. However, only a limited ratio can be achieved per stage (industry standard maximum 12). As a result, multi-stage gear units are required for higher ratios.

Parallel shaft gear units

There is a special type of helical gear known as parallel shaft gear. In contrast to conventional helical gear units, the input and output shafts are offset parallel to each other as far as possible. Due to their design, the axial dimensions of the parallel shaft gear unit are very compact and are therefore a good space-saving solution. These are usually multi-stage helical gear units with parallel shafts, comprising an output shaft which is usually a hollow shaft, allowing the gear to be mounted on an existing shaft.





Bevel gear units

Bevel gears are characterised by the fact that the axes are not parallel to each other, as is the case with helical gears. In principle, any axis angle can be achieved with bevel gear wheels. In most cases, however, the input and output axes are at an angle of 90 degrees to each other. In the case of a bevel gear set, the larger bevel gear wheel is referred to as a ring gear on the output side and the smaller bevel wheel as a pinion on the input side. In the single-stage design, a gear ratio of $i < 8$ can be achieved.

To achieve a higher gear ratio, a combination of one or more helical gear stages and a bevel gear stage is used in a gear unit; the bevel gear stage serves to rotate the axis of rotation by 90 degrees. Similar to helical gears, bevel gears also have different tooth forms. The simplest design in this case is also straight gearing. However, this is accompanied by a relatively high noise emission level. This can be counteracted with curved gearing. The tooth line does not run radially, but outwards in an arc. A distinction is made between spiral, involute, circular and cycloidal lines. In addition to the lower noise emission, a higher torque can also be transmitted with curved gearing, as with helical gears. Crown gears are very similar to bevel gears. In this case, the ring gear teeth are perpendicular to the circumference, and a conventional helical gear is used as the pinion.

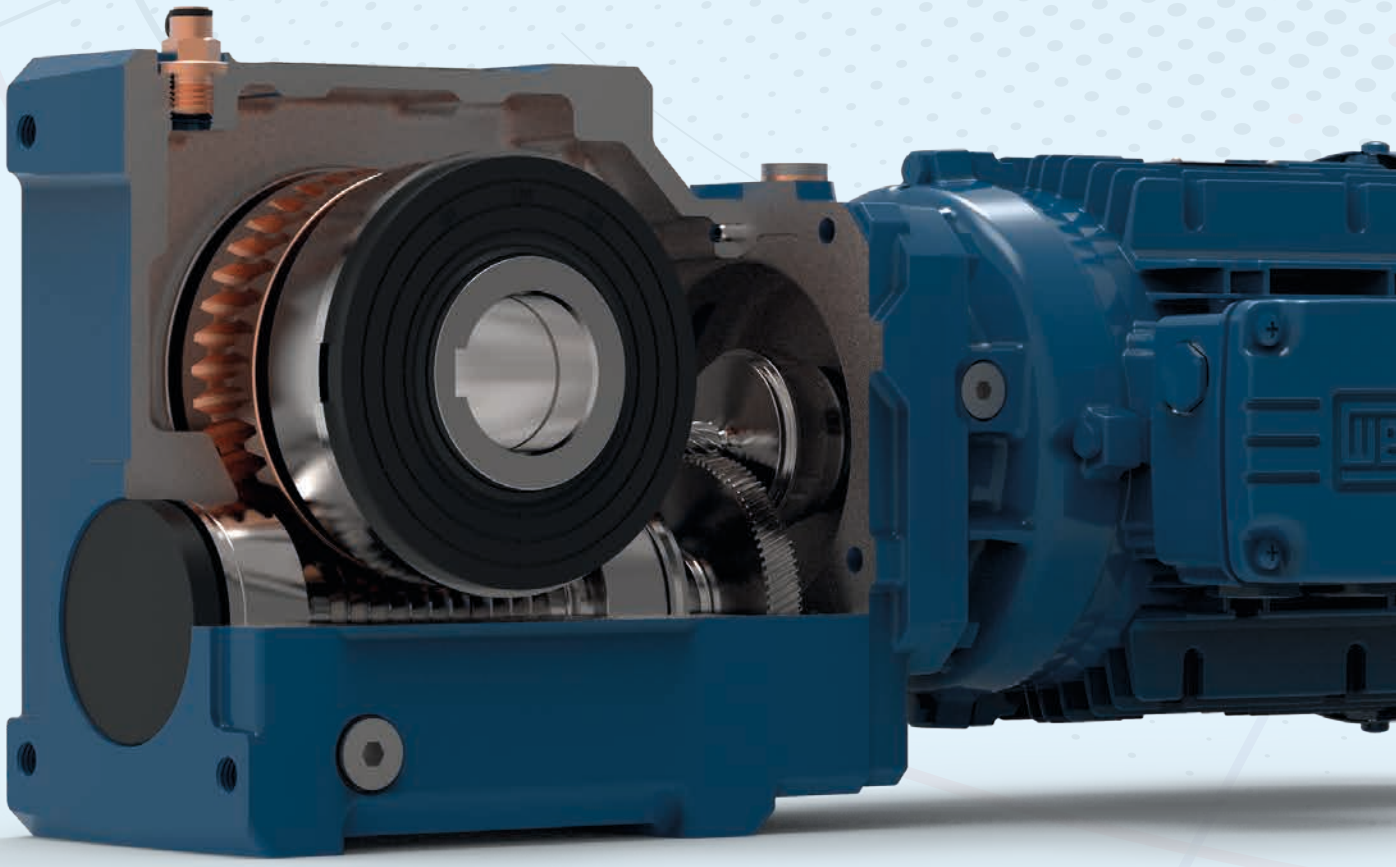
Worm gear units

Despite their comparatively low level of efficiency, worm gears are widely used due to their wide range of applications and large ratios. In contrast to helical and bevel gears, which belong to the rolling contact gear category, a worm gear is known as a worm rolling contact gear. In its design, the worm gear consists of the worm and the worm wheel. A worm can be imagined as a screw. There are single and multi-stage worms. The number of teeth in the gear wheel corresponds to the number of gears in the worm.

With worm gear units, the input and output shafts are at right angles to each other. The ratio of a worm wheel set depends on the number of teeth of the worm wheel and the number of leads of the worm shaft: $i = T_{worm\ wheel} / T_{worm}$.

With a large number of teeth on the worm wheel and a single-stage worm, a very high transmission ratio of $i > 100$ can be achieved in a very small space. As several teeth of the worm wheel are usually engaged at the same time, very high torques can be transmitted with the worm gear unit. At the same time, the gears operate very quietly due to continuous sliding.

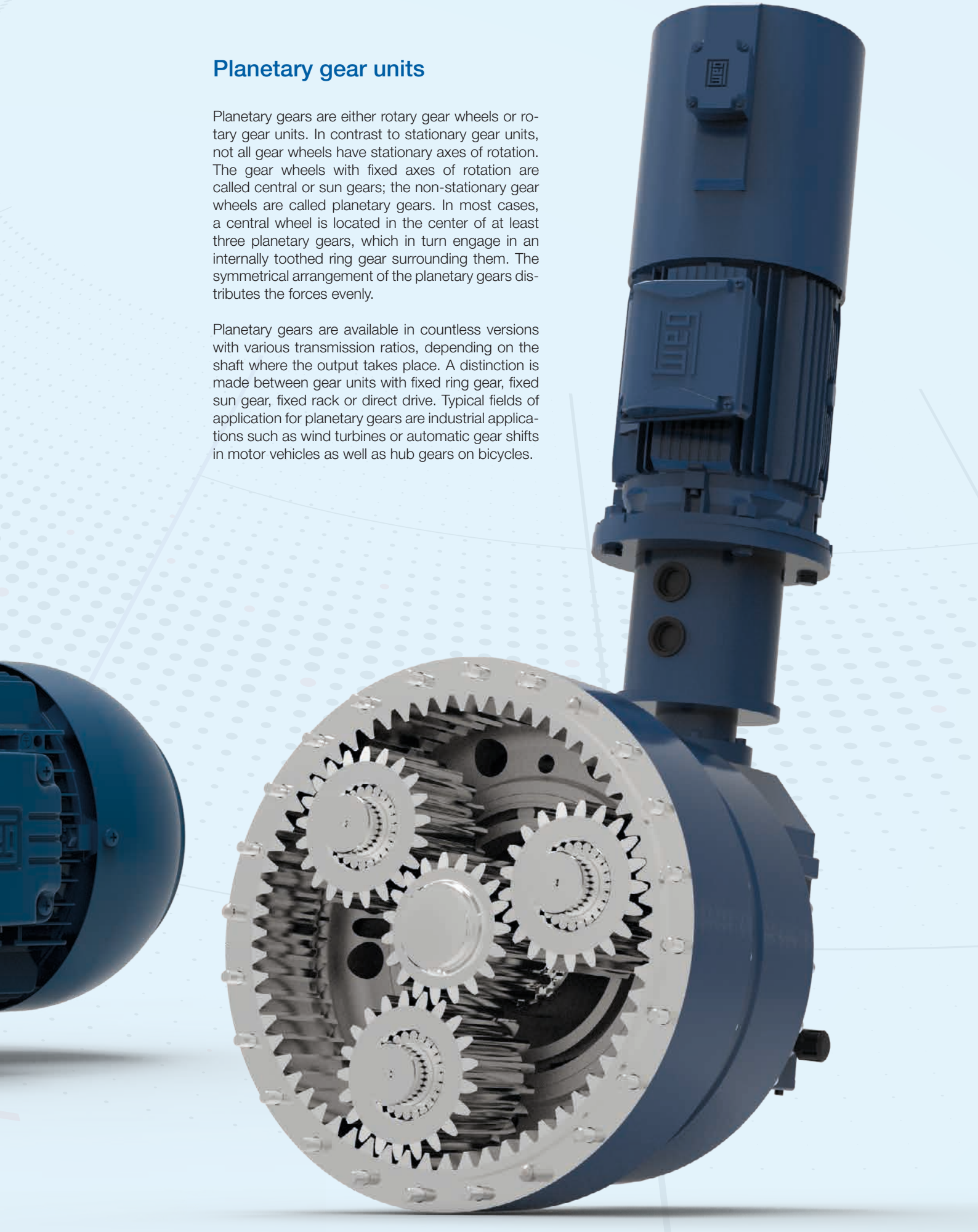
However, due to the friction that occurs on the flanks of the worm and worm wheel, the efficiency of the worm gear unit is lower than that of helical gears, for example. The resulting friction also requires good lubrication and possibly additional cooling for high power outputs.



Planetary gear units

Planetary gears are either rotary gear wheels or rotary gear units. In contrast to stationary gear units, not all gear wheels have stationary axes of rotation. The gear wheels with fixed axes of rotation are called central or sun gears; the non-stationary gear wheels are called planetary gears. In most cases, a central wheel is located in the center of at least three planetary gears, which in turn engage in an internally toothed ring gear surrounding them. The symmetrical arrangement of the planetary gears distributes the forces evenly.

Planetary gears are available in countless versions with various transmission ratios, depending on the shaft where the output takes place. A distinction is made between gear units with fixed ring gear, fixed sun gear, fixed rack or direct drive. Typical fields of application for planetary gears are industrial applications such as wind turbines or automatic gear shifts in motor vehicles as well as hub gears on bicycles.



Which factors determine the choice of gear type?

The gear types described above dominate the industrial gear market. For this reason, WEG offers the WG20 geared motor as a helical, parallel shaft or helical bevel geared motor. This type series allows WEG to cover the majority of the types of geared motors in demand. The WEG portfolio also includes worm gears and customized drive solutions.

Bevel gear units and worm gear units have similar characteristics. The input and output shafts are positioned at right angles to each other, allowing them to be installed very close to the machine and attached to the respective machine shaft by means of a hollow shaft. The bevel gear is more efficient, but the worm gear is more compact at high ratios. The most cost-effective gear of the gear types described above is the helical gear. In the case of parallel shaft gear units, the shafts are offset parallel to each other, which is an advantage of this type series depending on the application.

Which gear unit is used in an application depends primarily on the available space in addition to the above-mentioned characteristics. If the axial installation space is limited, a bevel gear is typically used. A helical gear unit, on the other hand, has a longer design; it is used where sufficient space is available. This gear has the advantage that the input and output axes are arranged axially, i.e. practically in one line. At the same time, the unit has a central center of gravity, which is advantageous depending on the design. Installation space or available room, costs, center of gravity and efficiency are therefore the determining features for the choice of gear unit.

The interactive product catalog
“cat4CAD“
will help you to choose the best drive component from our entire range of gear units/geared motors and modular motor systems.

Online Version: **www.cat4cad.com**
Offline Version is available as download at:
www.wattdrive.com

Technical trends in gear development

On the mechanical side, the development of gears and geared motors is at an extremely advanced stage. Materials, designs and efficiencies have largely been exhausted. It is more likely that new developments will be seen on the electronic side in the near future. In the course of Industry 4.0, these machine components will also be integrated into the overall “digital factory” package. These include control components and appropriate sensor technology, which provides the required data and feedback. Ultimately, the latter concerns the entire drive train – WEG offers all the necessary components. The focus of future developments could be components for predictive maintenance for larger gear units. However, trends focussing on development in the field of geared motor technology also include decentralized drive technology, such as geared motors with attached inverters.

Further literature on the subject:

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Edwin Kiel (Hrsg.)
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Springer Verlag, 2007 (ISBN-10: 3540734252)

About WEG

WEG is one of the world‘s leading manufacturers of electrical components and systems. The business is divided into five divisions: motors, power generation, power transmission and distribution, automation and varnishes. The company employs more than 31,000 people worldwide and in 2018 achieved sales of approx. 3 billion USD across a broad range of products. These include the latest generation of low/medium and high-voltage motors, transformers, generators, geared motors, low-voltage switchgear, frequency inverters, soft starters, ATEX-compliant flameproof motors, smoke extraction motors and full turnkey systems.

The company‘s solutions in the field of power generation, transmission and distribution guarantee more efficient plant operation in various industries, e.g. the oil and gas industry, water management, power distribution and the chemical and petrochemical industries. This means that they not only help to reduce energy consumption and CO2 emissions, but also improve environmental sustainability. WEG also provides comprehensive solutions for renewable energy projects, e.g. complete wind turbines.

About Watt Drive

Watt Drive, specialized in the development and manufacture of gear technology based in Markt Piesting, is part of the Brazilian WEG Group, one of the world‘s leading manufacturers of electric motors. Watt Drive sells products and solutions in the fields of drive technology and automation all over the world. With its modular motor and gear system, the company offers a complete range of combinable drive systems for production machines and industrial manufacturing plants.

If you have any questions about gear motors or need some advice about your planned application, please get in touch with us:

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