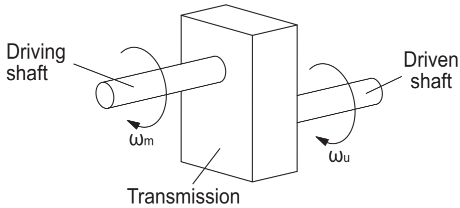
Transmission elements technical data index

elesa®

1. INTRODUCTION TO THE TRANSMISSIONS

A mechanical transmission is constituted by the complex of the elements required to transmit power in a mechanical system, thus transferring energy from an engine to a user for a certain period of time:

The transfer of this power from the engine to the transmission takes place generally via the driving shaft. A user shaft (also called driven shaft) allows instead the transfer of this power from the transmission to the user.



The power that reaches the user can never be equal to the one coming out of the engine. In fact, during transmission, part of this power will be dissipated by friction or heat. To evaluate how much power is actually used compared to the one generated, then an efficiency value (η) is used:

$$\eta = \frac{P_u}{P_m} = \frac{M_r \cdot \omega_u}{M_m \cdot \omega_m} < 1$$

where:

- Driving Power (P_m) = Useful Power (P_u) + Dissipated Power (P_d)
- M_m and M_r are, respectively, the driving torque and the resistant torque
- ω_m and ω_u are, respectively, the angular speed of the driving shaft and that of the user shaft

The driving power is generally expressed as:

$$P_m\,[W] = M_m\,[Nm] \cdot \omega_m \left[\frac{rad}{s}\right] = \frac{M_m\,[Nm] \cdot n_m\,[rpm]}{9.55} \qquad \text{where} \qquad \omega = \frac{2\pi \cdot n}{60}$$

where n_m is the number of rounds of the driving shaft expressed in revolutions per minute (rpm) and 9.55 is instead the conversion factor for transforming radians per second in rpm.

The characteristic parameter of the transmission is the **transmission ratio (τ)**, the ratio between the angular speed of the driving shaft and that of the driven shaft:

$$\tau = \frac{\omega_m}{\omega_u} = \frac{n_m}{n_u} \qquad \begin{array}{l} \tau > 1\text{: transmission with reduction} \\ \tau = 1\text{: transmission without variation} \\ \tau < 1\text{: transmission with multiplication} \end{array}$$

2. TRANSMISSION ELEMENTS

To allow the transmission of the motion as seen in the previous paragraph, special mechanical parts are required. A gear is a mechanism used to transmit a movement and / or a mechanical moment from one object to another. Generally it consists of two or more toothed gears, which can be of the same or of different size. One of the two gears transmits the motion (driving gear) and the other receives it (driven gear). The driven gear rotates in the opposite direction to the driving gear. The smallest gear is commonly called a pinion, while the largest is simply called a gear.

There are different types of toothed gears, the most common are: spur gears, helical gears, bevel gears, rack and pinion and worm gears. Each type of toothed gears allows the transmission of motion between differently positioned axes.

2.1 The tooth

The toothed gears perform power transmission between rigid bodies through the interaction of teeth progressively in contact. The circumference along which the contact between the two toothed gears takes place is referred to as the **pitch circle**. The distance between the centers of the pitch circles that constitute a pair of gears is called the **operating distance**.

The teeth can have different types of profile. The most widespread profiles have the shape of an **involute**, a curve obtained as the trajectory of a point belonging to a line that rolls without sliding on a circumference.

Commonly, the teeth develop in a radial direction straddling the pitch surface. The top land is defined as the part protruding from the pitch surface and included between the pitch circle and the addendum circle. The part between the pitch circle and the root circle is called the bottom land. Each of the tooth's side surfaces is called a profile. It is divided into two portions from the pitch circle: the external portion is called the **face of the tooth**, the internal portion is called the **flank of the tooth**.

The profile of a tooth (Fig.1) can be divided into two parts: the **addendum (h_a)** is defined as the distance in the radial direction between the **pitch circle (d)** and the **addendum circle (d_a)**; the **dedendum (h_f)** is defined as the distance, also radial, between the pitch circle and the **root circle (d_f)**, which delimits the tooth bottom. The sum of these two sizes constitutes the **height of the tooth (h)**.

The **circular pitch (p)** is defined as the distance between two homologous points of two consecutive teeth, measured along the pitch circle. The **space width (e)** is the length of the arc of the pitch circle between two consecutive teeth. The **tooth thickness (s)** is the length of the pitch circle arc limited by a tooth. Finally, the **face width (b)** is defined as the axial size of the tooth.

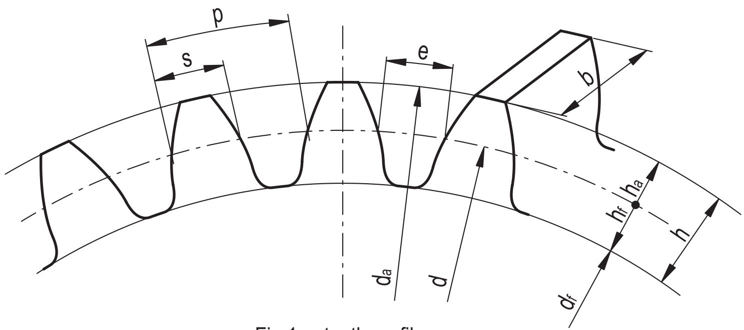


Fig.1: a tooth profile

In order to mesh correctly, the two toothed gears, with a radius of the pitch circle equal to r_1 and r_2, must have the same pitch (p). The circular pitch is therefore linked to the pitch circle by the following relation:

$$2\pi \cdot r_1 = p \cdot z_1 \qquad \text{and} \qquad 2\pi \cdot r_2 = p \cdot z_2$$

where z is the number of teeth present on the gear. From here, a fundamental measure can be obtained for the use of the toothed gears, is the **module (m)**:

$$m = \frac{p}{\pi} = \frac{d_1}{z_1} = \frac{d_2}{z_2}$$

To mesh correctly with each other, two gears must have the same pitch (p), hence they must also have the same module (m).

The number of teeth can also be related to the transmission ratio (τ) by the following formula:

$$\tau = \frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} = \frac{z_2}{z_1} = \frac{r_2}{r_1}$$

Another necessary condition for two gears to mesh is that they have the same angle of inclination of the helix. The teeth of the driving gear transmit to the teeth of the driven wheel a force (F) which has a direction such as to form a pressure angle (α) with the tangent common to the two pitch circles. The value of the pressure angle (α) influences the minimum number of teeth that a gear can have so that the whole tooth profile has an involute shape. ELESA transmission elements have pressure angles of 20°.

2.2 Spur gears

The most common toothed gears are the so-called spur gears, which have their teeth radially on the external (or internal) surface of the gear. In particular, the spur gears are used to transmit the rotation motion between two parallel axes (or shafts).

The data of the maximum torque shown in the tables of the technical data sheet are the result of a cross between the theoretical calculations and the experimental data obtained in the laboratory.

Theoretical calculations are based on the Lewis formula. According to this formula the tooth, considered as a shelf wedged on the gear, does not yield under the action of the force (F) (considered as static force) transmitted by the gears. This theory is based on the following hypotheses:

- the stress of the total force (F) on the tooth is considered as applied to the tip of the tooth itself
- the radial component of the force (F_r) which determines a compression stress on the tooth is considered negligible; it follows that the component of force (F) that determines the bending of the tooth is the only one considered and, for simplicity, will have the same value as the tangential force (F_r) on the pitch circle
- for the calculation the most unfavorable situation is taken into consideration, with only one pair of teeth engaged

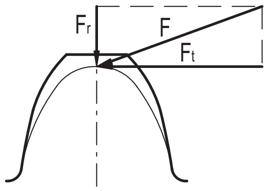


Fig.2: Application of forces on the tooth using the Lewis formula

The force (F_t) is then correlated to the torque (M) by means of the pitch diameter:

$$M = F_t \cdot \frac{d}{2}$$

The experimental data has been obtained by laboratory tests and checked with software taking into consideration the VDI 2736 guideline for the design of technopolymer toothed gears. The tests have been carried out in continuous operation and at a speed of 100-150 rpm without any lubrication, to test the most severe conditions.

The torques in the tables of the technical data sheets provide a rough information and cannot be considered valid for every possible application. The operating conditions (rpm, working temperatures, coupling with transmission elements made of different materials, lubricated or dry conditions, service factor, etc.) strongly influence the performance.

The design engineer must take into account the actual conditions of use, different from those of the laboratory.

2.3 Racks

A rack can be considered as a gear with an infinite radius. It is used to transform rotary motion into translational motion and vice versa. The toothed gear that meshes with the rack is called a pinion.

Unlike the spur gears, the most important mechanical value for the racks is the maximum stress that can be applied on a single tooth. This is due to the fact that, on this particular transmission element, no torque is applied.

The maximum stress values reported in the tables of the datasheet are the results of laboratory tests in which the force applied to the tooth of the rack increases until the tooth breaks. The maximum stress values reported in the datasheet show the maximum stress that can be applied when a single tooth is meshed.

An increase in the number of meshed teeth will not linearly increase the maximum applicable stress because only one tooth will ever work in optimal conditions.

3. TECHNICAL NOTES

3.1 Coupling

The technopolymer transmission elements can be paired with both technopolymer and metal gears. In the case of coupling with metal gears, the higher thermal conductivity of the metal allows a faster dissipation of the heat accumulated during the operation. In the case of metal-technopolymer coupling, the metal pinion and the technopolymer gear are the best option, as the wear of the technopolymer toothed gear is lower.

3.2 Operating distance

The operating distance (I), is the distance between the centers of the shafts on which the toothed gears are mounted, is given by the following formula:

$$I = \frac{d_1 + d_2}{2}$$

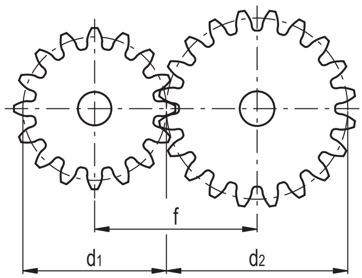
where d_1 and d_2 are the pitch diameters of the gears.

In order to get an optimal meshing between two gears, it is necessary to have a positive backlash between the centers of the two shafts: the effective distance (f) between the two centers of the shafts on which the gears are mounted is slightly longer than the operating distance (I).

$$f = \frac{d_1 + d_2}{2} + t$$

The meshing without backlash or with a negative backlash would increase the friction between the teeth, thus increasing the operating temperature and diminishing the resistance to wear and stress. To avoid these problems, for ELESA gears, the following tolerances (t) are recommended:

- (+0.03 +0.1) for modules 0.5 – 1.0 – 1.5
- (+0.08 +0.3) for bigger modules



3.3 Lubrication

One of the main advantages of the reinforced technopolymer gears is the chance to use them without lubricating oil, thanks to the intrinsic nature of the polymers. Where possible, the use of lubrication is however recommended, to reduce friction and wear, thus increasing the service life of the product. For Elesa gears it is recommended to use lubricating grease based on lithium soaps and synthetic oil.

On equal use conditions, revolutions per minute and torque, the use of lubricants considerably increases the service life of the gears if compared with their operating in dry conditions.

3.4 Machining

For a correct operation on the technopolymer spur gears, the mechanical machining has to be made by positioning the clamps on the teeth, as shown in the Fig.3. The diameter of the clamps must be turned by referring to the tip of the gear.

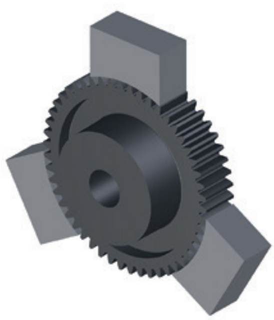


Fig.3: Gears machining

3.5 Materials

ELESA spur gears and racks are made of glass-fibre reinforced polyamide based technopolymer. The main mechanical characteristics of this type of material are:

- high resistance to torsion and tensile strength (about three times higher than acetal resin)
- good resistance to high temperatures
- a low friction coefficient, especially if compared to steel. Accordingly, the technopolymer gears can be used even when lubrication is not allowed
- low specific weight, a greater lightness of technopolymer gears over metal gears
- high dimensional stability, high resistance to wear and chemical agents

4. APPLICATIONS

The transmission elements in reinforced polyamide based technopolymer are an efficient alternative to metal transmission elements and can be used in all applications requiring noise reduction or the avoidance for the need of lubrication. The lightness of the technopolymer transmission elements allows their application in fields requiring a general weight reduction as well. Moreover, the technopolymer's high resistance to chemical agents limits corrosion in aggressive environment.

The steel gears are often oversized for the effective application they are used for: in this case, the technopolymer gears are an excellent solution and ensure a good mechanical resistance combined with an economical saving.

Application fields for technopolymer gears are various:

- Packaging and conveyor machines
- Industrial cleaning machines
- Glass and ceramic working machines
- Catering equipment
- Typographic industry
- Agricultural machines
- Chemical and pharmaceutical industry
- Household appliances

6. GLOSSARY

Addendum
Height of the top land, ie the part of the tooth between the pitch circle and the addendum circle.

Addendum circle
Circle that delimits the top of the tooth.

Backlash
Distance between the teeth of two gears coupled to each other. The backlash can also be conceived as the difference between the real distance between the centers of the shafts on which the gears are mounted and the operating distance measured as the sum of the pitch rays of the two toothed gears. A negative backlash (with a real distance lower than the operating distance) brings the teeth of the gears to be closer to each other, resulting in greater contact between the teeth and therefore a greater difficulty in the gearing, with the risk of seizure. A positive backlash leads to a reduction in the risk of seizing but, if excessive, reduces the contact between the teeth limiting the transmitted torque and lowering the transmission efficiency.

Bottom land
Part of the tooth that lies below the pitch circle.

Circular pitch
Distance between two homologous points of two consecutive teeth, measured along the pitch circle. The circular pitch allows to calculate the gear module and is a fundamental measure to evaluate if two toothed gears can be coupled: toothed gears with different pitches cannot mesh with each other.

Dedendum
Height of the base of the tooth, ie the part of it that is between the root circle and the pitch circle.

Driven shaft
A cylindrical transmission element of various length and thickness, which receives motion from a driving shaft or a driving gear.

Driving shaft
Cylindrical transmission element of various length and thickness, to which the driving force generated by a machine is applied and which transmits motion and power.

Face of a tooth
Lateral surface of the tooth lying above the pitch circle.

Face width
Axial size of the tooth.

Flank of a tooth
A lateral surface of the tooth lying below the pitch circle.

Friction
Frictional force that occurs in the contact between two bodies pressed against one another, which hinders their relative movement. The presence of friction implies a loss of mechanical energy, dissipated in heat.

Gear
Mechanism used to transmit movements from one shaft to another, by means of a pair of toothed parts, mostly gears. It generally consists of two or more toothed gears, which can be of equal or different size.

Lubricant
A substance, generally liquid, used to minimise friction between two surfaces that are creeping over one another and used to protect mechanical parts subject to wear. For Elesa gears it is recommended to use lubricating greases based on lithium soaps and synthetic oil.

Module
Ratio between the pitch diameter of the gear and the number of teeth of the gear. It is one of the parameters characterising the teeth of a gear: so that two gear wheels can mesh, they must have the same module.

Operating distance
Theoretical distance between the centers of the shafts on which the gears are mounted. It is given by the sum of the pitch rays of the two toothed gears.

Pinion
In a two toothed gear system, the pinion represents the smaller diameter wheel. It is also the toothed gear that mates to a rack (considered as an infinite radius gear) to transform the translational motion into linear or vice versa.

Pitch circle
Circle along which the contact of the pair of toothed gears occurs.

Pressure angle
Angle between the tangent to the pitch circle and the normal to the tooth surface, both taken at the point where the pitch circle comes into contact with the tooth surface. It is a fundamental feature of the toothing: only gears with the same pressure angle can be coupled together.

Rack
A rack is a linear gear (a gear with infinite radius) that together with a toothed gear, called a spool or pinion, is used to convert the rotary motion into continuous linear motion or vice versa.

Root circle
Circle that delimits the base of the tooth.

Space width
Length of the arc of a pitch circle between two consecutive teeth. It represents the empty space between two teeth.

Spur gear
Gears with teeth parallel to the cylinder axis that allow the transmission of motion between two parallel axes.

Tooth
Protruding element externally or internally from the root circle and allowing, by contact with another tooth of a second transmission element, the transmission of the torque or force between two different transmission units.

Tooth thickness
Length of the pitch circle arc delimited by a tooth.

Top land
Part of the tooth protruding from the pitch circle.

Wear
Consumption of a material due to rubbing with other material.