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A WEAR DEVICE FOR PLASTIC GEARS

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Abstract

Our goal was to design and build a device that allows the investigation of wear for plastic spur gears. In the initial phase of the design process, cost-effectiveness was at the forefront. The device is part of a license project for the Faculty of Mechanical Engineering at Sapientia Hungarian University of Transylvania and it will be used for research purposes in the Polymer Technologies Laboratory of the university. The designed test equipment allows the investigation of plastic spur gear wear properties at different loading and rotational speeds.

Keywords*: spur gears, wear, plastic, design.*

1. Introduction

The spur gear has a cylindrical cross-section, with teeth located on the surface. Spur gears are most commonly used to transfer the rotating motion from one shaft to another. There are several other choices regarding the transfer of rotating motion or torque from one shaft to another, however gears are exclusively used when slip between the two rotating parts is not permitted.

Spur gears are used in different industrial application, for example in agricultural machines, automotive transmissions, electrical home appliances, tools etc. The usability of spur gears is also widened by their increased load bearing nature. The high precision, high load bearing and high rotational speed can be seen as advantages of spur gears.

Steel is the material of choice for gears. In the case of metal as raw material, there are four types of base material to choose from, depending on the applied stresses and the use of the gear: non-alloy or low alloy steel, stainless steel, case hardenable steel and nitride steel. Each of these materials has its advantages, for example, hardened steel is more durable, nitrideable steel can be used to increase the insertion strength, but the highest strength is achieved with case hardened steel.

Depending on accuracy and productivity requirements, gears can be manufactured using the profiling process, a disc mill or finger mill, or the hobbing method. The hobbing method can be carried out by using a gear rack, gear hobs or gear shaper cutters. These processes, although widespread in industry and highly productive, require large and expensive equipment. Consequently, in an increasing number of applications, metal gears are being replaced by plastic gears.

Plastic gears have unique advantages over metal gears, including high efficiency, quiet operation, no external lubrication is needed and lower production costs. As a shortcoming, it should also be mentioned that the load bearing properties of plastic gears are inferior to that of metal gears. However, one of the most important consequences of their use is the significant weight reduction **[1]**. As a result, they are widely used in the automotive and aerospace industries, as well as in household and various appliances

Several technologies exist for the production of plastic gears. Machining processes are used for low volumes, but injection moulding is an economical way to produce high volumes. Over the last 10-15 years, however, 3D printing technology has become increasingly popular for the production of polymer substrate parts. 3D printing is cost-effective compared to plastic injection moulding when the production volume is below 1000 units.

The disadvantages of plastic gears include lower wear resistance, due to the friction generated by the gear drive causing them to heat up and wear more quickly. According to the literature, there is a large difference in wear between injection molded gears and 3D printed gears. At a torque of 5 Nm, injection molded gears can withstand up to 2.4 million cycles. In contrast, 3D printed gears fail after only 0.018 million cycles. Wear can be divided into three distinct phases, a high wear initial period, a linear wear period and a final rapid wear period. In all cases, the failure is caused by high temperature [2, 3].

2. Gear wear machine

2.1. Working principle and 3D model

The 3D model of the desi gear wear device is shown in Figure 1. The gears under test (16) and (17) are mounted on the driven shaft (7) and the drive shafts (13) respectively. The gears transmit the torque to the shaft by means of latches. The rotary movement of the drive shaft (13) is ensured by a monophase electric motor (10). Speed control is facilitated by the use of an inverter. The axis distance can be varied in the interval of 50 and 125 mm by means of a crank (14) fixed to a spindle and a nut (15) fixed to the movable table

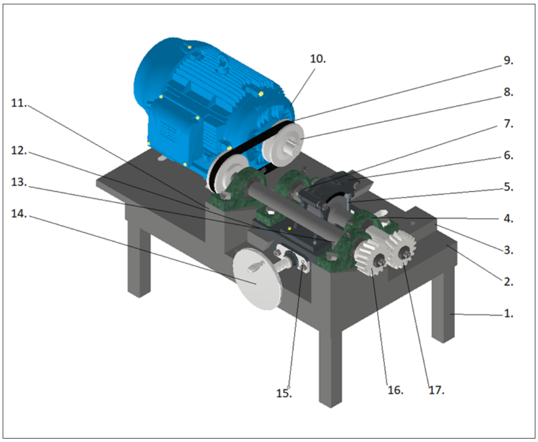

Fig. 1. *3D model of the gear wearing equipment: 1 - frame, 2 - base plate, 3 - Dovetail slot, 4 - bearings, 5 - weight support rod, 6 - brake system, 7 - drive shaft, 8 - belt pulley, 9 - belt, 10 - motor, 11 - support frame, 12 - slide table, 13 - drive shaft, 14 - drive lever, 15 - drive nut, 16, 17 - gears to be tested.*

(12). The spindles are fixed by a ball bearing (4). To achieve minimum shaft clearance, the drive shaft bearings had to be raised and tilted relative to the driven shaft bearings, as the retaining screws would have prevented the shafts from rotating. A tilted support frame (11) was therefore formed and fixed to the base plate. A brake disc (6) is mounted on the driven axle (7), to which a brake pad is connected, thus creating the braking effect. The braking torque is generated by applying different masses. The solution ensures that the torque remains constant after reaching the operating temperature.

2.2. The structure of the machine

2.2.1. Frame

The device is based on a frame structure, as shown in Figure 2. The legs of the frame are made of 25×25×2.5 mm angle steel and the upper part of 30×30×3 mm angle steel by welding. The frame is 160 mm high, 430 mm long and 265 mm wide. The holes in the upper part of the support structure are for the screw heads, which are formed by the bolted connections of the accessories fixed to the base plate. The frame and the base plate are connected by means of 4 M8 screws, which are cut to required length.

2.2.2. Base plate

The base of the unit is a 12 mm thick metal plate with dimensions 490 mm long and 265 mm wide. The base plate is fixed to the frame structure. On the base plate are the other components of the equipment, which are fixed by M8×25 screws with an ISO 4762 standard internal keyway bolt. This fitting allows the components to be positioned afterwards. Also visible on the base plate is a channel 14 mm wide and 80 mm long. Its role is to allow the free movement of the weight rod

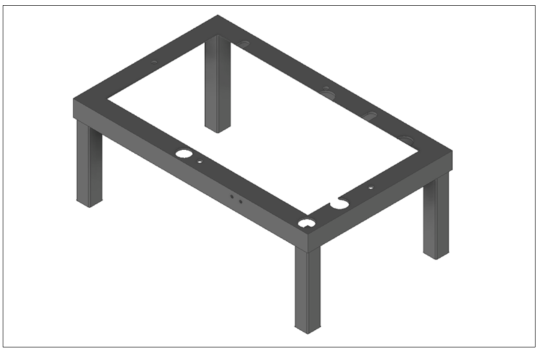

Fig. 2. *The 3D model of the frame.*

when changing the distance between the axis. Furthermore, it has four short channels which are used to tension the belt between the motor and the drive shaft. A 3D model of the motherboard is shown in **Figure 3** .

2.2.3. The moving plate

The driven axle is mounted on the movable table and a spindle is used to adjust the desired axle distance. All parts of the structure are made of metal and machined with a milling machine. The movement is generated by an M14×110 spindle which turns in a nut fixed on the table. This creates the linear displacement. The table consists of three parts. Parallel to the base, at a distance of 270 mm between the two uprights, are two 220 mm long, 45 mm wide and 21 mm high pair of dovetails, fixed by three bolts each. A 30° cut is made longitudinally, from the inside towards the bottom. The table rests on these two dovetails. Under the moving table there are also two shorter dovetails with the following dimensions: 130 mm long, 45 mm wide and 20 mm high. As a result of this method, the table can only move in the direction of the longitudinal axis. The bearing housings of the driven shaft are mounted on the two edges of the table. A 3D model of the moving table is shown in **Figure 4**.

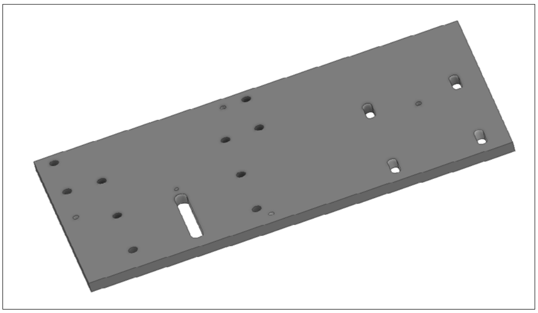

Fig. 3. *The 3D model of the base plate.*

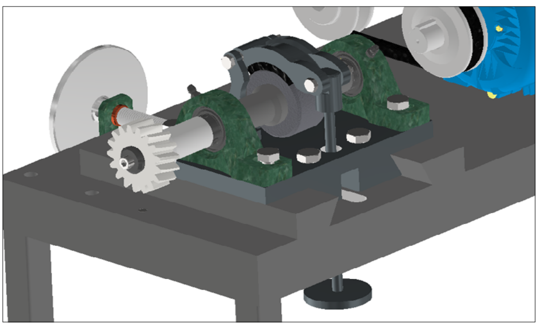

Fig. 4. *The 3D model of the moving plate.*

2.2.4. Angled support

The positioning of the driven axle is necessary to achieve the minimum axle distance. Positioning is provided by the two supports shown in **Figure 5**. The elements are made of 40 mm thick plate. The workpieces are made from scrap metal, which reduces the production cost. In addition, the machining was carried out on a milling machine. The upper plane of the support is positioned at an angular offset of 23° to the base, thus preventing the axles and the chassis bearing housings from colliding when the minimum axle distance is set. There are also two M8×30 holes on the top to fix the bearing housing.

2.2.5. Shafts

The equipment has two axles. In order to minimize the shaft clearance, the bearings of the drive shaft are positioned between the bearings of the driven shaft. Both shafts are manufactured on a lathe from c45 material. The length of the shafts is 331 mm. The drive shaft is connected to the motor by a belt drive. The gears transmit the torque to the shafts by means of a latching connection, and an M6×20 bolt connection ensures constant positioning in the axial direction. Measured from the bearing housing, the gear is located at a distance of 10 mm. The distance between the two bearing housings is 201.5 mm. On the drive shaft, the gear is located 42.7 mm from the bearing. At the opposite end of this shaft is a centering hole. A 3D model of the propeller shaft is shown in **Figure 6**.

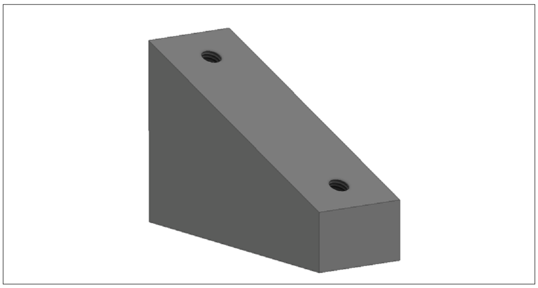

Fig. 5. *The 3D model of the angled support.*

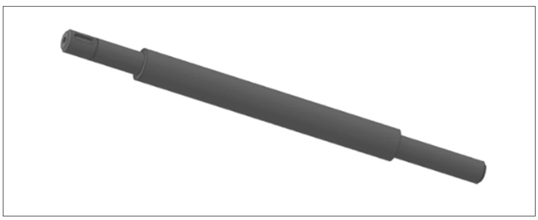

Fig. 6. *The 3D model of the drive shaft.*

A shorter length (249.75 mm) was specified for the drive shaft. The gears fixed to the two shafts must be in the same plane. The gears are also fixed by means of a latch and a locking screw. The bearing is located 69.75 mm from the end of the shaft. The space between the two bearings is 120 mm, in the middle of which a 30 mm wide brake disc will be located. The brake disc will also be secured by a latch. The other end of the axle can be used to retain the bearing. This end of the shaft also has a centering hole. A 3D model of the driven shaft is shown in **Figure 7**.

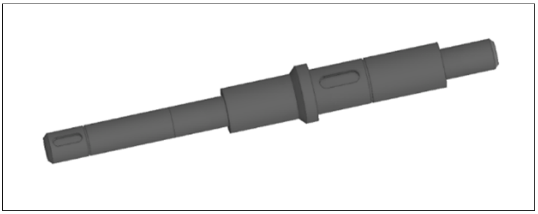

Fig. 7. *The 3D model of the driven shaft.*

2.2.6. Braking mechanism

The braking mechanism consists of five parts: a stand (1) which raises the brake disc (2) 57 mm on either side of the brake disc (2), and a brake insert (3) on which a brake pad (4) is fixed. In order to create a larger surface area, the brake shoe follows the curve of the disc at 100°. The braking torque is provided by means of load weights placed on the brake lever (5). This method has been chosen because it has proved to be the simplest way of providing a constant braking torque. The braking mechanism is shown in **Figure 8**.

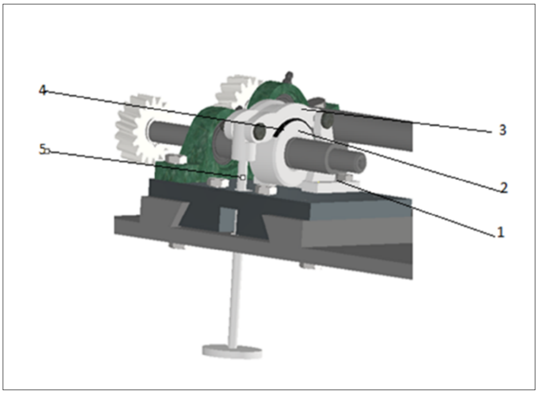

Fig. 8. *The 3D model of the breaking mechanism.*

3. Conclusions

We have successfully designed a device that is capable of testing the wear properties of plastic gears. 3D modelling was used to identify design flaws. We were able to correct these errors during the design phase, thus avoiding the production of defective or inappropriate parts. The production was entirely carried out by myself in my own workshop. In the majority of cases I used a milling machine and lathe for machining. This was an excellent opportunity to gain insight into the execution of a complex task. Small adjustments were also made during the production process to achieve a better result.

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