

# Construction of magnetorheological device for finishing of non-metallic materials

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**Abstract.** The paper deals with nano-finishing processes and nano-finishing processes in the presence of an external magnetic field. There is a construction of magnetorheological device for finishing of non-metallic materials and subsequent verification of the functionality on the change in micro-roughness of the PA-6 material.

## 1. Introduction

Magnetorheological polishing is a finishing method where a polishing effect is achieved in the presence of a magnetic field and a magnetorheological (MR) suspension generally consisting of magnetic microparticles, e. g. carbonyl iron powder (CIP), abrasive grains, carrier fluid, and other additives [1-3]. This composition gives the system specific field-responsive properties. The field-responsive properties of the MR suspension increase with increasing external magnetic field. When the relative movement between the MR suspension and the workpiece occurs, the normal force acts on the abrasive grains and the reaction shear forces the material in the form of micro- or nano-chips [4-8]. These chips mix with MR suspension and reduce machining efficiency. This results in wear, so it is necessary to replace the used suspension at regular intervals in order to minimize the decreasing MR effect as a negative phenomenon [9-10].

## 2. Construction of the device

The proposed device is designed only for planar surfaces. The repeatability of the speed control, the direction of rotation, the parallelism between the polishing surface and the polished surface must be ensured. Only non-metallic materials can be polished using the developed machine. The individual constructional elements of MR device are following.

### 2.1. Magnet drive design

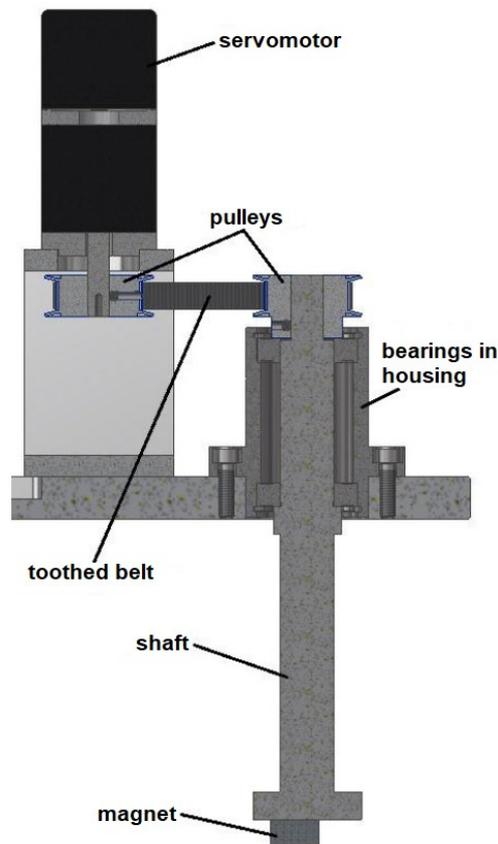
The first step in designing the construction of MR device for finishing of non-metallic materials was to determine the magnet drive. To achieve the torque transmission, toothed belt transmissions have been chosen to guarantee high torque transmission accuracy. Their advantages include (i) a form-fit in which they work without slip, (ii) can carry heavy loads with low space requirements and (iii) are quiet. The bearings do not require pre-stressing, which reduces their stressing. They do not require maintenance and lubrication. Among the disadvantages of toothed belts is the susceptibility to lateral slip of the belt, therefore at least one pulley is provided with a flange. In the vertical position of the pulley axes, both pulleys must be provided with guide flanges. In order to ensure a quiet and calm running of the belts, it



is necessary to maintain a sufficient parallelism of the pulley axes. The average permissible value is  $\pm 0.25^\circ$ .

### 2.2. Determination of the carrier drive

The Z axis, which is equipped with a position indicator with a resolution of 0.01 mm, was chosen to ensure repeatability of the distance between the carrier and the workpiece. The material of the shaft was chosen low carbon steel W.Nr. 1.0038. The trapezoidal screw Tr 20 × 4 is used to convert the rotary motion into a sliding motion. The cylinder on which the magnet is attached has a thickness of 10 mm as seen in figure 1. The maximum stroke of the axis is 212 mm.

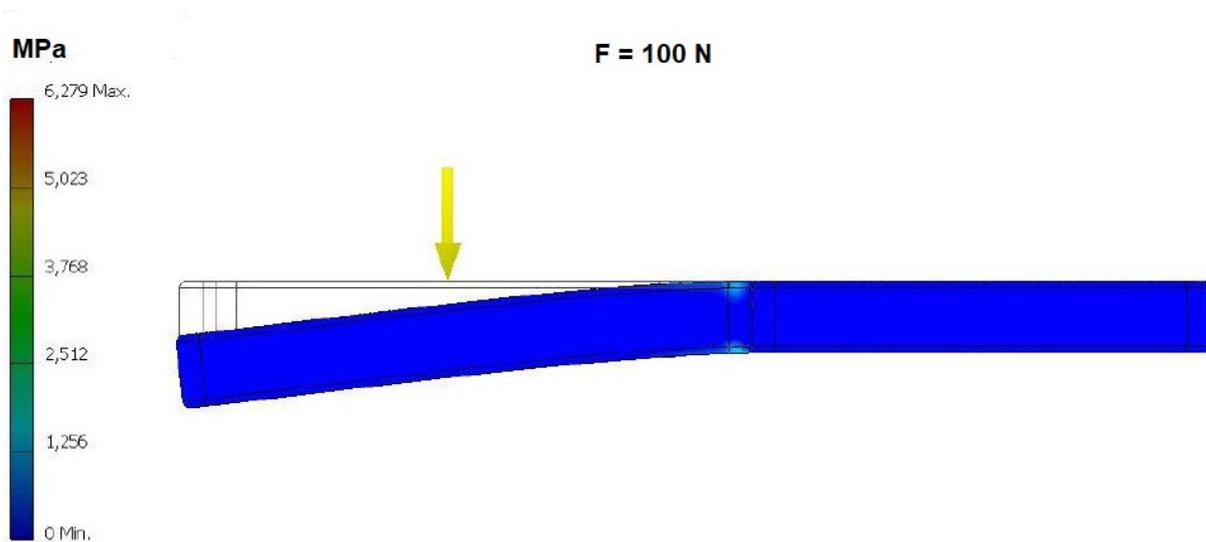


**Figure 1.** Scheme of the magnet drive. Check calculation

Ball bearings were chosen to accommodate the rotary parts. These bearings are designed for small and medium loads and can carry a part of the axial load in addition to the radial load. High stiffness bearings, such as ball or roller bearings, cannot compensate for misalignment. That compensate for only a very small misalignment when there is almost no load. The most stressed part is the plate that carries the drives. For this board the calculation was performed in the CATIA program as shown in figure 2.

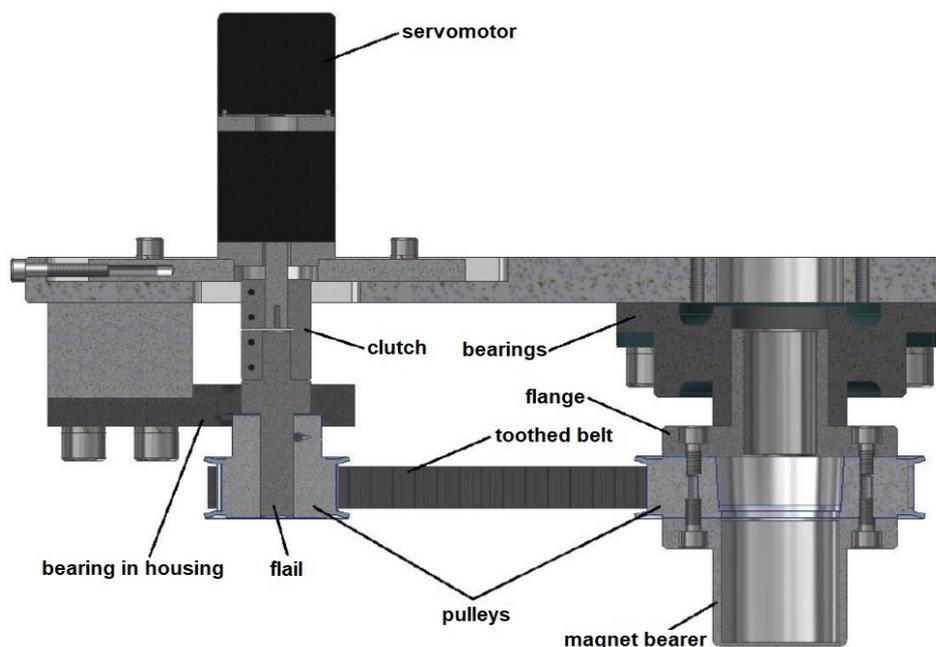
### 2.3. Description of output technical properties

The device for polishing non-metallic materials is designed for polishing any flat surface with a maximum dimension of 40 x 40 mm. The size of the gap between the material and the magnet can be controlled by a mobile mechanism in the range of 0 – 160 mm with an accuracy of 0.1 mm. The rigidity and vibration damping of the entire system ensure the specific arrangement of the plates and the position of the motors relative to the polishing axis (figure 2).



**Figure 2.** Verification of the mounting plate.

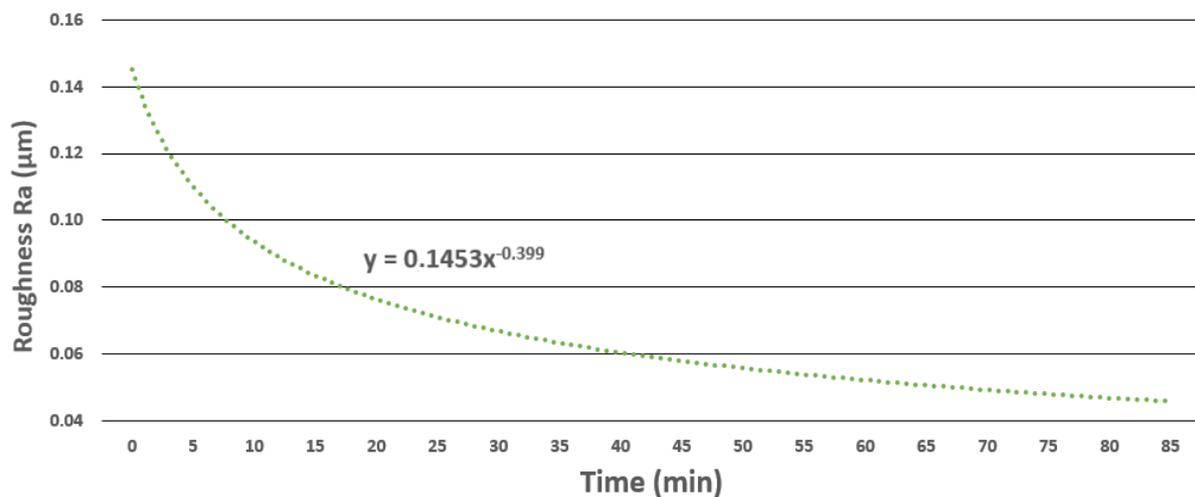
The motors also ensure speed control and smoothness of the entire polishing process. The whole device is low maintenance, which complements the overall environmental and energy-saving process in general. With the above advantages, a better surface finish can be achieved than with the conventional lapping method. A mobile mechanism is mounted on the base, which is primarily designed to adjust the distance between the magnet and the sample (including the MR suspension). It also serves for the vertical movement of the main part of the mechanism. It contains two 100W motors designed to rotate the magnet placed under the cover. Belts connecting the motors to the shaft mechanism allow this movement as seen in figure 2. The sample is located in a vice, which ensures the flatness of polishing between the magnet and the sample.



**Figure 3.** Scheme of the carrier drive.

### 3. Verification of the functionality of the device

The functionality of the device was verified on PA-6 RAVAMID B, which was dried at 80 °C for 12 hrs before testing. The test samples (20 × 20 mm) were injected on an Arburg Allrounder 470 E Golden Electric. The mold temperature was 50 °C, the injection pressure was 1 200 bar, the pressure time was 15 s, and the entire cycle lasted 48.5 s. Each test sample was then cast into GAFORM D30 resin and cured for 1 h. Subsequently, 10 samples were subjected to a polishing test, where the surface quality was evaluated using a Mitutoyo SJ-410 roughness tester according to ISO1997 at regular intervals of 5 min until there was not significant improvement in the resulting surface. The polishing medium used was MR suspension containing CIP (60 wt.%), water-based magnetic fluid (30 wt.%), and alumina (10 wt.%). Figure 4 represents the polishing curve expressed as dependence of surface roughness,  $Ra$ , on the time of polishing. Evidently, the equilibrium of  $Ra \approx 0.06 \mu\text{m}$  was obtained after 25 min of polishing using the MR suspension.



**Figure 4.** Polishing curve using MR suspension.

### 4. Conclusion

Polishing of ten PA-6 samples for 1.5 hrs in the presence of the MR suspension has proven the functionality of the device. All the samples showed a surface improvement of at least 34 %. Furthermore, it has been shown that the proposed suspension has polishing properties for polishing non-metallic surfaces and will be subject to further investigation.

### Acknowledgement

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