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PECULIARITIES REGARDING THE RECONSTRUCTION OF A CILINDRICAL GEAR DAMAGED

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Abstract

The work remark peculiarities that appeared in the reconstruction of an cilindrical gear damaged. The originality of subject consists in the realization of 3DPrint design, in the material changing which increased the reliability of the piece, baxed on the drawings of the reveal, executed according to the original damaged model, the proposed working method allows for the reconstruction of the entire damaged gear system, as well as the creation of a physical model using unconventional rapid prototyping technologies. The work enables the definition of a model for analysis and rapid prototyping for the reconstruction of damaged components made from plastic materials in small-scale, unique series. Based on the 3D model, tests/simulations can be performed on a series of different materials utilized by FDM technology to identify the best plastic material variant used for gear teeth.

Keywords: gear, design, CAD, 3DPrint, FDM

1. Introduction

Argument: "For the machinery park to work with maximum, economic efficiency of mechanization and works automation, in addition to rational exploatation and the proper maintenance, the organization must be ensured and performing current and capitals repairs at a high technical level as well as of assemblies". [1]

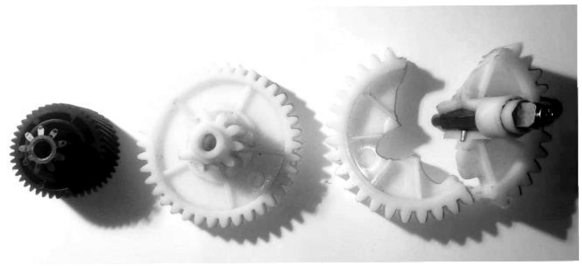

Fig.1 Cilindrical gear damaged

Studied the cilindrical gear damaged can be seen in fig.1. The first findings on the damaged piece are:
- is made through injection up of polyamide;
- identification of a method for revealing the cylindrical profiles of various partially damaged gear teeth;
- reconstruction of the cylindrical gear of the damaged teeth through manual revealing and dimensional identification of the cylindrical gears;
- based on the 3D model, rapid prototyping models are defined using FDM technology;
- the 3D/CAD model subsequently allows for the physical realization of the designed components from metallic materials, utilizing CNC technology.

This procedure is not presented in the article.

In Fig. 2, you can see the principle diagram of the gear mechanism is presented. The reconstruction of the geometry of the gear teeth is defined by the correct positioning of the conjugate gears; the principle diagram is necessary to identify the gearing ratios as well as the axial distances of the gearing segments.

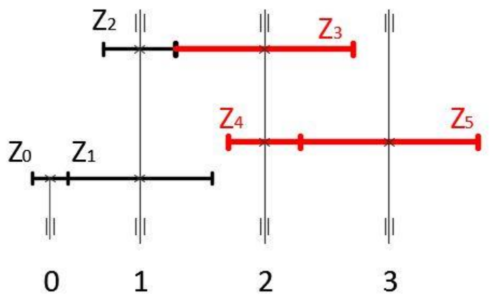

Fig.2 Cilindrical gear diagram

The gear mechanism is defined by 6 gears arranged in a speed-reduction gear system, in 3 stages of gearing, from the pinion (axis 0) to the output shaft (axis 3). [2]

Axis 0 represents the input of motion into the gear mechanism from the motor shaft to the reducer, where the transmission ratio $R_1 = Z_0/Z_1$ represents the first stage of speed reduction.

Axis 1 presents the input of motion into the mechanism through a monoblock assembly of two gear teeth made of metallic material (which are in perfect working condition with intact teeth); the transmission ratio $R_2 = Z_1/Z_2$ represents the second stage of speed reduction.

Axis 2 features an intermediate monoblock assembly of 2 gear teeth that takes the motion from the pinion and transmits it to the intermediate section, reducing the transmission ratio in the third stage of speed reduction.

Axis 3 presents the driven conjugate wheel, which transmits the output speed, reduced from the mechanism. The total transmission ratio is given by the relation (1):

$$Ri = \frac{Z_0}{Z_1} = \frac{Z_2}{Z_3} = \frac{Z_4}{Z_5} = i \qquad (1)$$

Z_0 represents the engagement with the motor shaft (the input of rotational motion into the reducer gear mechanism). The reconstruction of the gear mechanism involves reconstructing the damaged gears, specifically Z_3, Z_4, and Z_5. The teeth of the cylindrical gears have a straight, involute profile, where Z_3 = 9 teeth, Z_4 = 36 teeth, and Z_5 = 32 teeth.

2. Working method

The proposed method for revealing the geometry of the damaged gears is defined by identifying the geometric profile of the teeth for the pinion and the conjugate wheel. [3],[4]. The tip and root diameters of the tooth profile can be determined for each gear. These dimensions represent actual measurements that can be considered when determining the involute profile. In Fig. 3, the presented method is illustrated in the AutoCAD environment.

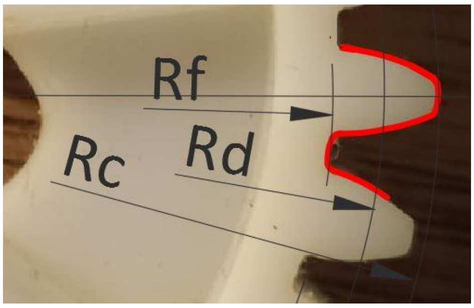

Fig.3 Releveu profil generator

The involutes profile is determined using an orthographic image for each tooth; the reference image is created through photocopying, after which the orthographic image is imported into the AutoCAD environment, scaled to the actual dimensions utilizing the measurements taken from the source model, and a new layer is created to define the scaled reproduction of the involutes profile for each damaged tooth.

The reference diameters identified from the original model of the damaged gears are located on an axial plane placed over the orthographic image that has been scaled to the initially measured dimensions.

The reference radius for the damaged reference points are identified in Fig. 3 and are as follows:

Rc - defines the tip radius of the tooth profile;

Rd - defines the radius of the pitch circle;

Rf - defines the root diameter of the tooth profile.

The construction stages of the new cilindrical gear damaged:

- determining the dimensions of damaged for each piece by hand made drawing sketch;
- the execution of drawings nedeed (2D);
- CAD – 3D model for each part of cilindrical gear redesigned;
- material choosing;
- establishing the way of manufacturing the part;
- determining 3DPrint procedure required for manufacture.

Based on the generating profile models associated with each damaged gear tooth, the execution drawings necessary for creating the 3D models defined within Autodesk Inventor are established.

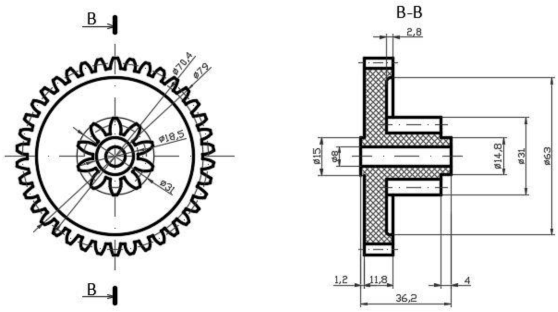

Fig.4 The execution draw of first gear damaged (pinion)

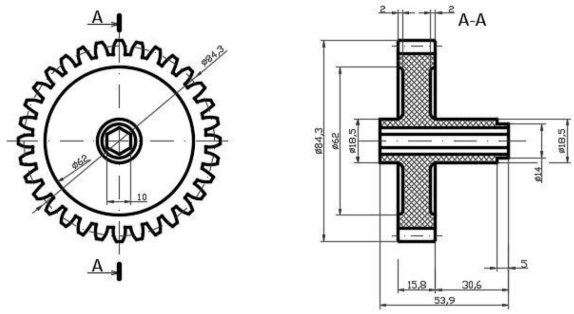

Fig.5 The execution draw of secund gear damaged

In Figs. 4 and 5, the execution drawings associated with the damaged gears are presented, based on the sketches resulting from the reconstruction of the tooth profile geometry from the original model, utilizing the AutoCAD environment.

2.1. Dimensions of piece and execution drawing

Dimensions determining of defective piece from fig.1. it was achieved with some difficulty due to advanced state of deterioration caused by impact.

Two micrometers of exterior with an aperture of 0-25 and 25-50[mm] were used for the measurements, having an accuracy of 0.01 [mm] and a caliper with rod having an accuracy of 0,02 [mm].

CAD design media AutoCAD/Inventor-Autodesk, it was used to elaboration the drawings present in this paper.

The cilindricale gear assemblies are shaft-hub assemblies designed to transmit torque and rotational motion. [4], [5].

The shape of the gear protrusion is identified with the rectangular profile, but the piece being made of polyamide, will not insist on aspects related to the precision of execution (with external centering, with internal centering or with centering on the flanks). Argument:

„Regardless of the category in which they fall, plastics have a high specific coefficient of expansion due to the Van der Walls bonds (week bonds) between the chains and their conformation". [6] [7] .

2.2 Choosing of material for cilindrical gear

The main framings of polyamide are: "Polyamide 6 (PA 6) and Polyamide 6.6 (PA 66). But by modifying the chemical structures (chain length and chemical organization), several other families of polyamides are obtained: PA 4.6; PA 6.10; PA 10.10; PA 11 and PA 12." [8]

There was no insisted for determining type of polyamide that made up the defective piece, because another material will be chosen. The argument for this option is:

- it is desired to use a material with better properties in terms of impact/collision at breakage;
- because the piece will be machined by splintering, newly chosen material must have technological and thermal properties superior to the original one;
- for the physical manufacturing of the gear mechanism, it is proposed to use unconventional FDM technology, based on the 3D model to obtain the conjugate components of the gear.
- Since defining the classical technology for producing cylindrical gears requires a high degree of difficulty regarding the tools used for gear cutting, and for the pinion gear (Z3-Z4), the processing of the tooth profile is very challenging to achieve, it is only possible to use the shaping process with a shaped cutter through direct division; thus, the execution of the gear mechanism presents a technological difficulty;
- In the case of using CNC technology, the processing of the pinion becomes technologically complicated, given that it is a common body with the intermediate gear.

2.3. Machining of the new gear

„Of all technological processes necessary for execution of equipment, machinery, machines, the one of mechanical processing is most complex", [4]

"The notion of manufacture derives from two latin words ***manus*** (hand) and ***factus*** (to do), resulting combination meaning "hand made". "Hand made" accurately described the manual methods used until the word "manufacture" was coined around 1567" [2] „and used as a verb, it first appears around 1683".

Next, piece will not be "hand made" totally, so we have „the elements of technological process of mechanical processing are: operation, placement/position, phase, passage, handling and movement". [4]. For the completion of gear manufacturing, unconventional rapid prototyping technologies are used [9], [10].

The 3D model is defined in the Autodesk Inventor design environment, taking the tooth profiles defined in the AutoCAD environment, based on measurements taken from the reference sketch. In Figs. 6 and 7, the resulting 3D models of the gears are presented.

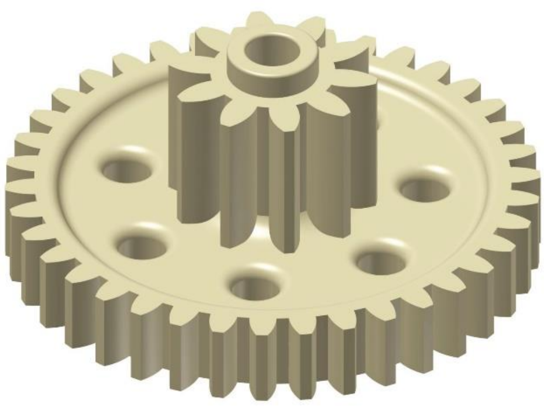

Fig.6 The 3D model of first gear damaged, Z_3-Z_4

The cylindrical gear being partially damaged, the sketch of the layout could be easily created, especially since there was no advanced wear on the tooth surface.

For the first component (Fig.6), the surveying problem was more straightforward due to the partial damage, and the layout was easily accomplished through direct measurements. For the second component (Fig.7), the surveying technique initially involves assembling the damaged components through bonding, followed by the dimensional determination of the tooth geometry.

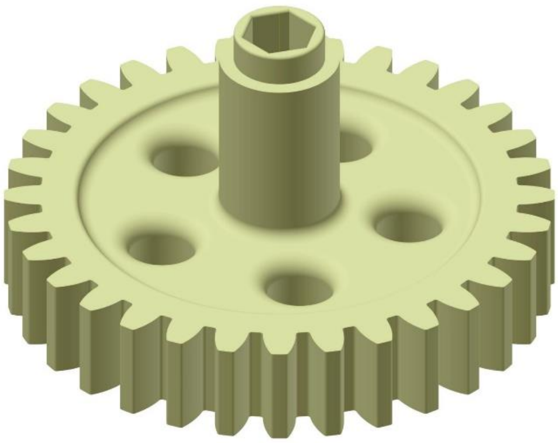

Fig.7 The 3D model of secund gear damaged, Z_5

2.4. 3D Printing Manufacturing

The manufacturing process involves the following stages: establishing working parameters specific to the type of material and filament used for the production of components, as well as defining the G-code for generating printed models. The working environment utilizes the Repetier-Host program for each model initially edited in Autodesk Inventor. The importation of 3D models into the 3D Printing environment is done using the STL extension.

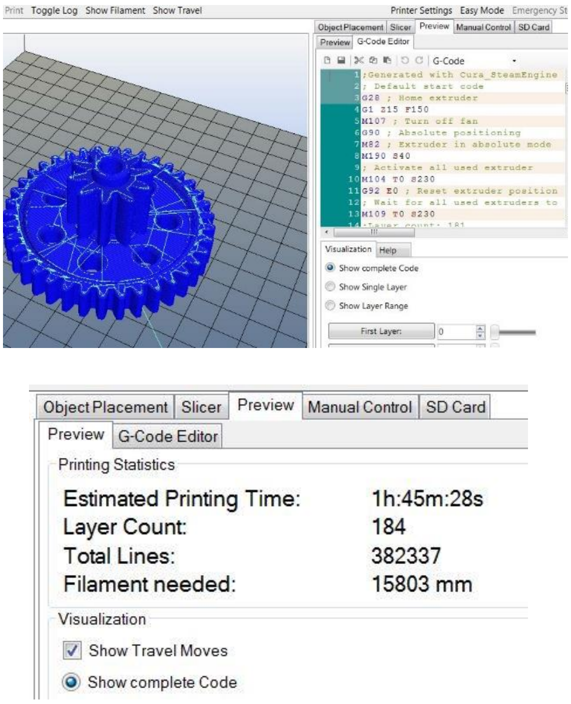

Fig.8 The 3DPrint model of first gear redesign, Z_3-Z_4

In Fig. 8, you can see a screenshot from the G-code source program associated with the gear component Z3-Z4 is presented.

The working parameters set for the pinion gear are as follows:

The material used is PLA type with a filament diameter of 1.75 mm; Printing temperature: 210°C;

Print bed temperature: 60°C; Estimated printing time t_1: 1 hour, 45 minutes, and 28 seconds;

The actual time was adjusted according to the printer's working speed, resulting in a final total time t_2: 4 hours and 42 minutes.

In Fig. 9, you can see a screenshot from the G-code source program associated with the gear component Z5 is presented. The design in the Inventor environment adheres to all dimensions initially surveyed based on the source model, and the 3D models can also be utilized in various simulations and animations with VR for educational study or in the case of using CNC technology for manufacturing components from different types of metallic materials.

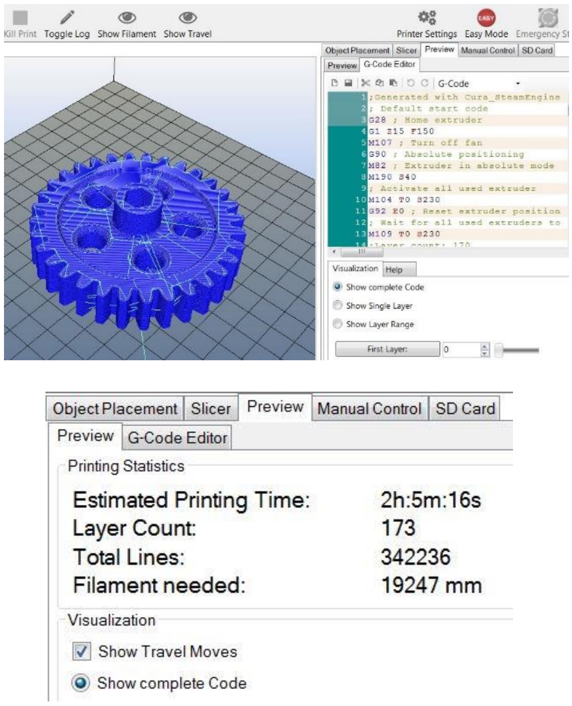

Fig.9 The 3DPrint model of secund gear redesign, Z_5

The material used is PLA type with a filament diameter of 1.75 mm; Printing temperature: 210°C;

Print bed temperature: 60°C; Estimated printing time t_2: 2 hour, 5 minutes, and 16 seconds;

The actual time was adjusted according to the printer's working speed, resulting in a final total time: 5 hours and 12 minutes.

The printing speed is 60 mm/s for the outline, while for the filling, the printing speed is 100 mm/s, with 100% infill. To ensure better wear resistance, printing was performed at maximum volume, without gaps between the printing layers. For filament economy, technological gaps were defined for each gear, arranged equidistantly in a radial pattern.

3. Results and discussion

Total timed time: 1h measurements + 1h parametric modeling of two drawings + 1h 55' 3DPrint + 8h 54' = TOTAL - 11h 39'. It is not possible to assess whether the realized time (11h 39') is more or less, this is. It would be desirable a theoretical calculation of time, for edification.

In Fig. 10, you can see a sequence from the printing process can be observed, specifically the print bed was set to a minimum in order to conserve material. For the printing, a magnetic metal foil bed with a silicone base was used, which allows for a much more stable adhesion of the first layer during printing. The removal from the bed can be done after returning to ambient temperature (T = 20°C). Due to the elastic properties of the metal foil, the separation is accomplished easily.

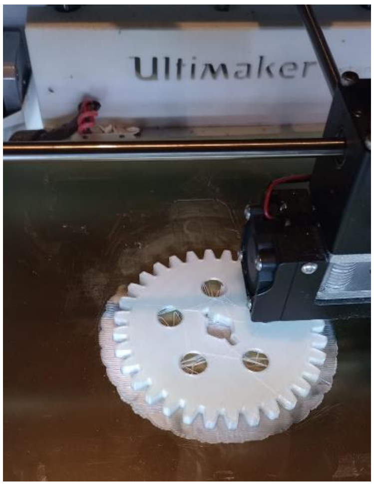

Fig.10 Manufactured of the 3DPrint model

In Fig. 11 you can see the final version of the parts manufactured using unconventional 3D printing technology is presented.

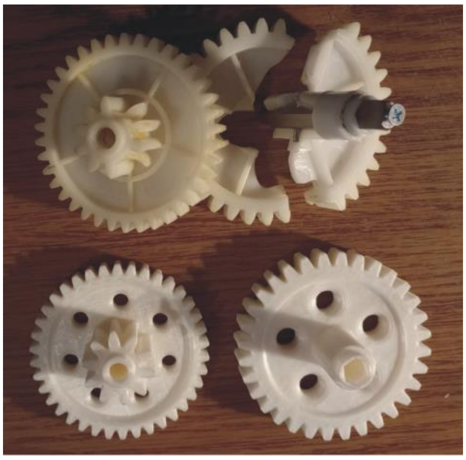

Fig.11 Cilindrical gear:
a.model 3DPrint, **b**.model sursă (original)

4. Conclusions

The article proposes an effective method for addressing and designing the reconstruction of damaged industrial components.

Dimensions of defective piece have been determined, in the Inventor-Autodesk enviroment, necessary 2D şi 3D drawings were designed, all the necessary nonconventional technological steps, necessary were completed.

Was possible to the piece fabricate in required parameters, according to endowment of the laboratory, no other faster or cheaper fabricate ways are disputed (3D printing or by other CAD/CAM ways), it would be interesting of an comparison in this sense.

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