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THE INFLUENCE OF CONTOUR NUMBER ON LOAD CARRYING CAPACITY OF GEARS IN AIRCRAFT GEARBOX DEMONSTRATOR MADE BY MEM

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Abstract

The paper presents an outcome of load carrying tests of gears in an aircraft gearbox demonstrator made of ABS B601polymer by means of INSPIRE D290 device. These tests checked an influence of an additional number of contours in gear models on durability of cooperating wheel pair during stand tests.

The CAD models of the gears for stand tests were made in Autodesk Inventor program and were used as a base for making physical models. Therefore, Inventor files were exported to STL format. The following stage of data preparation was made in Model Wizard.

The gears for stand tests were made by means of MEM method on INSPIRE D290 printer. Unlike most devices, this printer makes it possible to control not only the density of the filling in a model, but also to increase the number of contours. ABS polymer was chosen to make the gears. The choice was due to its good properties and because it is commonly used and also because it was possible to make the parts of the gearing at the Rzeszow University of Technology. Subsequently the gear pair was fixed on a test stand. The stand was designed in an open system. It was powered by a three-phase 0.75 kW electric motor. The control was provided by a single-phase inverter. Load on the stand was provided by an electromagnetic powder brake.

This paper is a part of implementation of the research task number 4 „Development of a new, simpler and cheaper toothed gear in place of complicated and expensive planetary gears" of the project „Modern material technologies in aerospace industry."

Keywords: *test stand, Rapid Prototyping (RP), an aircraft gearbox, gears*

1. Introduction

Rapid prototyping methods are nowadays widely used in many fields of technology [5, 7, 8]. Continuous development of aided design systems and methods of Rapid Prototyping allows for their use in making research prototypes [4, 6]. This process can be divided into three stages: 3D-CAD models, data processing for the purposes of RP devices and making physical models by means of RP methods.

2. Preparing models

Gears with the following parameters were adopted for stand tests:
- teeth number of pinion $z_1 = 27$,
- teeth number of wheel $z_2 = 53$,

- module m = 2 mm,
- effective facewidths b = 10 mm,
- total gear ratio u = 1.963.

The CAD models of gears for stand tests were made in Autodesk Inventor program. Teeth of the gears were shaped with rack-type tool by direct simulation of machining [3]. Solid models served as a base for making physical models. To this end, the CAD files were exported to STL format, which is the most widespread format of data in RP systems. Tessellation parameters play a very important role while exporting to STL format. These parameters (especially a density of a grid of triangles) directly affect the accuracy of the models imaging and the size of the received files.

The following stage of data preparation was made in the environment of a program intended to be a PR device support. The example presented here was created by means of ModelWizard program [2]. After importing files, the models were distributed on a working platform (Fig. 1). Fig. 1 also shows a dialog box for setting basic parameters. The program makes it possible to set up, for example, an additional number of contours. Photographs of examples of gear models with different numbers of contours and structure are shown in Fig. 2 (an inner structure of the model - Fig. 2a, b, d, standard filling of the outer horizontal surface - Fig. 2c). A kind of structure is determined by setting up parameters of the model density (applying an appropriate type and thickness of printed paths).

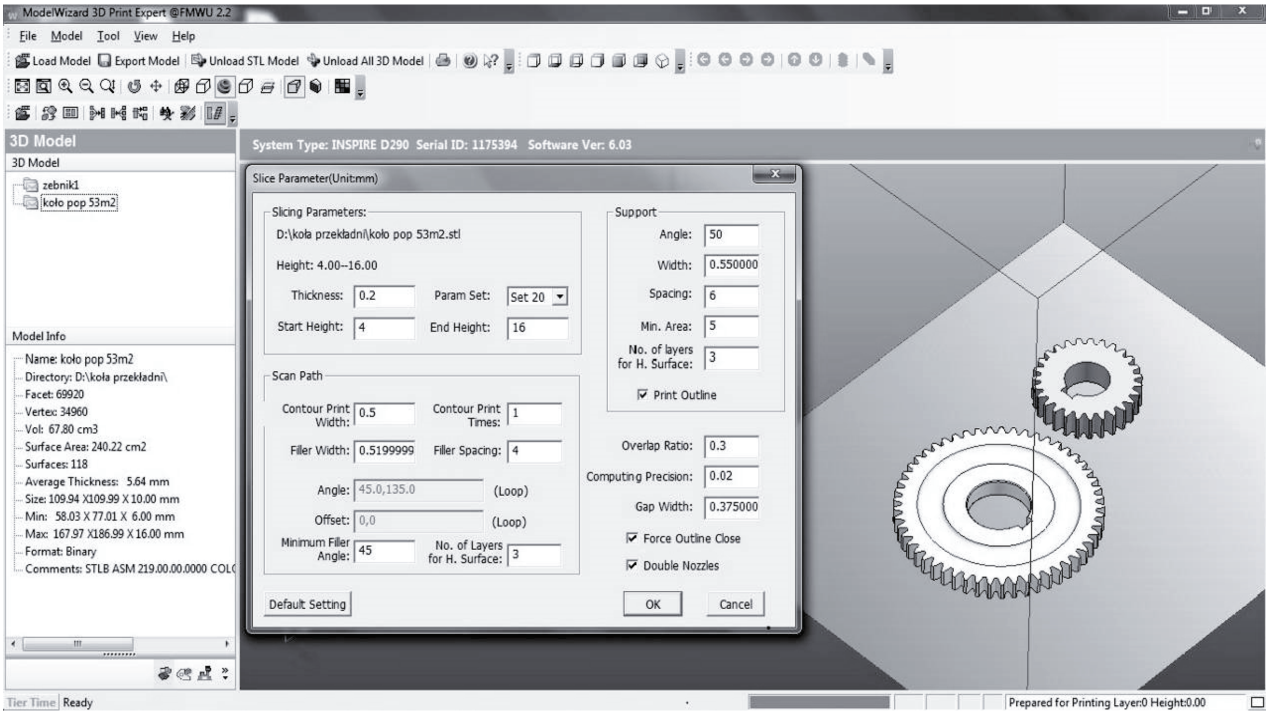

Fig. 1. Slicing parameters with the possibility of setting the number of contours

Because of the way of arranging material with a predetermined inner structure and radial distribution of gear teeth, the size of the space to fill in the area near contours is varied. As a result, the way of filling in these places is different (Fig. 2), and therefore the strength of individual teeth is not the same.

In ModelWizard, one can also select printing nozzles and get a preview of subsequent layers to be created. There is also a possibility of selecting several automatically defined settings concerning not only the print parameters of the model itself, but also the parameters related to supports. Their task is to combine a created model with a working platform. Depending on the complexity of the model, it is possible to set up a density of supporting structures.

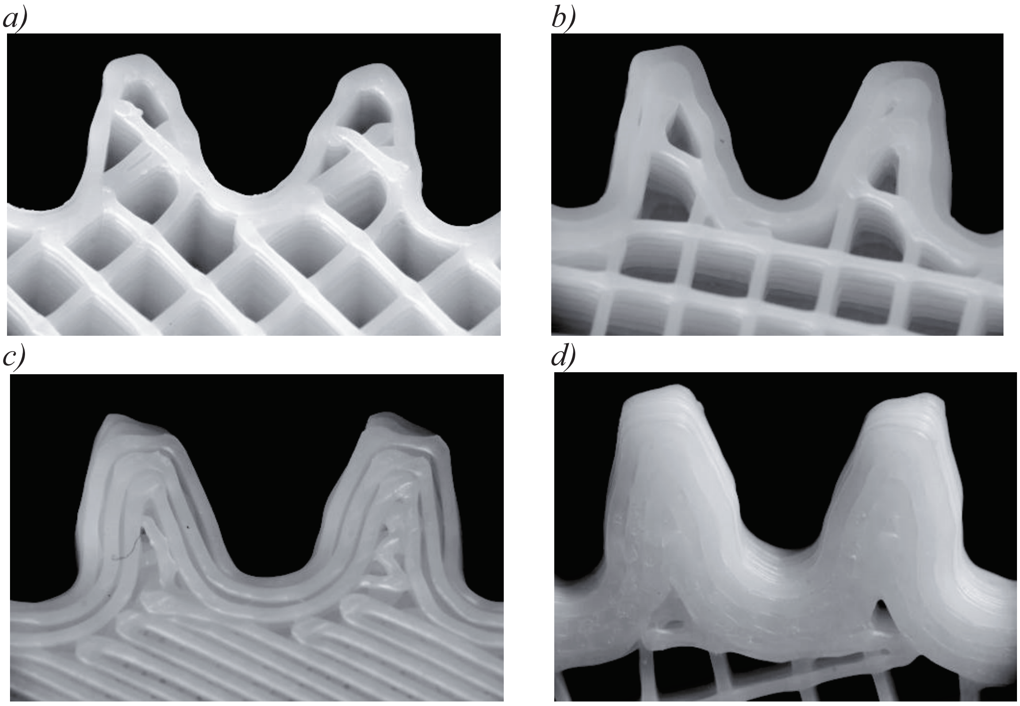

Fig. 2. Models of gears with different contour numbers: a) option I – with a basic contour, b) option II – with 1 additional contour, c) option III – with 2 additional contours and standard filling of horizontal surface, d) option IV – with 3 additional contours

When the parameters of the supporting structure are set appropriately, removing them after printing does not cause any problems.

The gears for stand tests were made on INSPIRE D290 device (Fig. 3) by means of MEM (Melted and Extruded Modeling) technology [1]. This is an incremental method, in which the model is built by layered application of thermoplastic material extruded in a temperature of about 300°C. The material used for making the gear was ABS B601 polymer.

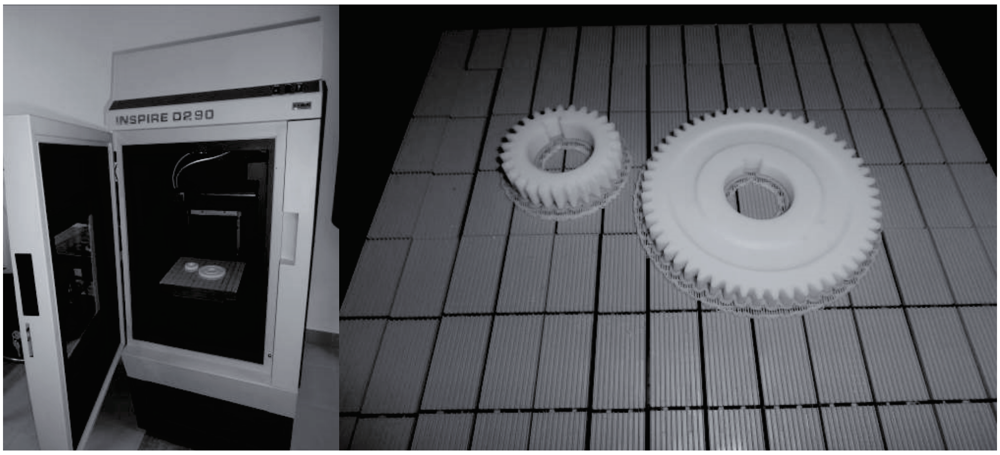

Fig. 3. Gear models made by MEM

The ABS material obtained by MEM differs by strength properties from the one made by injection. It is caused by the inner structure depending on the technique of arranging filament made of plasticized ABS polymer and on the applied software allowing for shaping the structure of a model with different density.

In the following stage, the models were detached from working platforms and supports were removed. Then the gear pair was fixed on a test stand.

3. Performing tests and analysing results

The test stand (Fig. 4) was designed in an open system. It was powered by a three-phase 0.75 kW electric motor. The control was provided by a single-phase inverter. The inverter was a frequency converter assuring full control of engine parameters. Load on the stand was provided by an electromagnetic powder brake. Torque incriminating gear depended on the supplied current.

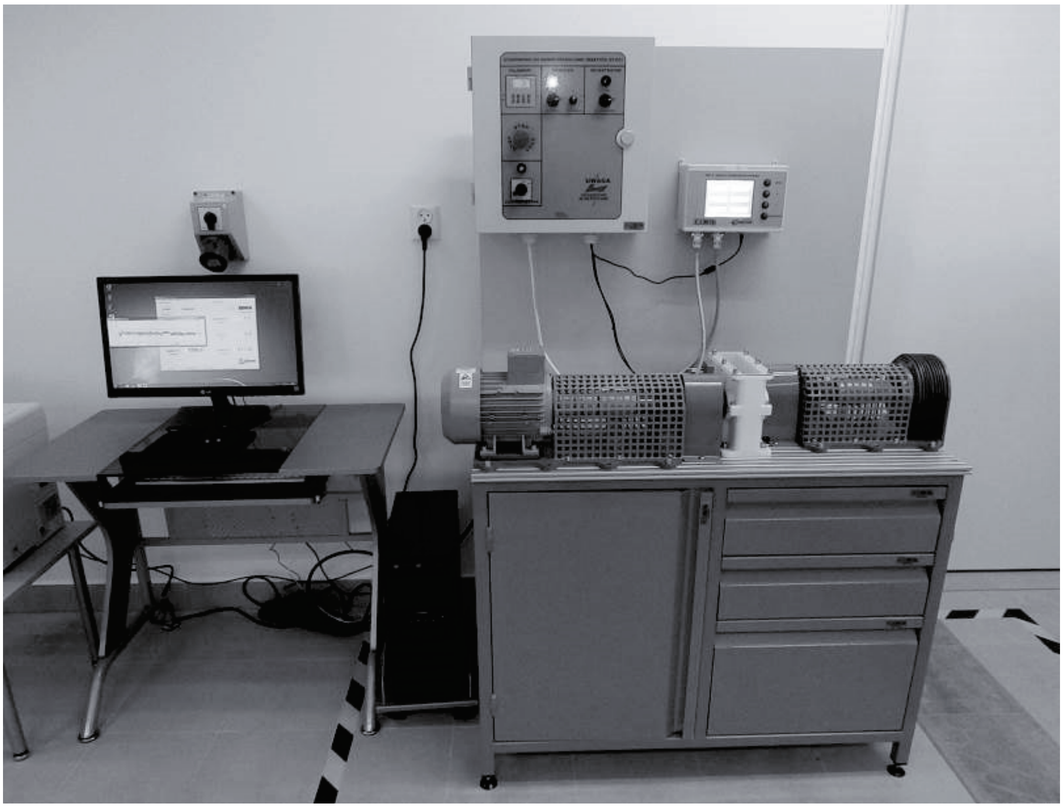

Fig. 4. The test stand

The stand was equipped with torque sensors and a recorder of RMC-M parameters. The RMC-M module was a standalone measuring device for registering parameters of the carried out tests. It was used for measuring and registration of torque, rotational speed and strength. The RMC-M application was designed to cooperate with the module of the recorder, which enabled recording the data. Moreover, it made it possible to calibrate, to determine the process parameters and to visualize the measurement data.

The aim of the research was to check the influence of contour number of gears made by MEM on their load caring capacity. The research schedule assumed a gradual loading of each prepared gear pair with braking torques in 30-minute time periods under different loads.

The first stage was performed without any load, at 1200 rotations per minute speed set on input by an inverter. The subsequent stages of work were held at the same speed, but with load set by an adjustable brake. The initial value of 2 Nm was incremented by 1 Nm up to the destruction of one of the gear wheels (Fig. 5).

During the course of work, it proved to be necessary to make a slight adjustment of the torque and rotation. Each phase of work of the transmission was recorded and saved in the RMC-M application at a frequency of 10 measurements per second, which gives a satisfactory record for quick changes to the registered parameters. A recorded course of each stage of the research was also registered in a TXT file, which made it possible to process the data in any other application.

The study used sets of wheels with 1, 2 and 3 additional contours and with the same kind of filling of the model.

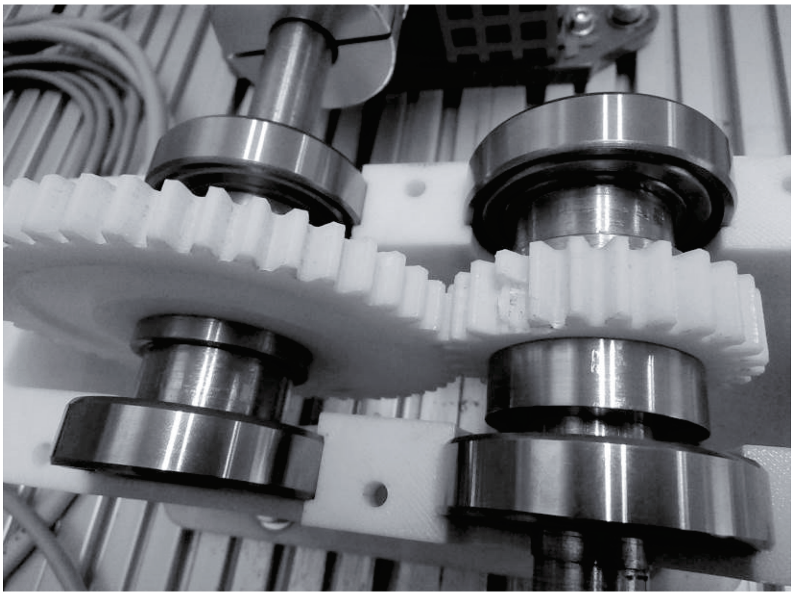

Fig. 5. The tested gears after finishing the research (the pinion is destroyed)

Several pairs of gears were tested for a given number of additional contours. Average operating times for a pair of gears to be destroyed is presented in Tab. 1.

Tab. 1. Average operating times of a gear pair depending on the number of contours for increasing load

Load	operating time for a given load		
M [Nm]	t [min]		
	Pinion 1*	Pinion 2*	Pinion 3*
2	30	30	30
3	30	30	30
4	30	30	30
5	25	30	30
6		30	30
7		13	30
8			20
** – pinion number indicates the number of additional contours*			

4. Summary

The use of CAD systems combined with rapid prototyping methods is an effective tool of making prototypes. Prototype models made of materials with appropriate characteristics can be used directly in stand tests. The carried out research makes it possible to determine the correctness of adopted solutions.

The strength of parts is mostly determined by properties of material of which they are made.

In case of Rapid Prototyping methods, most devices make it possible to control only the density of the model filling. On Inspire D290 printer, it is also possible to increase the number of contours, which enhances the strength of each part.

The previous research had proved that the relationship of operating time to load concerning the number of contours is not directly proportional. The reason for this may be the fact that with greater number of contours, each tooth of gears is filled with more material (in case of three additional contours, there is almost no empty space in teeth).

The possibility of introducing additional contours causes that, on one hand, it is possible to influence the increase of strength of parts made of plastic (which was confirmed by the research) and, on the other hand, an appropriate selection of strength parameters causes greater modelling similarity.

Acknowledgement

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