

## MODELLING AND PROTOTYPING OF AERONAUTICAL PLANETARY GEAR DEMONSTRATOR

Grzegorz Budzik, Bogdan Kozik, Jacek Pacana, Bartłomiej Żmuda

Rzeszów University of Technology  
Faculty of Mechanical Engineering and Aeronautic  
Powstańców Warszawy Av. 8, 35-959 Rzeszów, Poland  
e-mail: gbudzik@prz.edu.pl, bogkozik@prz.edu.pl

### Abstract

The article presents methodology of modelling and prototyping process for the demonstrator of aeronautical planetary gear. Contemporary methods of designing gear make use of computer aided designing systems (CAD), computer aided engineering (CAE) and computer aided manufacturing (CAM) including also rapid prototyping (RP). First stage of designing gear is always defining basic parameters of the gear work (among others: transmission ratio, rotational speed, power) determined by the gear destination. After carrying out the gear calculations it is possible to create 3D-CAD models of wheels and other elements of the gear. 3D-CAD systems are often equipped with a module for analysing geometrical parameters and cooperation of its individual elements e.g. the track of cooperation. A detailed analysis of cooperation of gear wheels' elements allows for early detection of construction mistakes of models and for deleting the mistakes. If 3D-CAD models are made correctly, it is possible to record the geometrical data in an appropriate format of numerical data. The following stage of making the prototype of the gear is preparing numerical data necessary for making the demonstrator by means of rapid prototyping method. The accuracy of making physical prototype depends a lot on the accuracy of 3D-CAD/3D-RP model made by means of processing the numerical data.

The demonstrator allows for analysis of constructional solutions of the gear based on physical model and for doing introductory stand tests. The paper presents the process of making the demonstrator of planetary gear applying 3D-CAD modelling and Rapid Prototyping. For making the physical prototype a Fused Deposition Modelling (FDM) method of Rapid Prototyping was applied.

**Keywords:** rapid prototyping, gear, CAD, FDM

### 1. Introduction

Epicyclic gears have numerous advantages and above all the possibility of getting big transmission ratio in spite of quite small size and generally greater efficiency than other gears. All these factors cause huge popularity of this kind of gear in aeronautical constructions. Implementing gear into a driving unit must be preceded by a process of calculations and three-dimensional 3D-CAD models must be created on the basis of the calculations. This kind of models can undergo kinematic analysis and an analysis of cooperation of meshings in CDA/CAE environment. Then one can create, using Rapid Prototyping, testing models which will undergo stand tests. This kind of tests make it possible to verify the calculations' results and the created 3D-CAD models [1-7].

### 2. Making 3D-CAD and 3D-RP models of planetary gear

As a result of an analysis of constructional solutions of aeronautical gear we chose an exemplary model of planetary gear with a transmission ratio  $i=5$ . The calculations were made in Mathcad program and were founded on a methodology applied in calculating this type of gear [4-6]. Then 3D-CAD models of the gear parts were created on the basis of the calculations. Subsequently the parts were put together (Fig. 1).

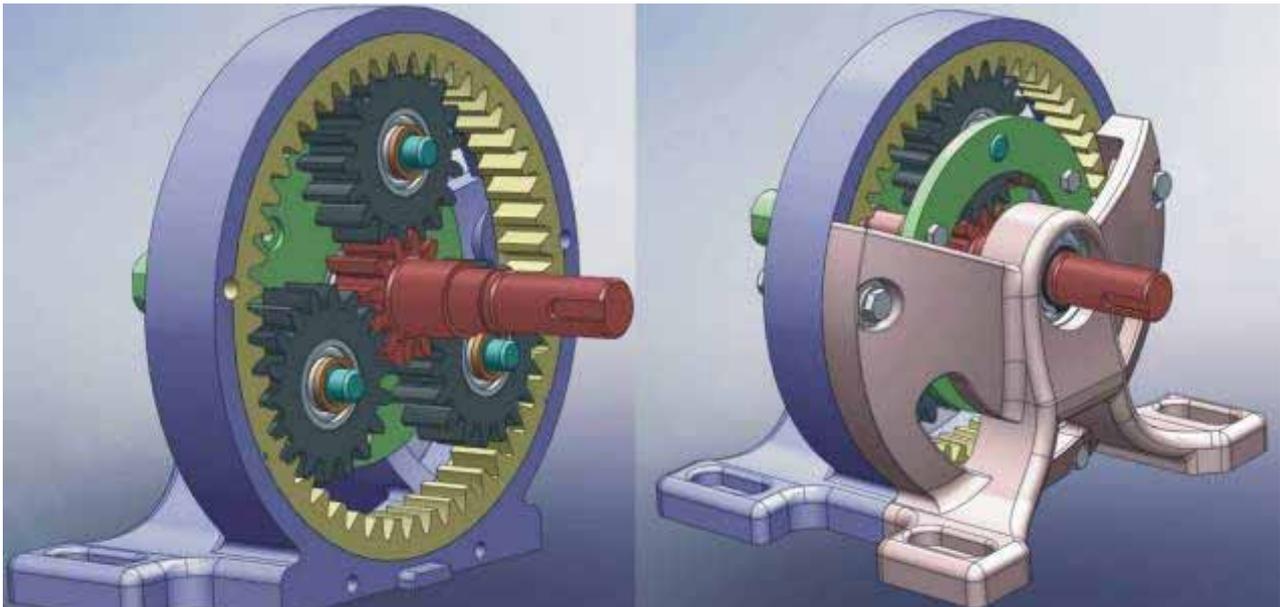


Fig. 1. A CAD model of planetary gear

The following stage of the designing process was an analysis of individual gear parts' cooperation [12]. An analysis of the meshing was made as an intersection of teeth in subsequent angle positions of gears (Fig. 2).

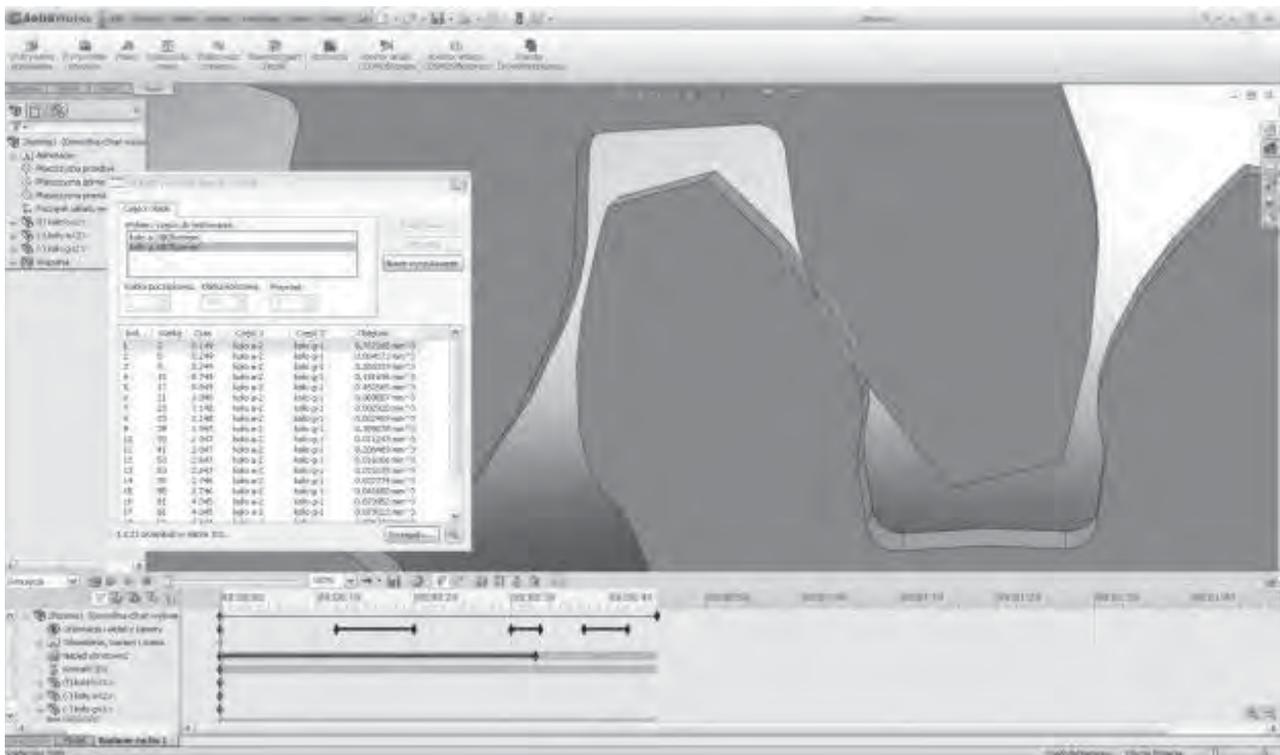


Fig. 2. An analysis of meshing cooperation on 3D-CAD models

The 3D-CAD solid models of all the elements of the gear were then recorded as a data read by Rapid Prototyping devices' software. The most widely used format of recording and reading data in RP systems is STL format [7] so this format was used in the numerical data processing. The STL format describes the surface of 3D-CAD model via a network of triangles. Fig. 3 shows 3D-CAD and 3D-STL models of one of the gears' case elements.

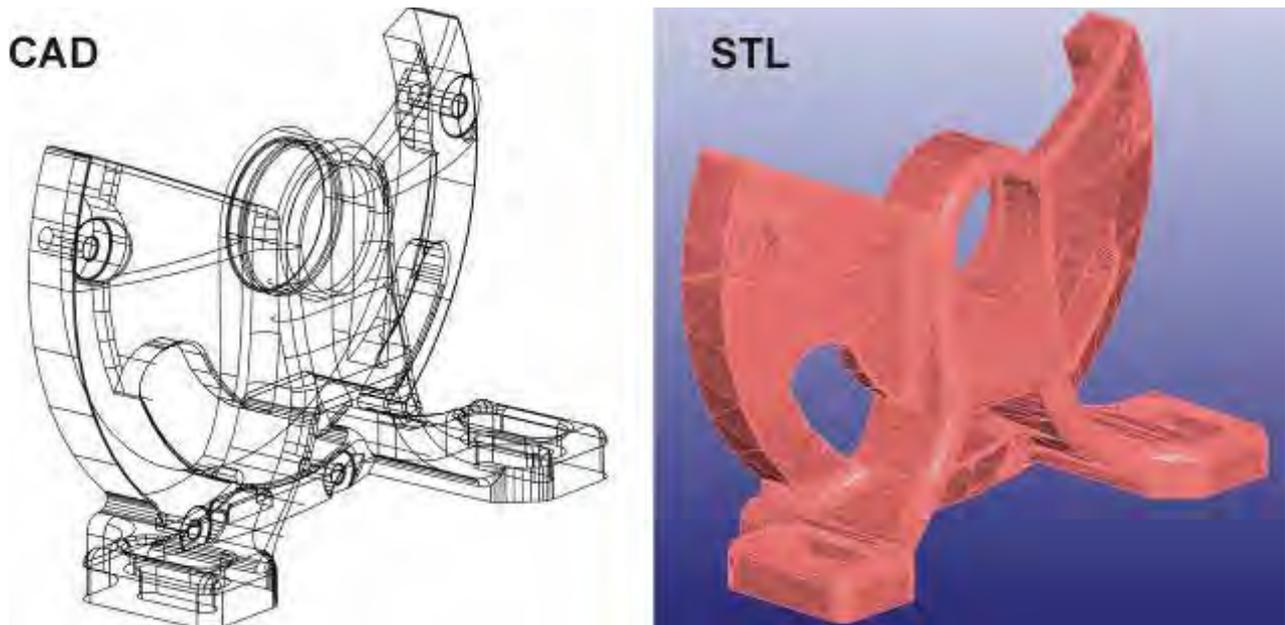


Fig. 3. A 3D-CAD and 3D-STL model of the gears' case element

### 3. Making the planetary gear prototype by means of FDM

The basis for making the research prototypes were models recorded in STL format which later underwent a program processing – a division into 0.254 mm thick layers using CatalystEX program on FDM machine - Staratasys. In this program the models were placed on a working platform's surface of U-Print device (Fig. 4).

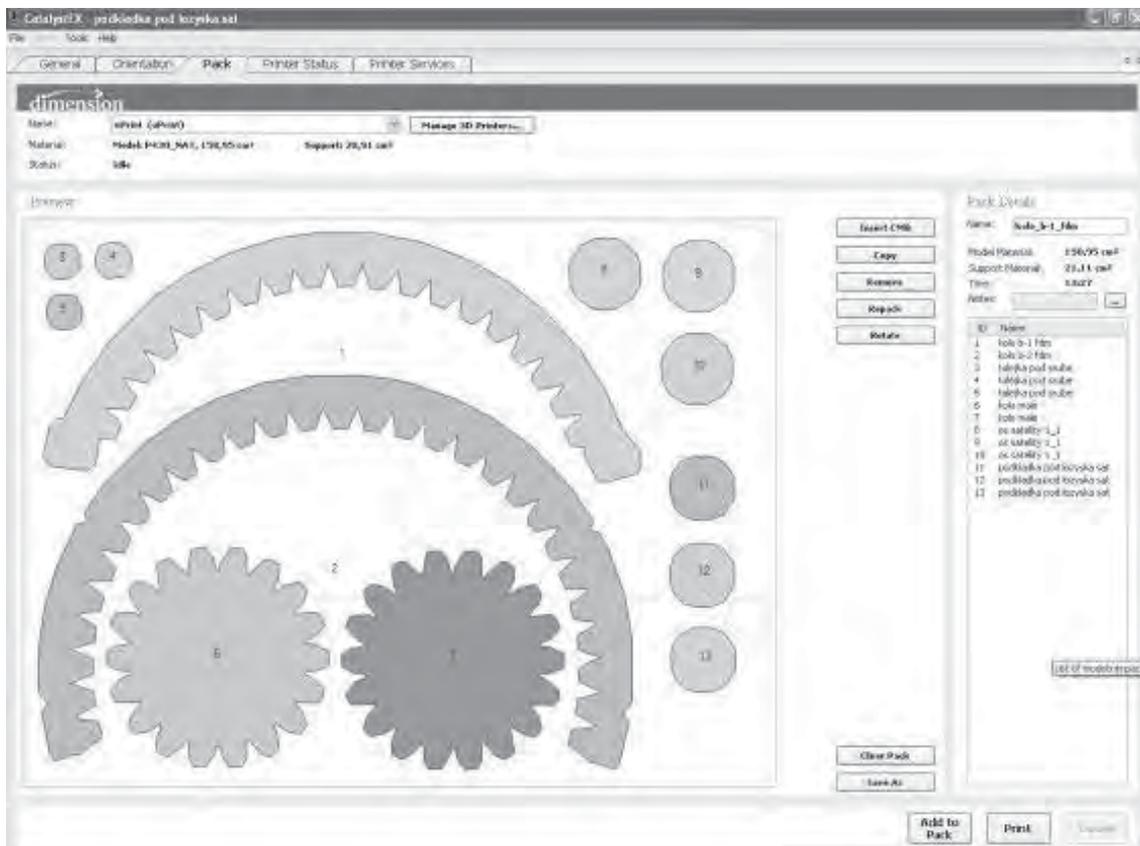
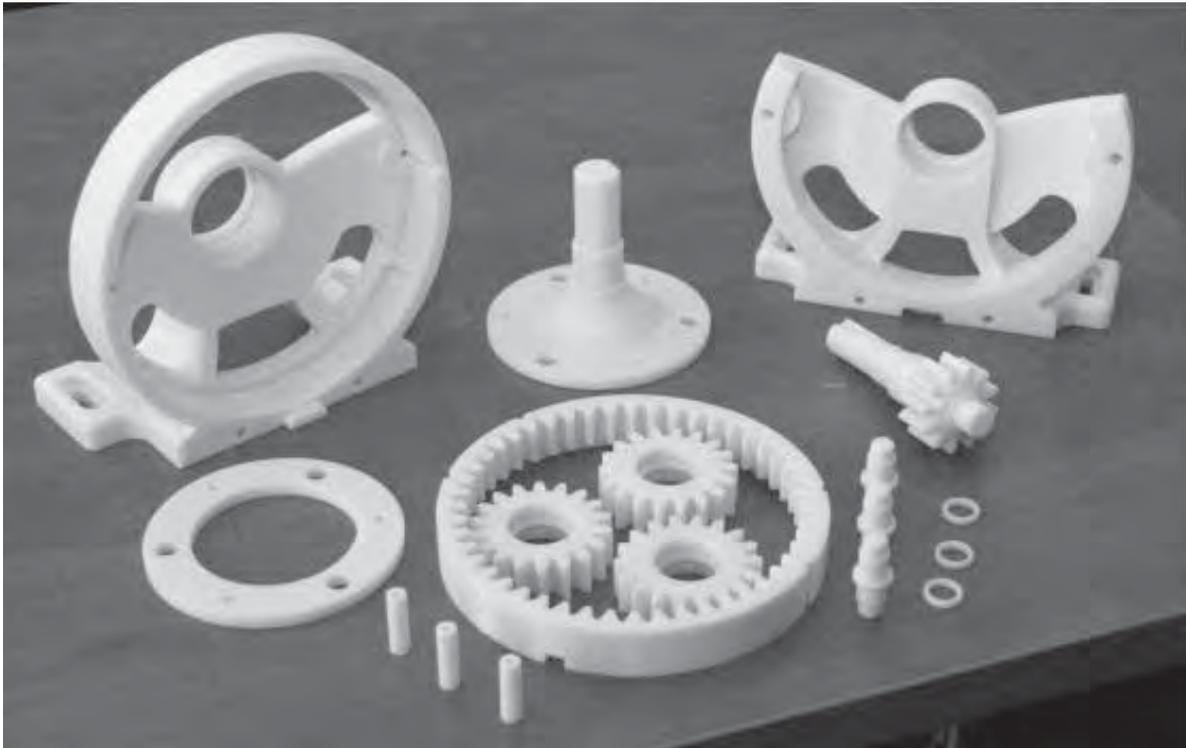


Fig. 4. The decomposition of elements on the working platform in CatalystEX program

In FDM a model is built of a material forced through a nozzle. The nozzle is fixed to shears which enable it to move horizontally. Vertical moves following y axis are made by moving the working platform. Putting all the movements together allows for arranging individual layers of material on a working space in accordance with the assigned geometry of the model. The put on layer of material solidifies and unites with a layer put on earlier [8-10].

In the process of creating the model a material for making the model is forced through one nozzle and the material for supports is forced through the other nozzle. This material is also supposed to combine the model with the working platform. The supports are made simultaneously with the model. For removing the supports easily they are often made of a material dissolving in water solution.

A few kinds of materials are used in FDM including waxes, ABS and polycarbonates [9-11]. The models of the research gear were made of ABS (Fig. 5) using U-Print device by Stratasys.



*Fig. 5. FDM models of the planetary gear's elements*

Then the individual elements of the gear were combined in a unit (Fig. 6) ready to be installed on a test stand.

#### **4. Conclusion**

Methods of computer aided designing CAD and computer aided engineering CAE together with Rapid Prototyping technologies allow for quick and that is why relatively cheap making research and demonstrative prototypes of aeronautical gears.

The research prototype presented in this paper was made by means of FDM and the material used was ABS. The properties of ABS and the applied mode of model construction (SOLID) make it possible to directly use the model for stand tests. The carried out introductory tests on models of this kind allow for analysis determining correctness of the applied designing methodology and the constructional solutions of planetary gear received on the basis of the above. In case of using other constructional materials than the material of the real gear, it is necessary to determine the modelling criterion of similarity to the target materials.



Fig. 6. A model of the research gear made by means of FDM

The next planned stage of making a prototype of aeronautical gear will be creating the gear's elements out of materials which have properties close to the target ones and then creating a prototype of planetary gear for testing in conditions complying with real loading.

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