THE ANALYSIS OF PRECISION OF MAKING ELEMENTS FOR AERONAUTICAL DUAL-POWER PATH GEAR DEMONSTRATOR APPLYING VENTURE BATY COORDINATE MEASURING MACHINE

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Abstract

The paper presents the process of measuring and analysing precision of making toothed wheels for a demonstrator of aeronautical dual-power path gear by means of FDM [2]. A coordinate measuring machine VENTURE BATY has been used in the research. The capabilities of the presented optical measuring machine make it possible to measure spur gears with different modules including small ones (m<1)which is a great advantage of this kind of measuring equipment.

Analysing precision of making elements of gears is one of more important stages in creating them [6]. However, it is necessary to remember that the controlling stage should be carried out in accordance with standards concerning measuring toothed wheels defining this activity. The measuring method presented in the paper and the outcome of measurements allowed for designing a demonstrator of dual-power path gear intended for stand tests. The correct operation of a gear is assured by proper choice of constructional parameters of cooperating wheels taking into account materials used in FDM technology.

The optical machine BATY is equipped with FUSION software used while measuring and analysing precision and it allows for data processing and exchanging the data with other programming environments. It is, however, restricted by one data exchange format – DXF. With regard to 2D measurement specific character, the machine does not make it possible to control tooth outline and as a consequence, it is possible to measure only gears with straight teeth. On the other hand, the advantage of the above is the possibility of comparing the measurement to CAD-2D model, which makes it possible to analyse the precision of wheels with non-standard profiles (other than envolute ones).

Keywords: *analysis of precision, coordinated measuring machine, dual-power path gear, demonstrator*

1. Introduction

The accuracy of gear elements' representation, especially in case of toothed wheels, determines its proper functioning both on a test stand and in real working conditions. It is especially important in case of multi-power path gears, including dual-power path gear. The dual-power path gear is one of multi-path solutions of power transmission where two paths are used to distribute the carried power [3, 4, 8]. In a classic multistage gear, gearing carries the whole power on each stage. In an analogous dual-power path gear, two gearings are found on each stage and they jointly carry the required power. That is why modules of these wheels are smaller and size of the gear is comparable to the size of traditional gear.

Analysis of precision of making toothed wheels with straight teeth and with small modules (m≤1) can be carried out on the basis of measurements done by means of a coordinate measuring machine. The machine measurement is based on detecting edges of a measured object on a measuring plane.

The paper presents the outcome of measuring selected toothed wheels for a demonstrator of aeronautical dual-power path gear by means of coordinate measuring machine VENTURE BATY.

2. A model of dual-power path gear made for the research

For making a 3D-CAD model of dual-power path gear we applied INVENTOR system which allows creating geometrical prototypes and makes it possible to carry out introductory analysis in order to confirm designing assumptions or to modify them [1, 7].

The toothed wheels' models have been generated on the basis of tooth profiles generated applying copyright computer programmes developed in accordance with INVENTOR environment. Subsequently 3D-CAD models of all gear parts (Fig.1a) and the prototype was made by means of FDM technology (Fig. 1b).

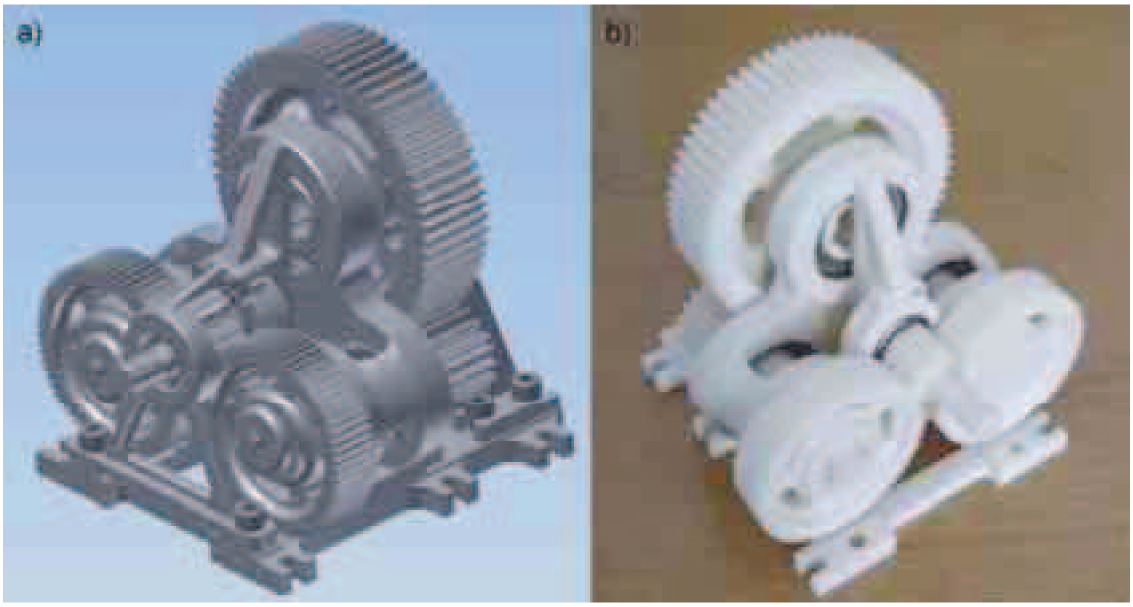

Fig. 1. A model of dual-power path gear: a) 3D-CAD, b) FDM

The basis for making the research prototype was 3D-CAD models recorded in STL format. The STL models were subjected to further program processing – divided into layers 0.254mm thick by means of Staratasys U-Print - StalystEX program attending the FDM machine. In the same program the models were also set on the plane of working platform of the device. Individual parts of the prototype; toothed wheels and body were made of ABS applying U-Print device. Some normalized parts were also used to build the demonstrator; rolling bearings and binding screws. After fixing all the parts we obtained a gear prototype ready for research.

3. Analysis of precision of making the gear wheels

Measurement of the toothed wheels' profiles was carried out on a measurement stand applying optical measuring machine Venture by BATY (Fig. 2a). The machine is equipped with rules of higher resolution with sliding fixing of Z-axis and it also has got lens with colour high resolution CCD video camera. Measuring system, which includes also LED lighting of the measured object and an automatic sensor detecting edges of image of the measured object, makes it possible to gather thousands of measure points within seconds. There are two ways of lighting the measured model: with top LED lighting integrated with measuring head or with bottom lighting going through glass pane of measuring table. Additionally the optical system is equipped with auto-focus working in CNC mode and with a system of finding focal point of the picture. During manual measuring the system assures fast and accurate detection of edges of the measured parts.

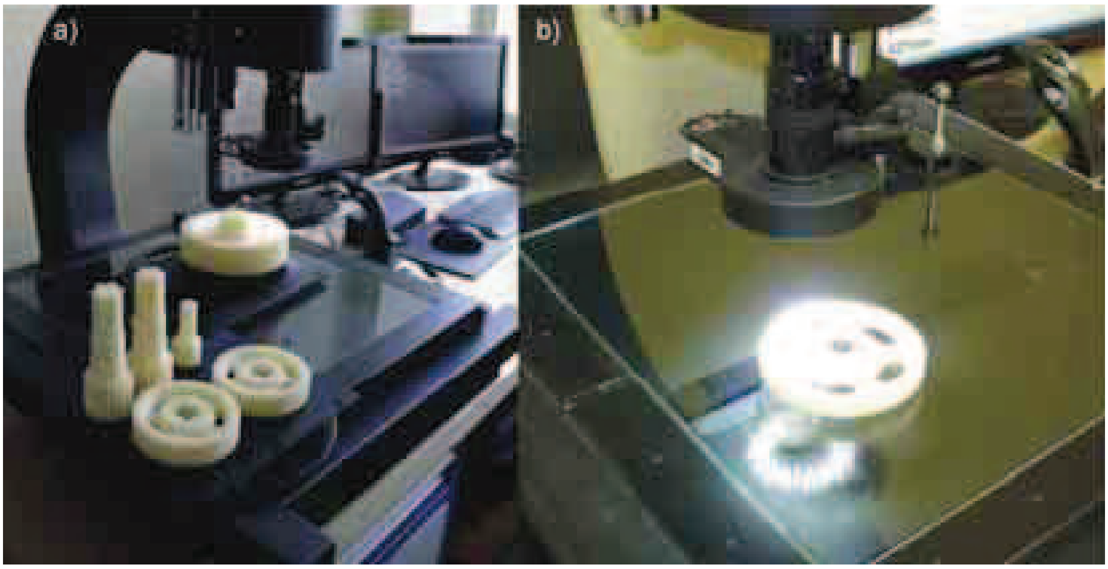

Fig. 2. A measurement stand with VENTURE BATY optical system: a) overall view, b) measuring a toothed wheel with light radiated from measuring head

Carrying out the measurement with optical measuring machine Venture BATY consists in detecting the measured edges of a detail and comparing them to nominal profiles. The measurement can be done automatically assuming that the measured detail has clearly outlined edges. In other cases, the measurement becomes time-consuming because it is necessary to join together fragments of measured profile. It is also difficult to adjust light and its intensity so that it allowed for detecting appropriate edges of the measured toothed wheels (Fig. 2b).

Specifically designed programmable head with lighting makes it possible to freely define which LED segment should be turned on. Thanks to that, one can get lighting to show different, optically difficult edges. Adequately adjusted lighting of the measured object assures high quality picture received from the camera. Fig. 3 shows a view of a gear-toothing fragment, which was measured.

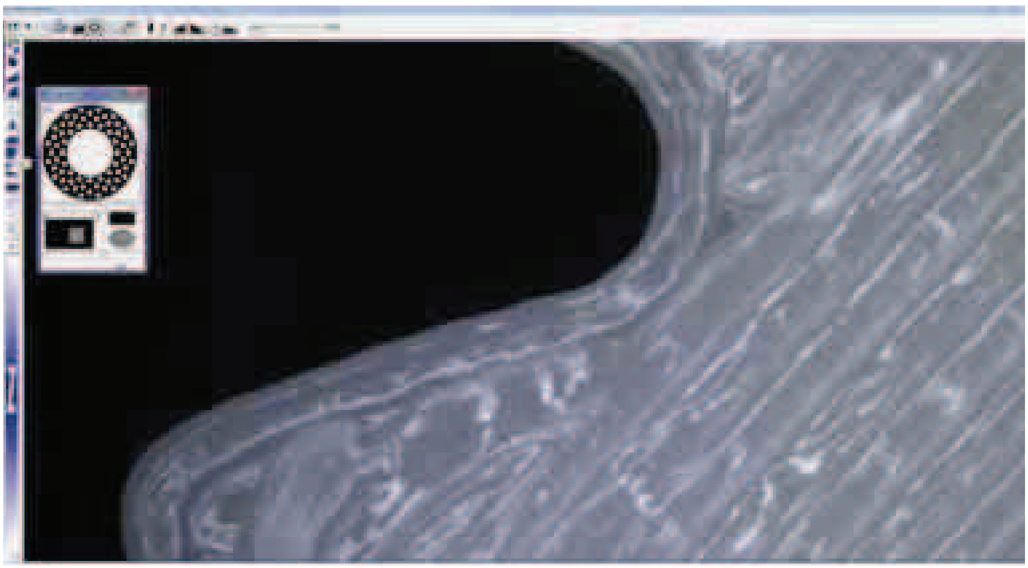

Fig. 3. A view of a gear-toothing fragment

The measuring machine software allows importing a file with standard profile. On its basis it is possible to compare the standard profile with the measured one. Joining both profiles in order to analyse accuracy can be done by optimal match of the measured profile points to the nominal one in a process called best fit. The analysis of shape and location deviations can be done directly in the software during measurement. Measure points located within the assumed tolerance are printed in green and located outside the tolerance is printed in red. It allows for immediate visual assessment of accuracy of the object (Fig. 4).

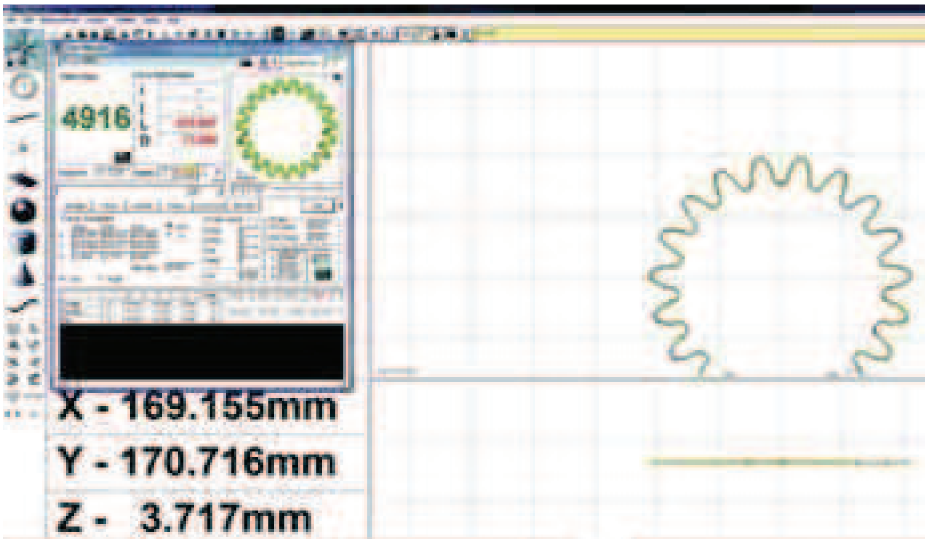

Fig. 4. Analysis of wheels' outline measurement results

Measurement report visually shows nominal outline of edges of the measured object, measure points recorded while measuring and a field of assumed tolerance in relation to nominal outline (Fig. 5).

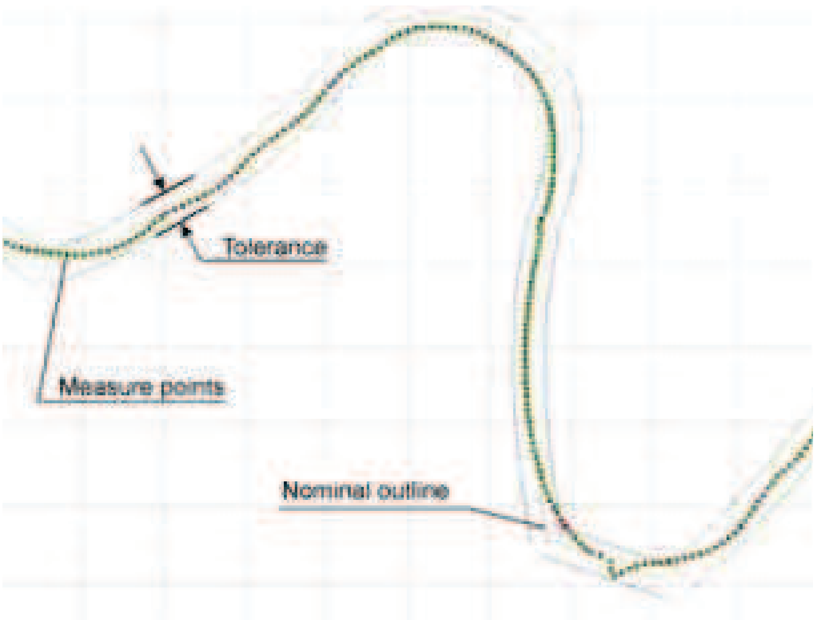

Fig. 5. Analysis of gear outline fragment measuring results

Conclusion

Optically carried out measurement of the demonstrator's toothed wheels made by means of incremental method FDM allowed for quick determination of real accuracy of creating a model.

Making toothed wheels using Rapid Prototyping is based on 3D-CAD model. Therefore it is always possible to apply measuring strategy based on 3D-CAD model.

Coordinate measuring methods make it possible to determine real accuracy of models made by means of Rapid Prototyping methods. By measuring and analysing geometrical parameters of toothed wheels it is possible to define value of compensation for RP devices [5].

One of ways of improving prototype accuracy can be changing the modelling manner of toothed wheel rim and hub. It is especially noticeable in case of stage II wheel that is sensitive to shrinkage of material because of its size and hub shape. The examined wheels have greater accuracy than assumed for this method (±0.1mm).

Another cause of occurring errors is nominal accuracy of the device especially defined on axis with thickness of applied layer (0.256mm). However the average value of deviations is lower than values assumed by the producer of U-Print device. This kind of toothed wheels can be used in prototype examination of gear also because of good qualities of applied material (ABS).

The research prototype of gear presented in the paper was made by means of FDM, the material used was ABS. Qualities of ABS, and employed style of construction of the model layers allows for using the model for stand tests. The choice of measuring systems should be made considering accuracy of making wheels' models, verification of materials of which the wheels are made and considering measurement needs.

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