ISSN: 1231-4005
e-ISSN: 2354-0133
ICID: 1133895
DOI: 10.5604/12314005.1133895

METHODOLOGY OF MEASUREMENT AERONAUTICAL BEVEL GEARS USING AN OPTICAL SCANNER ATOS II TRIPLE SCAN

Adam Marciniec, Grzegorz Budzik
Tomasz Dziubek, Bartłomiej Sobolewski, Małgorzata Zaborniak

Rzeszow University of Technology
Faculty of Mechanical Engineering and Aeronautic
Powstańców Warszawy Av.8, 35-959 Rzeszow, Poland
e-mail: amarc@prz.edu.pl, gbudzik@prz.edu.pl
tdziubek@prz.edu.pl, b_sobolewski@prz.edu.pl, mzab@prz.edu

Abstract

Properly prepared and carried out the measurement process of bevel gears determines its accuracy and productivity. This also has an influence on the final accuracy of bevel gears and the production costs of aeronautical gearbox.

In the process of assessing the accuracy of manufacturing, majority of manufacturers of bevel gears use specialized contact coordinate measuring machines. The application of such machines as well as specialized programs dedicated to measuring the geometry of bevel gears are authoritative but in turns this requires substantial financial resources for the purchase of machinery. Thereby, this causes the limitation only of the gear assortment. Therefore, this article depicts different perspective on measurements of bevel gears using a universal measuring device, which is an optical 3D scanner ATOS II Triple Scan.

Due to the use of the optical scanner ATOS II Triple Scan in measurement process, it was necessary to develop a methodology dealing with the process of assessing and accuracy, in order to achieve the desired results of measurement. This need arises from the fact that the optical scanner ATOS is not dedicated, specialized device for measuring gears. Despite of this fact, maintaining the appropriate measurement procedures and a proper preparation of the measured model allows for rapid and accurate assessment of the accuracy of production.

The article presents the analysis of conditions and developed rules concerning the preparation of a model for measurement. It also contains hints and a description of the measurement process. Furthermore, it depicts the rules specifying the interpretation of measurement results as well as the technical rules of their realization.

Keywords: *bevel gear, aircraft gearbox, optical scanner, coordinates measuring technique*

1. Introduction

The aim of the research is to develop a methodology for the non-contact measurement of bevel gears of aircraft gearbox using a 3D optical scanner Atos II Triple Scan.

The goal of analysing the accuracy of the geometry of bevel gears was to present the possibilities of using universal coordinate optical measuring machine. For this purpose, due to the lack of specialist software dedicated to measurement of the gears, it was necessary to develop procedures dealing with the preparation of the measurement, its process, the method of devising and the analysis of measurement results. Taking into account all the factors allowed performing the analysis concerning the global assessment of the accuracy of bevel gears of aircraft gearbox as well as the analysis of the outline and the line of the tooth. The developed methodology of measuring was used to evaluate the accuracy of machining, as well as, to assess the deformation of the geometry arising in the incremental process of manufacturing components with the use RP techniques.

2. The preparation of the measuring process

In order to verify property the accuracy of machine components, it is essential to conduct the appropriate preparation of the element for the measurement process. This stage is particularly important if we deal with such specific geometry as bevel Sears (Fig. 1).

The used method of controlling the geometry of bevel gears was based on obtaining the geometry with the use of optical 3D scanner. Moreover, the analysis was conducted using universal measuring software. Consequently, it is required to prepare the measuring model, which ensures capturing the entire geometry.

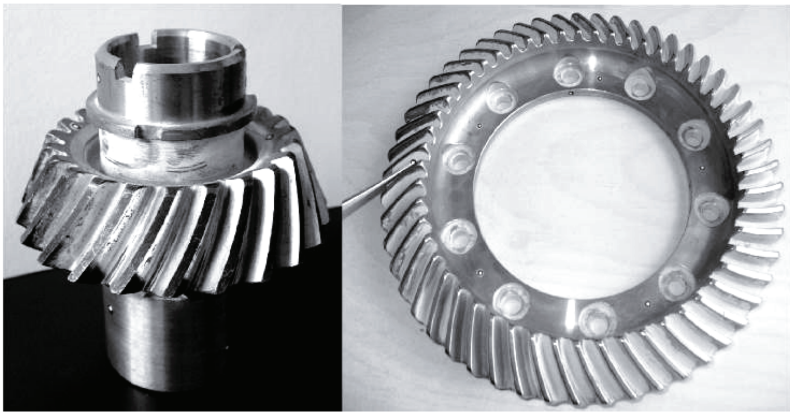

Fig. 1. Measured bevel gears with reference points

This was achieved due to elaborating on the system of deployment of reference points, which are placed on analysed geometry of wheels. During the research, it was observed that in the case of the rotary elements, especially the gears, in order to obtain a proper connection of items of geometry, it is necessary to place the reference points, which define the scanned geometry clearly (Fig. 2). The conclusion is that the markers, particularly on the toothed-wheel rim, cannot be arranged in an orderly way, because it may cause an inappropriate connection of particular fragments of obtained geometry. In the case of an ordered deployment of reference points, some fragments of surface may overlap because of the improper identification of reference points, as well as the specific geometry of the ring of wheel measured. Therefore, it was stated that the best results are obtained when markers are placed in the way, which clearly identifies particular parts of the surface, and thus it eliminates incorrect similarity of different parts of geometry.

Another aspect of preparation of the measurement model is the measurement with the use of rotary table, in two positions of measured wheels. Therefore, in order to obtain the digitization of contact surface of wheel with the rotary table and the geometry placed outside the camera area, it is necessary to measure two independent measuring series.

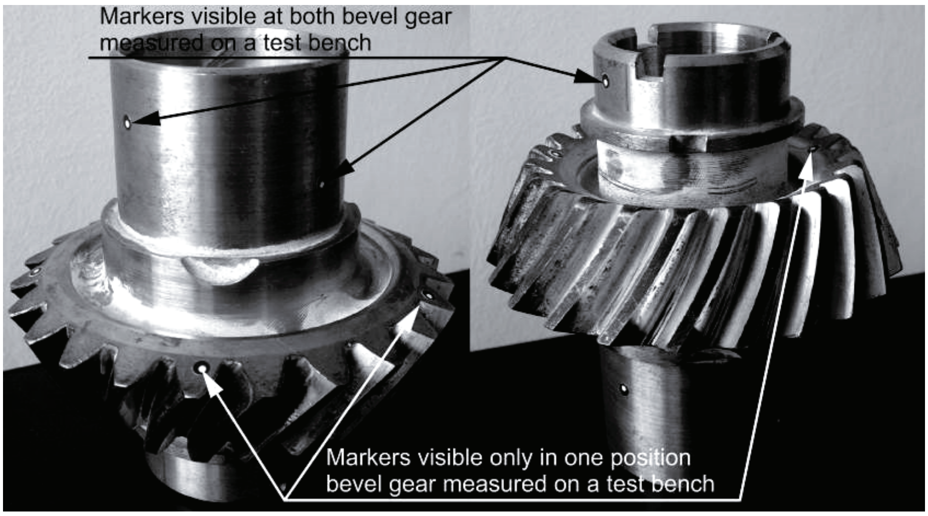

Fig. 2. Bevel gear with reference points visible in both series of measurement

The measurement process is configured so that measuring was carried out for the wheel placed in two positions: in the plane of table and in the plane rotated 180 degrees. However, it is required to place reference points in such a way that at least three of them are visible in both series of measurement (Fig. 2). The aim of such operation is the possibility of combining the particular geometry. The greater number of identified points in both positions is the less errors in fitting the measuring series.

The final stage of preparation of bevel gears for the measurement process was covering its surface with anti-reflective coating of powdered chalk. This operation prevents from appearing undesirable reflections on the scanned surfaces. Moreover, it improves greatly the efficiency of measurement process and it reduces measuring errors. Because of the fact that covering takes place only after application of reference points on measured wheel, they are also covered with this coating. Therefore, it is necessary to clean them. In addition, it was found that carrying out this operation is much more convenient on the test bench, in the light of the projector. This procedure ensures current observation presented on the screen. So that it is known, which points should be cleaned. Consequently, it accelerates the preparation process and it also prevents from omitting some markers.

3. The process of the digitalization of bevel gears and the machining process

To ensure the proper digitization of geometry, it is vital to develop an appropriate methodology for measuring and processing of data. It is especially important when it comes to using a universal measuring machine for measuring the geometry of bevel gears.

Fig. 3. Measuring of bevel gears conducted in particular positions on measuring table with the use of optical scanner 3D ATOS II Triple Scan

Measurements of bevel gears of aircraft box were conducted with the use a 3D optical scanner ATOS II Trilpe Scan. The rotary table was also applied, which automates measuring and, in the end, it shortens that process. A formulated methodology for measurement takes into consideration the measuring in two positions of gear with respect to the measuring table (Fig. 2 and 3). Due to this measurement strategy and possibilities given by ATOS Professional V 7.5 software, an efficient and accurate method of obtaining the entire geometry of gear is achieved. The study shows that this method can be successfully used to verify the accuracy of elements with such complex geometry.

The developed methodology provides for conducting measurement that gives the possibility to acquire the entire geometry of wheel together with its hub. Hence, the measurement was carried out in two independent measurement series.

The measuring strategy requires the measurement data, which are obtained after conducting two independent measurement series, to be compiled on the basis of the reference points and then after assembling, they create surface models of studied bevel gears (Fig. 4). To perform this operation, at least three reference points should be visible on a measured wheel and they need to be found in two independent series of measurements. The more reference points are found by the system, the less number of errors associated with the deviations of transformation.

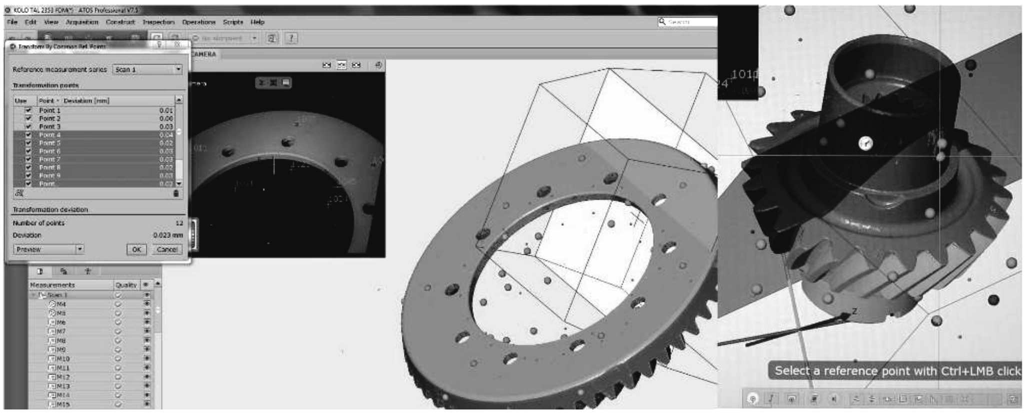

Fig. 4. Combining of scanned pictures obtained from two independent series

3.1. The process of creating geometry in order to define the coordinate system

The next stage of the developed methodology is the procedure of basing the coordinate system with respect to the obtained geometry according to the assumptions. This means that it is described on the axis of wheel rotation. This is the result of specific nature of software as its algorithms define the coordinate system freely during the measurement process. In contrast to the contact, coordinate measuring machines which need to define coordinate system before measuring. Firstly, the geometry of the measured component is obtained, and then in the following stages, the coordinate system is defined on the basis of complete measurement data.

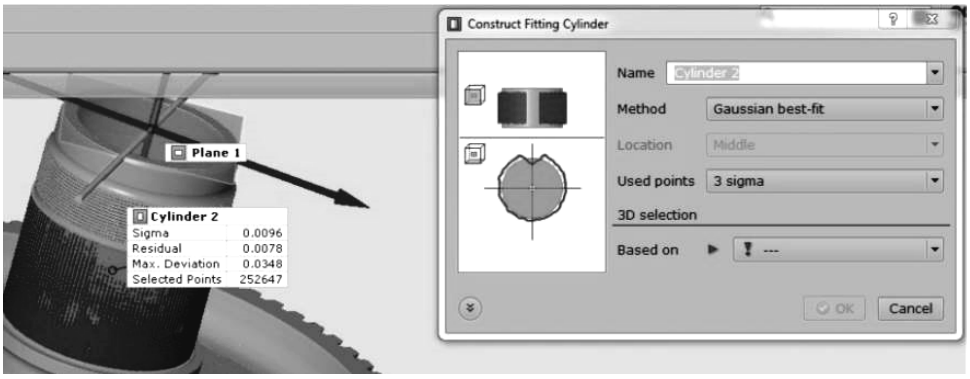

Fig. 5. Defining the geometry in order to determine the position of coordinate system on the first bearing journal

The defining procedure, on the obtained model of coordinate system, is commenced by specifying the rolls, which, in this case, describe bearing journals (Fig. 5). Their characteristic feature is high accuracy and they also guarantee pointing properly the axis of wheel rotation. This has impact on the accuracy of results and on their appropriate interpretation.

In the next step, to such prepared geometry, it is attached a reference model by importing control model 3D CAD to software. Then, both models are subordinated to the procedure of basing – model in relation to the controlled geometry.

Firstly, the preparation of the measurement should be performed correctly. Moreover, the digitizing of geometry of studied wheel need to be conducted. Then data are processed together with the description of coordinate system and the creation of models. The final stage is analyse of the accuracy of the obtained geometry.

4. Determination of the procedures concerning the analysis of measuring results

Software of coordinate optical scanner ATOS II Triple Scan enables to analyse the accuracy of manufactured components. The results of analysis are presented quantitatively as well as in the form of collared maps of deviations. There were specified procedures, which determine the total accuracy or the size of wheel deformation. Moreover, they assess the accuracy of side surface of teeth and they control the outline and the teeth line.

The possibility of global analysis was determined as a result of applying the surface geometry of bevel gears, which was obtained by using optical scanning, to standard models 3D CAD. These analyses allow evaluating visually the accuracy performance.

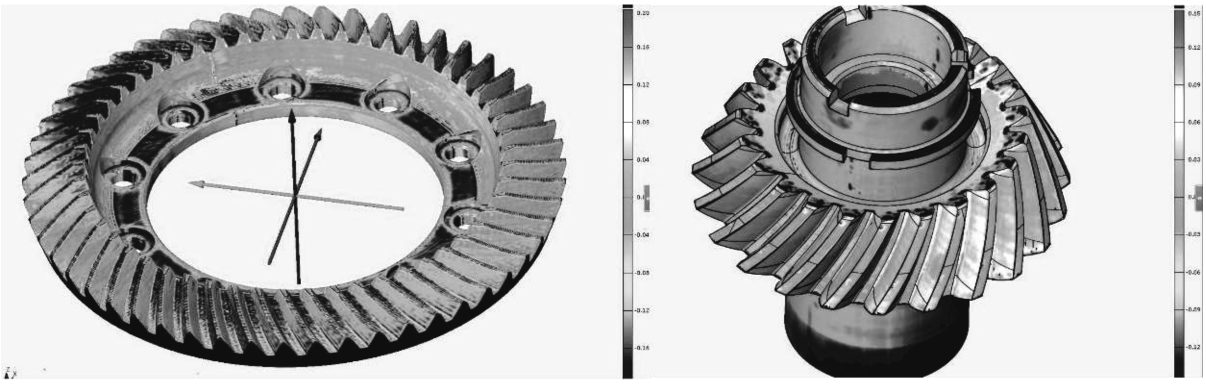

Fig. 6. Exemplary global analysis of surface deviations of bevel gear with the reference to 3D-CAD model

Deviations of all individual measuring points are calculated with reference to the nominal geometry. Due to their quantity, deviations are visualized as a colour map. Such a picture depicts the critical points of measured wheel, which should be analysed thoroughly (Fig. 6).

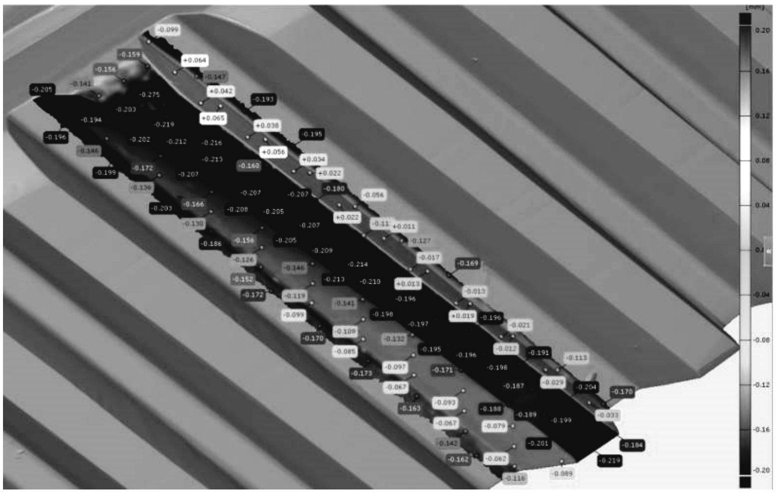

Fig. 7. Exemplary local analysis of surface deviations of represented side of the tooth together with defined reference points

During the research, it was found that apart from global analysis, it is necessary to verify the accuracy of side surface of teeth. For this purpose, it was developed the procedure, which reduces the analysed parts of surface via the choice of geometry of representative teeth (Fig. 7) and compares it to the standard 3D-CAD. Due to this more thorough determination of deviations from the reference, geometry was obtained.

Through selecting representative elements of the teeth surface and referring to pattern, there was acquired visual and quantitative analysis of the deviations of the side surface of teeth (Fig. 7).

Such a verification of accuracy is possible for the entire ring, but much more time is needed to conduct analysis. Hence, it was used a strategy which initially assesses the accuracy, and then selects the most critical points including the greatest number of deviations.

ATOS Professional V 7.5 Software allows generating a section through the measurement data and CAD data. In selected points, it can be attached information about the deviations and if it is within the tolerance.

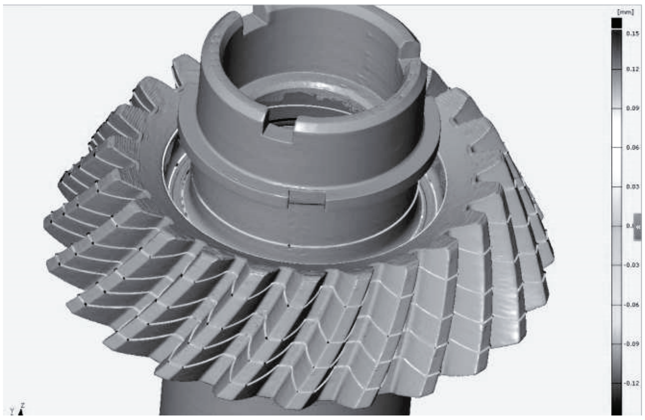

Fig. 8. The position of cutting planes created for the analysis of deviations of the teeth outline

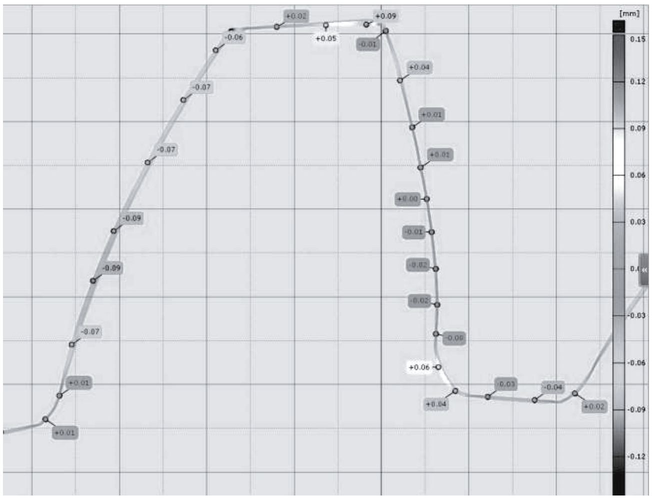

Fig. 9. Analysis of deviations of the tooth outline in the selected section presented on the particular tooth with its numerical value

Such analyses depict the global deviations of the outline with reference to the entire teeth ring (Fig. 8). Moreover, there is a possibility of precise evaluation of the deviations with their visualization (Fig. 9). One of the characteristic of thorough control is the fact that the deviations can be assessed by reducing the evaluated area. The analyses, conducted in a presented way, can verify the accuracy of manufacturing and also determine the amount of surplus on the finishing processing in case when the measurement is available between the various stages of manufacturing.

Corresponding to the control of the outline, during the development of measuring methodology of the tooth line, it was found that it is possible to verify it through creating proper section and referring it to 3D-CAD pattern. However, in this case there is no such instruction, which provides for gaining the measurement results automatically.

For this reason, there was developed a method, which generates the geometry rising from the intersection of the measured wheel with the identical geometry of 3D-CAD standard wheel and then also compares them.

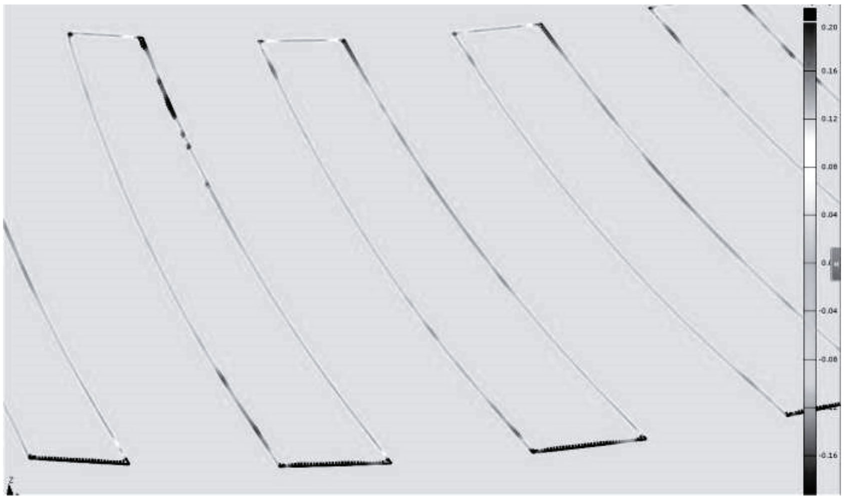

Fig. 10. Graphic analysis of deviations of the teeth line created for crown wheel

It allows determining both the deviation of the line from the nominal outline, which is presented in the global form, as well as a precise evaluation of deviations (Fig. 10).

Conclusions

Non-contact methodology for measuring bevel gears with a use of 3D optical scanner allows verifying the accuracy of manufacturing fast and generally. When assessing the accuracy, most of the gear-manufacturers use coordinates measuring machines together with the software created to measure this type of geometry. Therefore, this study presents another view on the measurement of gears.

Due to the use of the optical scanner ATOS II Triple Scan in the measurement, in order to achieve the desired results, it was necessary to develop a methodology for measuring process and the evaluation of accuracy. This need arises from the fact that the optical scanner ATOS is not a specialist device for measuring gears. Despite of the fact, the assessment of manufacturing accuracy can be fast and precise only if the measurement procedures are used properly and the measured model is prepared in an appropriate way.

The study includes instructions for the preparation of bevel gears to the measurement process, then advice dealing with this process, as well as rules specifying how to carry out the analysis of accuracy. Prepared methodology enables to assess fast and effectively both the manufacturing accuracy and the deformation of the geometry of bevel gears. It also visualizes the deviations of the geometry and determines their size easily.

Acknowledgement

Financial support of Structural Funds in the Operational Programme – Innovative Economy (IE OP) financed from the European Regional Development Fund – Project “Modern material technologies in aerospace industry,” No POIG.0101.02-00-015/08 is gratefully acknowledged.

References

[1] Budzik, G., Dziubek, T., Murkowski, O., Total, M., *Automatyzacja i robotyzacja pomiarów współrzędnościowych*, Stal Metale & Nowe Technologie, Nr 5-6, s. 34-36, 2011.

[2] Budzik, G., Pisula, J., Dziubek, T., Sobolewski, B., Zaborniak, M., *Zastosowanie systemów CAD/RP/CMM w procesie projektowania kół zębatych walcowych o zębach prostych*, Miesięcznik Naukowo-Techniczny Mechanik, Nr 12, s. 988, 2011.

[3] Budzik, G., Dziubek, T., Sobolewski, B., Zaborniak, M., *The application of the coordinate measuring technique for the determination of accuracy of gear wheels produced by selected incremental rapid prototyping methods,* Advances in Coordinate Metrology, Zeszyty Naukowe ATH w Bielsku-Białej, 2010.

[4] Dziubek, T., Budzik, G., Kozik, B. , Sobolewski, B., *The determination of accuracy of test gear wheel for aeronautical dual-power path gear before heat treatment,* Journal of KONES Powertrain and Transport, Vol. 20, No. 2, Warszawa 2013.

[5] Humienny, Z., *Specyfikacje geometrii wyrobów (GPS), Podręcznik europejski* ,Wydawnictwa Naukowo-Techniczne, Warszawa 2004.

[6] Marciniec, A., Budzik, G., Dziubek, T., *Automated measurement of bevel gears of the aircraft gearbox using GOM,* Journal of KONES Powertrain and Transport, Vol. 18, No. 2, pp. 289-292, Warszawa 2011,

[7] Markowski, T., Kozik, B., Budzik, G., Dziubek, T., *Analiza wymiarowa kół zębatych demonstratora przekładni lotniczej wykonanych metodą MEM,* 52. Sympozjon Modelowanie w mechanice, 2013.

[8] Ratajczyk, E., *Współrzędnościowa technika pomiarowa*, Oficyna Wydaw. Politechniki Warszawskiej, Warszawa 2005.