METHODOLOGY OF MEASUREMENT AERONAUTICAL BEVEL GEARS UTILIZING AN OPTICAL 3D SCANNER USING WHITE AND BLUE LIGHT

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Summary

Accuracy diagnostics bevel gears of aircraft gearbox has become a key component in today's manufacturing process. Properly prepared and carried out the measurement process of bevel gears determines its accuracy, productivity 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. Therefore, this article depicts different perspective on measurements of bevel gears using a universal measuring device, which is an optical 3D scanners ATOS, using in the process of measuring white and blue light.

Due to the use of the optical scanners ATOS 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. The studies take into account the economic aspects of the use of technical diagnostics in the production process.

The article presents an 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: diagnostics, bevel gear, aircraft gearbox, optical scanner

METODYKA POMIARÓW STOŻKOWYCH KÓŁ ZĘBATYCH PRZEKŁADNI LOTNICZEJ ZA POMOCĄ OPTYCZNEGO SKANERA 3D Z ZASTOSOWANIEM ŚWIATŁA BIAŁEGO I NIEBIESKIEGO

Streszczenie

Diagnostyka dokładności wykonania stożkowych kół zębatych przekładni lotniczych stała się obecnie kluczowym elementem procesu ich wytwarzania. Odpowiednio przygotowany i przeprowadzony proces pomiaru stożkowych kół zębatych determinuje jego dokładność, wydajność oraz koszty produkcji przekładni.

Większość producentów stożkowych kół zębatych w procesie oceny dokładności wykonania, stosuje specjalistyczne stykowe współrzędnościowe maszyny pomiarowe. Dlatego niniejszy artykuł będzie innym spojrzeniem na pomiary stożkowych kół zębatych z zastosowaniem uniwersalnego urządzenia pomiarowego, jakim są optyczne skanery 3D ATOS wykorzystujące w procesie pomiaru białe i niebieskie światło.

Z uwagi na zastosowanie w procesie pomiaru optycznych skanerów Atos, w celu osiągnięcia pożądanych wyników pomiarów niezbędne było opracowanie metodologii dotyczącej przebiegu procesu pomiaru oraz oceny dokładności. Przeprowadzone badania uwzględniają ekonomiczne aspekty zastosowania diagnostyki technicznej w przebiegu procesu produkcyjnego.

Artykuł przedstawiał będzie analizę warunków oraz opracowane zasady dotyczące przygotowania modelu do pomiaru. Zawarte zostaną w nim również wskazówki oraz opis samego procesu pomiaru. Ponadto przedstawiono zasady określające interpretację wyników pomiarów wraz z technicznymi zasadami ich wykonania.

Słowa kluczowe: diagnostyka, stożkowe koła zębate, przekładnia lotnicza, skaner optyczny

1. INTRODUCTION

The aim of the study was to develop a methodology for contactless measurement of aeronautical bevel gears using 3D optical scanners ATOS working together with blue and white light.

The aim of developed and performed accuracy analysis of created geometry of helical-bevel gears was to present the universal usage of optical

measuring devices. For this purpose, due to the lack of specific software dedicated to measurement of the gears, it was necessary to develop procedures suitable for the preparation of measurement, its course and a method for developing and analyzing results. Taking into account all dependencies, the analysis was performed concerning global assessment of accuracy of creation of aeronautical bevel gears, analysis of outline and the tooth line. The developed methodology was used to evaluate the accuracy in the context of machining as well as to evaluate the geometry deformation generated in the incremental process of creating demonstrators using RP techniques.

2. THE PREPARATION OF 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 gears (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, were conducted using universal measuring software. Consequently, it is required to prepare the measuring model which ensures capturing the entire geometry.

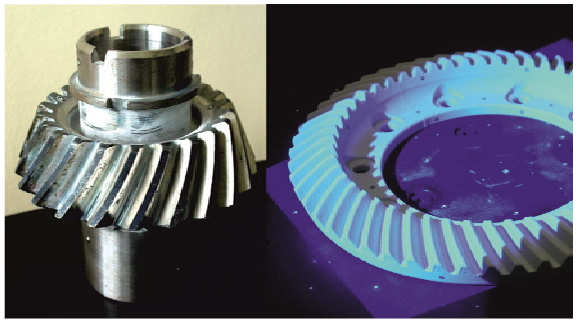

Fig. 1. Measured bevel gears with reference points

This was achieved due to elaborating on the system of deployment of reference points which are placed on analyzed geometry of wheels (fig. 2). The markers, particularly on the toothed-wheel rim, cannot be arranged in an orderly way. In the case of an ordered deployment of reference points, some fragments of surface may overlap because of the improper identification of reference points. In addition, because measuring wheels in two positions with respect to the measuring table, it is necessary to prepare reference points so that at least three of them are visible in each of these positions. This provides the opportunity to combine the geometry of each measuring series in the integral surface model which is subjected to a subsequent analysis.

The final stage of preparation of bevel gears for the measurement process was covering its digitalized surface with anti-reflective coating and cleaning all previously deployed markers.

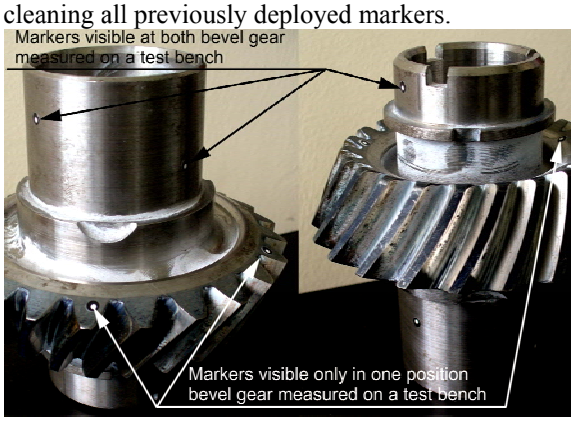

Fig. 2. Bevel gear with reference points visible in both series of measurement

3. THE PROCESS OF DIGITALIZATION OF GEOMETRY OF BEVEL GEARS AND MACHING PROCESS

To ensure the proper digitization of geometry, it is vital to develop an appropriate methodology for measuring and processing of data.

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 (fig. 3).

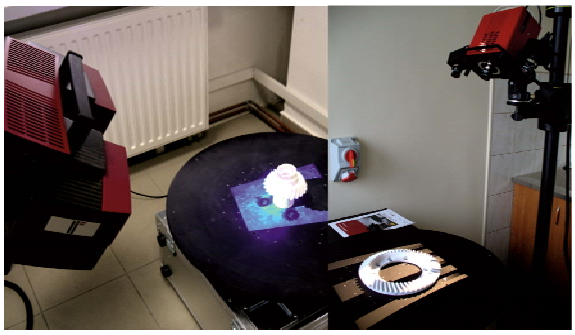

Fig. 3. Measuring of bevel gears using 3D ATOS optical scanners- blue and white and light

During research, the methodology, which predicts measuring geometry in two positions of wheels with respect to a turn table, was applied for both devices. Due to such comparison, you can observe differences of features between scanners, and finally differences in the measuring process.

Scanners ATOS II and ATOS II TripleScan have software with similar functions. That is the reason it was possibly to use identical measuring methodology. Due to digitalization of geometry in two independent series, it is necessary to combine obtained geometry. To do so, you have to point to joining points (at least three), which occur in two

series of measuring, as this enables to transform and match geometry (fig.4).

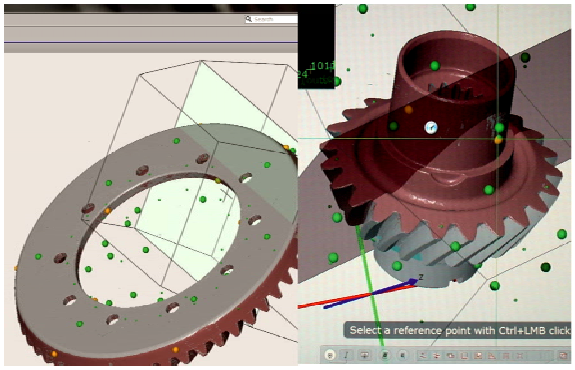

Fig. 4. Combining scanned pictures which are the results of two independent measuring series

The processes of obtaining measuring data of bevel gears with the use of both devices were corresponding. However, using scanner with blue light in the process of digitalization have definitely accelerated measuring. Additional measuring data have less geometry mistakes in the form of missing parts of surface. Another advantage of ATOS II Triple Scan is greater stability of device, which is obtained due to software stabilization.

3.1. The process of creating geometry to determine the coordinate system

The indispensible stage of verification of geometry accuracy of bevel gears is creating the coordinate system according to obtained measuring data. In contrast to classical coordinate measuring machines, you create the coordinate after obtaining complete geometry.

The coordinate is positioned on the basic geometry such as a point, a line, a circle, a conic or a plane which is corresponding to classical tactile coordinate measurements. However, in the case of optical scanner, it deals with pointing the basic geometry on the obtained completed data of measuring and, on its basis, combining it with the coordinate (fig. 5).

In order to base, using appropriate functions, you can indicate specific creatures of geometry and base geometry on which the coordinate system of measured parts is subscribed and combine with it.

One of the advantage of this, is the possibility of changing the position of the coordinate. Due to this, you can analyze without the necessity of repeating measuring.

Due to the fact that both scanners have similar possibilities, the procedures of basing were corresponding. In order to position the coordinate properly, the Z axis of the coordinate, which was related to the axis of wheels, was based. To do so, it was determined on the rotary surfaces which are more accurate. The other axis were located on such selected geometry in the form of plane of edge, which provides for corresponding position of the coordinate system with the coordinate of 3D-CAD model.

Thanks to such strategy of basing, you do not need to correct the position of models, resulting in decreasing of basing mistakes.

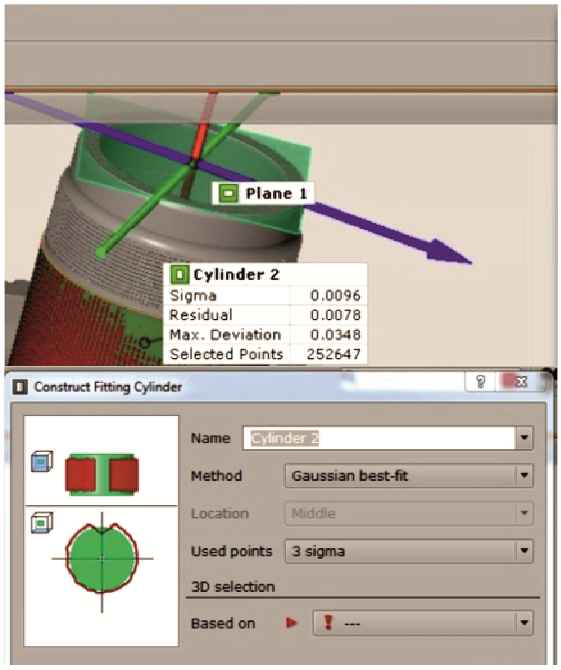

Fig. 5. Defining geometry in order to determine the location of the coordinate system

In order to verify the correctness of work with respect to 3D-CAD model, it is necessary to import it to scanner software and combine it with measured geometry.

This work mode of optical devices is not until measuring and machining of measuring data. It is not necessary, as in the case of tactile coordinate machines, to combine reference model with the coordinate system at the beginning of measuring. That is the reason why you can relate to reference model many times and change models and the coordinate systems.

4. DETERMINATION OF THE PROCEDURES CONCERNING THE ANALYSIS OF MEASURING RESULTS

Scanners ATOS II and ATOS II Triple Scan have adequately ATOS Professional V7 and V7,5 software which have similar possibilities when it comes to the analysis of geometry accuracy of bevel gears. That is the reason why the strategy was applied to both devices.

The software enables to analyze the accuracy of geometry of bevel gears which results are presented quantitatively as well as in the form of colored maps of deviations.

As the result of placing surface geometry of bevel gears, which was obtained by using optical scanning, to reference 3D CAD models, the possibility of global analysis was determined which allows you to evaluate visually the accuracy of performance (fig. 6).

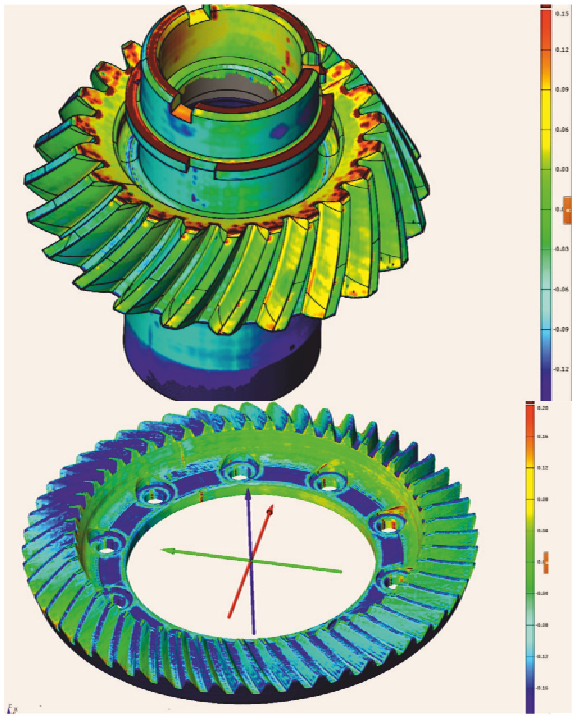

Fig. 6. Exemplary global analysis of surface deviations of bevel gears to 3D-CAD model

The aim of global strategy of analysis of geometry accuracy is to indicate deviations on maps. Due to this, you can access geometry and correctly define places on general geometry, which should be analyzed thoroughly.

One of the deep analysis of verification of accuracy is surface control of deviations of selected geometry fragments. Such defined methodology enables you to check mapping of surface of side teeth (fig. 7).

You can do so on each tooth separately. It requires more time but geometry is better verified. You can create only colored maps of deviations as well as determine their value in a quantitative way in the selected points (fig. 7).

Despite of the fact that such measuring is time-consuming, it is definitely shorter than measurements using tactile coordinate devices.

Another method of deep analysis of bevel gears geometry is verification of geometry on the basis of cutting measuring data with properly defined section planes. Due to these operations, you can control the outline geometry or teeth line. Such analysis enables you to determine deviations graphically as well as quantitatively so that you can refer the results to normatives concerning bevel gears.

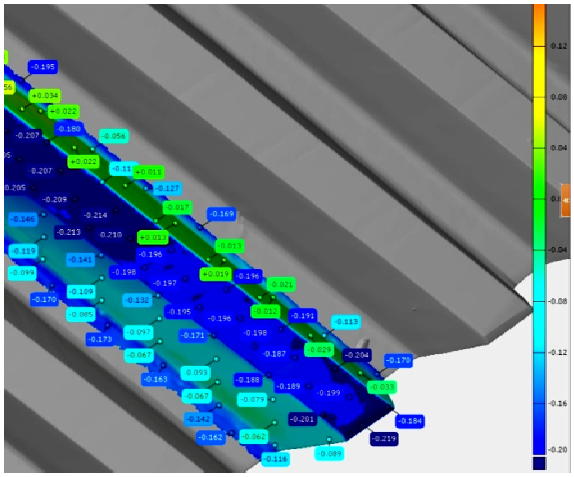

Fig. 7.Exemplary local analysis of deviation surface of represented side tooth of face bevel gear with defined inspected points

Generating sections through measuring data and 3D-CAD nominal data created with above assumptions depict the profile deviations with the reference to the whole teeth ring (fig. 8).

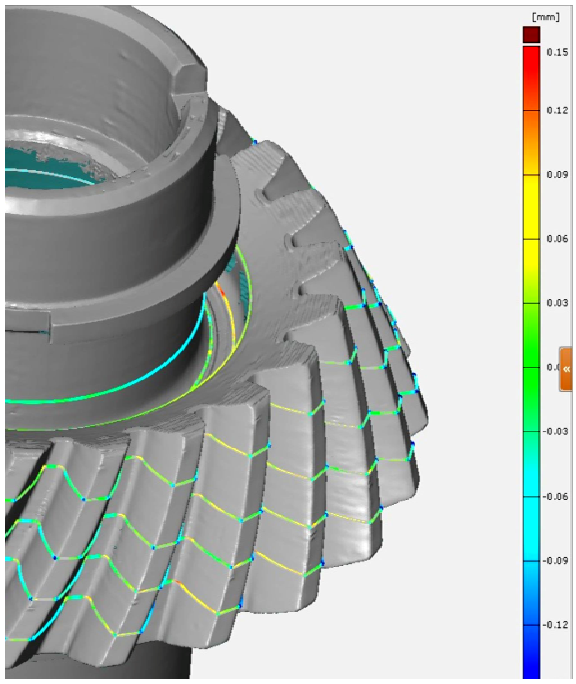

Fig. 8. The position of cutting planes created for the analysis of deviations of the teeth profile

In order to improve visibility of deviation map for the profile, you thoroughly evaluate deviations with their visualization on the selected model (fig. 9). As a result, the report is more precise and it can be used to assess the surplus on the finishing processing.

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

The corresponding methodology of control, you can use while assessing the accuracy of teeth line. In this case, the software does not give you the possibility of creating section directly using software planes. That is the reason why the methodology of creating additional geometry was developed. It deals with generating the shape of teeth outline being the result of intersecting of measured circle with additional geometry. You can apply similar operations to 3D-CAD model. Such obtained teeth lines are compared, which enables you to determine the deviations between nominal and real geometry (fig. 10).

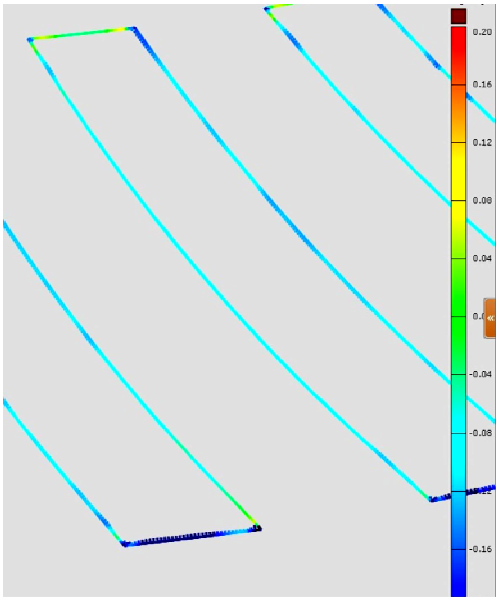

Fig. 10. Graphic analysis of deviations of the teeth line created for bevel gear

Similarly to teeth line, you can present the outline analysis only in the graphic way on a deviation map as well as with numerical values in the selected points of section.

3. CONCLUSIONS

Optical techniques are more often used in machine industry while measuring. The choice of measuring method should be adequate to measured object and to place of measuring process during production.

The development of optical systems of measuring such as ATOS II and ATOS II Triple Scan scanners which operate on the basis of structured light enables to measure more precisely and shorten the process.

Measuring with the use of blue light, comparing to white light, is shorter and it can be conducted during daylight. This enables to activate scanner in the production.

The developed methodology of non-contact measuring of bevel gears using 3D optical scanner provides for faster and complex diagnostics and verification of accuracy.

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 bevel 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 diagnostics of accuracy. Prepared methodology enables you 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.

Using such verification of accuracy of geometry can be applied to gears created with the use of machining methods in order to determine the surpluses on the finishing processing. The presented methodology can be also used for incremental rapid prototyping methods.

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BIBLIOGRAPHY

[1] Budzik G., Dziubek T., Markowska O., Tutak M.: *Automatyzacja i robotyzacja pomiarów współrzędnościowych*, Stal Metale & Nowe Technologie ISSN 1895-6408, 5-6/2011, s. 34-36
[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, PL ISSN 0025-6552, NR 12/2011, s. 988
[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*. Advences 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]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, Warszawa 2011, s. 289-292
[6] Pacana J.: *Development of Bevel Gear Motion Transmission Graphs with FEM*, Key Engineering Materials Vol. 490 (2012), Trans Tech Publications, Switzerland 2012, str. 83-89
[7] Ratajczyk E. – *Współrzędnościowa technika pomiarowa* – Oficyna Wydaw. Politechniki Warszawskiej, Warszawa 2005.
[8] Sobolewski B., Marciniec A.: *Method of spiral bevel gear tooth contact analysis performed in CAD environment*, Aircraft Engineering and Aerospace Technology: An International Journal 85/6 (2013), pp.467 - 474

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