ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1136265

THE DETERMINATION OF ACCURACY OF TEST GEAR WHEEL FOR AERONAUTICAL DUAL-POWER PATH GEAR BEFORE HEAT TREATMENT

Tomasz Dziubek, Grzegorz Budzik, Bogdan Kozik, Bartłomiej Sobolewski

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

Abstract

Manufacture of aircraft gearbox elements requires control of gear geometric parameters at different stages of technological process. In case of measurement of gear wheels using modern technologies based on numerical machines, measurement process is based on processing of numerical data obtained by measurement using coordinate measuring machines.

The goal of this paper is to present the measurement process of gears, using coordinated optical scanner ATOS II TripleScan by GOM, equipped with a turntable. The aim of this study is to develop and execute the analysis accuracy of the geometry of the gear of aeronautical dual-power path gear after the roughing operation using optical coordinate measuring methods. Executed research will enable the detection of errors occurring in the machining process and to determine the value of founded the machining allowance finishing in relation to the CAD model.

Using coordinate measuring technique, one can specify a set of methods and procedures for the designation of the complex dimensions of physical objects and transform them into a computer program space of coordinate measuring devices.

On this basis, it is possible to determine the accuracy of the gear wheel as the workpiece prior to heat treatment. The results will be the basis to determine the effect of heat treatment on changes in the geometry of the gear and the benchmark for determining the correctness of the finishing.

Keywords: *gear, aircraft gearbox, coordinate measuring technique, dual-power path gear*

1. Introduction

The need to maintain high precision and repeatability of manufactured products forces the need to apply advanced methods of control of dimensions and shapes. Therefore methods for verification of correctness of products in a relatively short period of time assuring required accuracy become essential.

A branch of coordinate techniques subject to continuous development and meeting the requirements for coordinate measuring devices are optical methods. They are being used increasingly by leading manufacturers of automotive, aeronautical or electronic industry.

Undoubted advantage of optical measurements is the speed of measurement compared to the typical measurement systems with contact measuring probe. Items with complex shapes are easier to measure by means of non-contact methods, because measurement done with a coordinate measuring machine due to the need to gather a large number of measuring points is difficult and therefore time-consuming.

This applies also to verifying the accuracy of making gears with the optical scanner ATOS II TripleScan with 'blue light. Applying the scanner in combination with a turntable in the process of measurement, gave opportunities to significantly reduce the time of measurement. 3D ATOS II TripleScan, which uses blue light during the process of digitising a surface for the purpose of projecting stripes, creates possibilities for a comprehensive dimensional and shape analysis of gears. In addition, getting the full wheel geometry allows an analysis of precision of changes of its geometry at different stages of the fabrication process.

The research carried out during accomplishing the task aimed at gaining the full geometry of a spur gear of a dual-power path gearing which makes it possible to verify deformations of the wheel after heat treatment (Fig. 1). For this reason, the digitisation process has been carried out after completing the roughing machining, and the gained geometry has been referred to a standard 3D-CAD model. On this basis, specific values of deviations from the assumed surplus for after-machining have been specified and the geometry has been verified at this stage of fabrication.

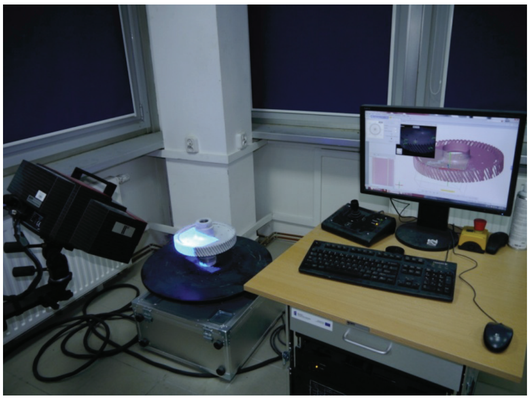

Fig. 1. Measuring the gear wheel for aeronautical dual-power path gearing by means of optical 3D scanner ATOS II TripleScan

The surface 3D model of the digitised wheel obtained as a result of measurements will be used in later stages as a reference model in order to determine deformation arising during heat treatment. It will allow to determine correctness of the assumed geometry of the gear's hub and disk and to make adjustments in order to eliminate possible undesirable deformations.

2. The process of measuring the gear of aeronautical dual-power path gearing by means of 3D Atos II TrilpeScan with a turntable

The process of measuring the spur gear of aeronautical dual-power path gearing applying 3D Atos II TrilpeScan has been carried out with the use of turntable which enabled its automation and as a result reduced the duration time. Before the measurement, the measured gear has been adequately prepared through placing reference points on its surface required to connect individual fragments of geometry (Fig. 2).

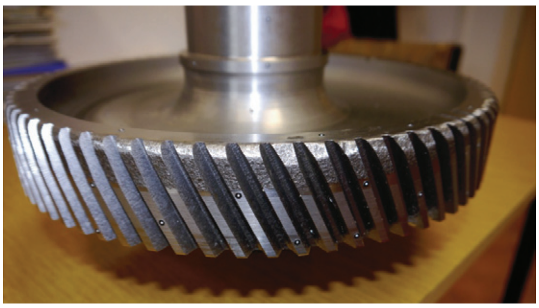

Fig. 2. The measured gear with reference points marked on it

After preparing the model to measure, this process has been carried out in several locations of the measuring system, so as to assure gaining full geometry of the gear to be measured. The number of steps that has been used in every rotation of the scanner around the rim has been set at 36 and made all the teeth visible in lenses of cameras (Fig. 3).

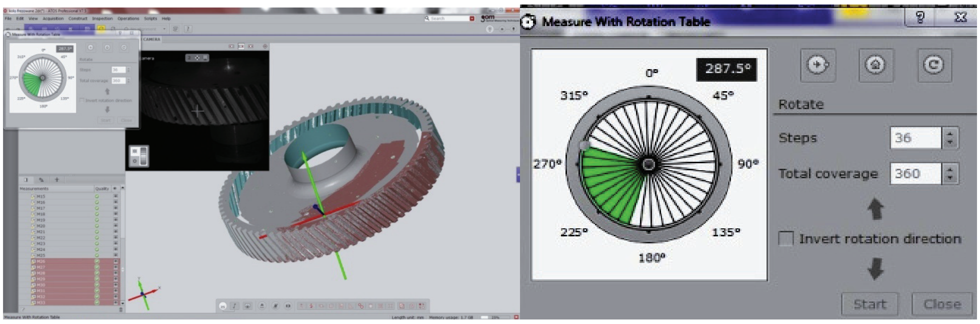

Fig. 3. The GomInspection scanner software window during the process of digitizing using a turntable

In order to implement measurement ensuring the possibility of obtaining complete geometry of the gear along with its hub, it has been conducted in two independent measurement series which after compounding created a surface model of the test gear.

Some irregularities arising in the course of measurement have been removed and missing parts have been completed and now having the surface 3D geometry of the research model, we have imported the standard 3D-CAD model into the environment of inspection software. Then the procedure of basing the pattern with respect to controlled geometry has been executed (Fig. 4).

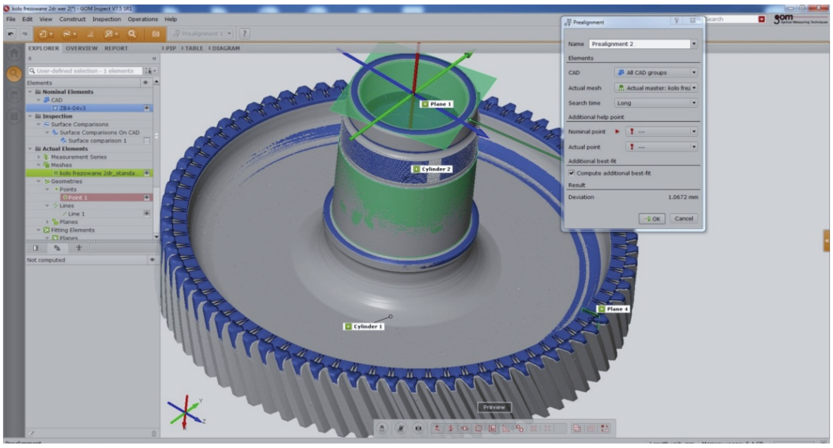

Fig. 4. Combining the CAD model with the surface model of the measured gear after the coordinate system is eventually defined

3. The analysis of the measurement results

The basis of analysing the accuracy of geometry representation in Atos II TripleScan scanning system is an analytical 3D model of the gear. Applying 3D optical scanner and the methodology developed for measurement of gears allowed metrologically valid measurement of geometric characteristics which determine the accuracy of the measured spur gear of aeronautical dual-power path gearing after roughing stage and before heat treatment.

3.1. A global analysis

After accomplishing basing stage of the tested geometry in relation to the standard CAD model, general information about geometric deviations of the whole gear has been obtained. With regard to the nominal outline, deviations of all single points of measurement are calculated and due to their number the deviations are visualized as a colourful map. Such a picture of deviations visualizes critical places of the measured gear to be subject to detailed analysis. The analysis has been made comprehensively (Fig. 5) in accordance with basing coordinate system on the actual axis of rotation of the gear.

After analyses carried out in this way, one can define inspection points and dimensions that are included in the measuring plan. Critical areas can be clarified and documented for further analysis.

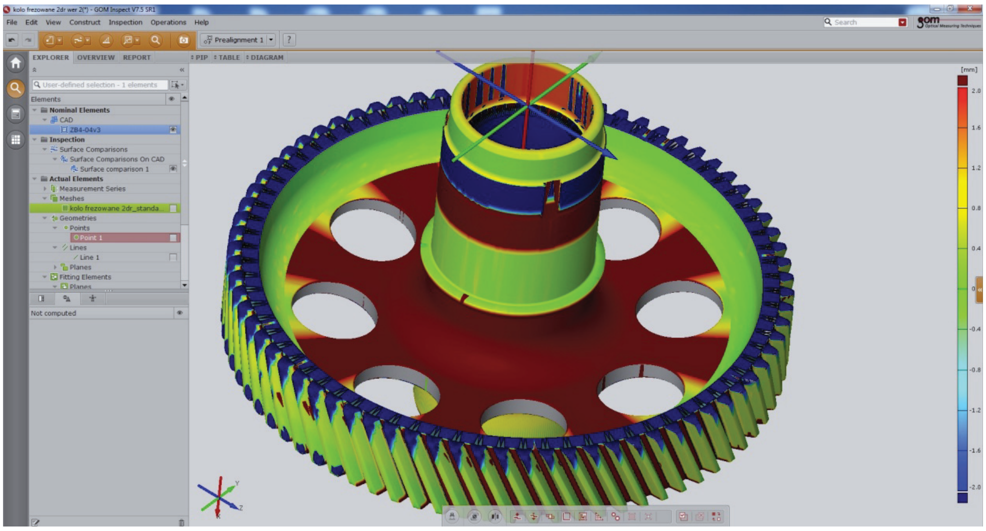

Fig. 5. The global analysis of deviations of the gear surfaces on the CAD model

3.2. A local analysis

Local areas of the gear were subject to analysis of detail geometry (Fig. 6). In addition to the control of the geometry we also obtained the relative position of individual characteristics. The analysis of surface deviations for selected teeth of the gear rims gave a picture of deviations for established allowances for after-machining. In addition, it allowed to detect the distribution of the largest deviations and helped to determine further course of proceedings.

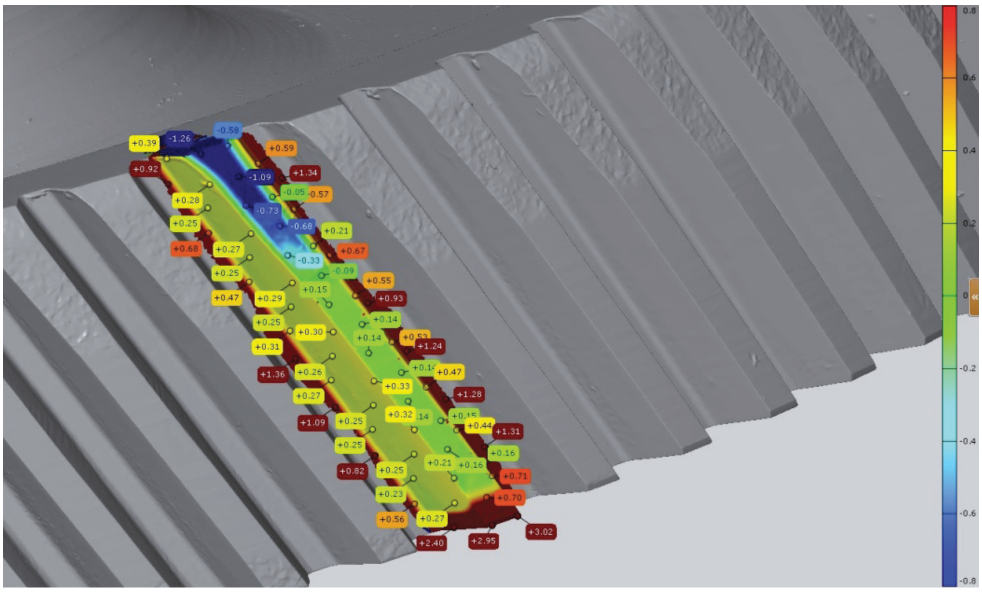

Fig. 6. An exemplary local analysis of deviations of a selected tooth side

The local analysis carried out in the way presented above on two representative teeth showed that allowances for after-machining are greater than the ones assumed in manufacturing process documentation. It also gave grounds to adopt a verification strategy of gear geometry of the test gear rims in intersections perpendicular to the axis of the gear and to check the accuracy of representation of the tooth line.

3.3. An analysis in cross-sections

The created inspection cross-sections enabled a deeper analysis of the accuracy of the gear fabrication in critical areas. GOM Inspection software allows to generate a cross-section through measurement data and CAD design data. The deviations of these two cross-sections are also shown in different colours. At selected points one can attach information about a value of a deviation and whether it is within a specified tolerance.

On the basis of obtained results of research we carried out an inspection of the outline of 5 cross-sections of toothed-wheel rim perpendicular to the gear axis. Fig. 7 shows an example of distribution of deviations on a cross-section on the outline of the gear in relation to the CAD model.

Moreover, Fig. 8 shows the arrangement of analysis of detailed deviations in relevant cross-sections on selected teeth located every 120° on the toothed-wheel rim. Fig. 9 shows a detailed distribution of deviations in specified locations along with their values.

As is clear from the analysis of tooth profiles made along the whole circumference of the rim and the detailed analysis in representative areas, the allowances that have been received during the processing of the gear, are twice as big as the assumed ones. In addition, the distribution of deviations indicates unevenness in scale in all cross-sections made during the analysis.

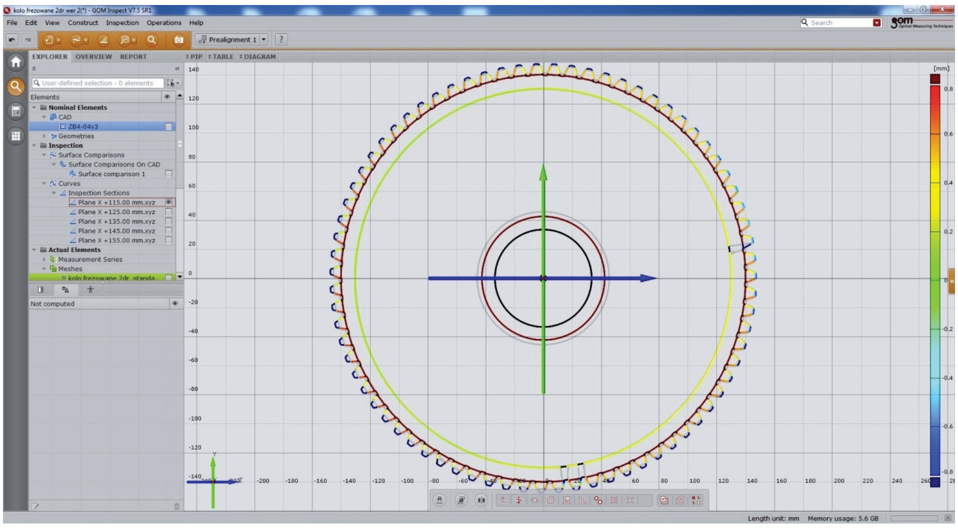

Fig. 7. The analysis of profile deviations on cross-section 1

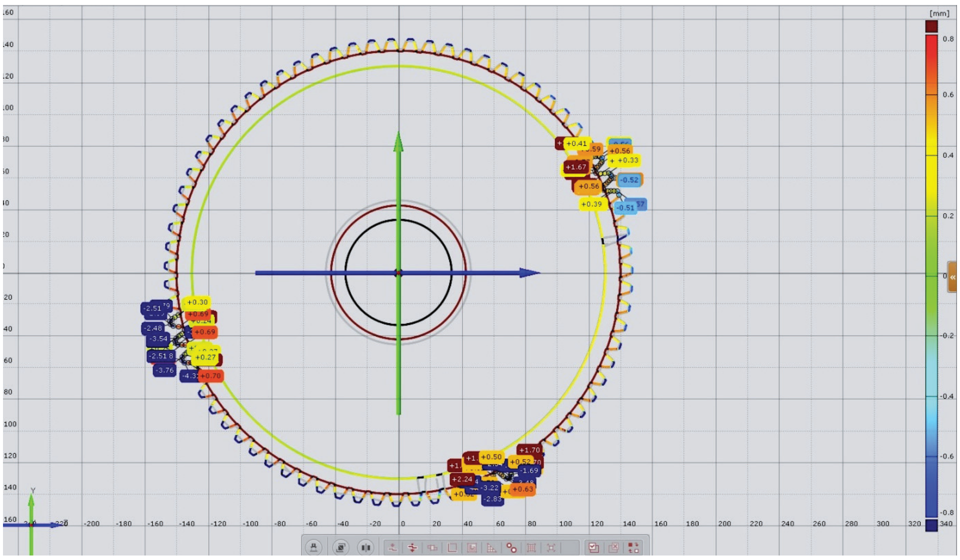

Fig. 8. The distribution of areas of executing the profile analysis on cross-section 1

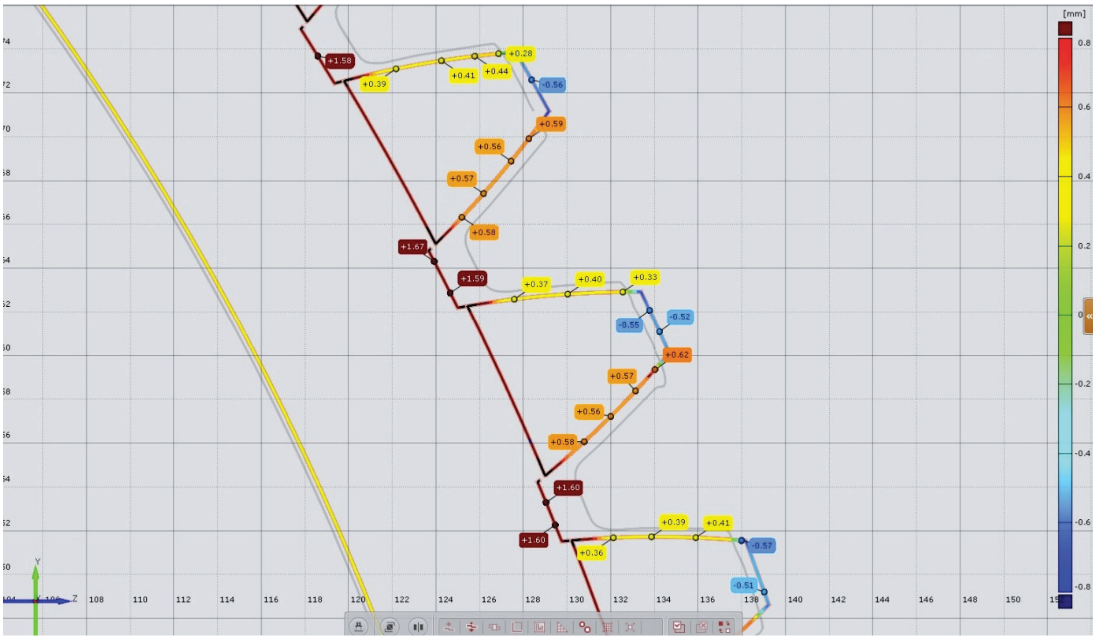

Fig. 9. The analysis of profile deviations on cross-section 1 - position 1

The results obtained in the first two cross-sections suggest that a part of the circumference has too small outer diameter of gear blank. However, as the values of deviations indicate after making the full tooth profiles , at the stage of finishing, it is possible to get the full tooth depths. Therefore, there is a possibility of varying the thickness of the improved layer on the circumference of the rim.

In the process of analysing the accuracy of making the test gear of the aeronautical dual-power path gearing we also carried out a verification of correctness of tooth line representation. On the surface geometry received during the measurement of the test gear we made a cross-section of the rim with a cylinder having the reference diameter which allowed to determine the value of deviation from 3D-CAD nominal contour line. The layout of representative teeth to be verified is shown in Fig. 10, while detailed analysis is illustrated in Fig. 11. They indicate that deviations in a tooth line position have appeared as a result of roughing and they are consistent with the values of deviations of the tested teeth profiles.

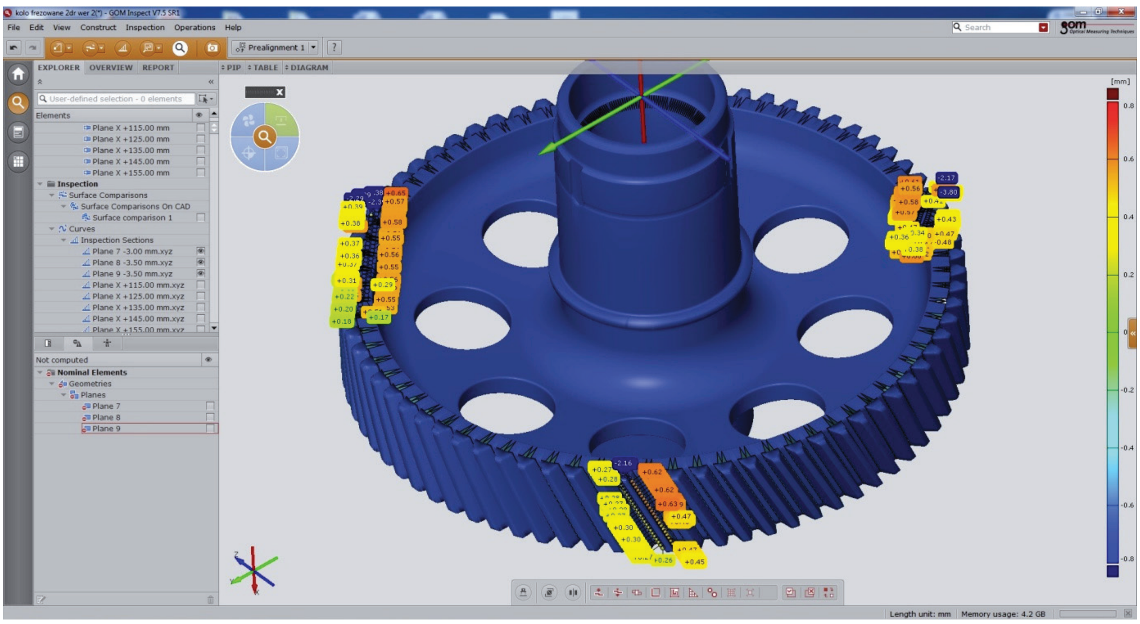

Fig. 10. The analysis of tooth line deviations with the layout of making it

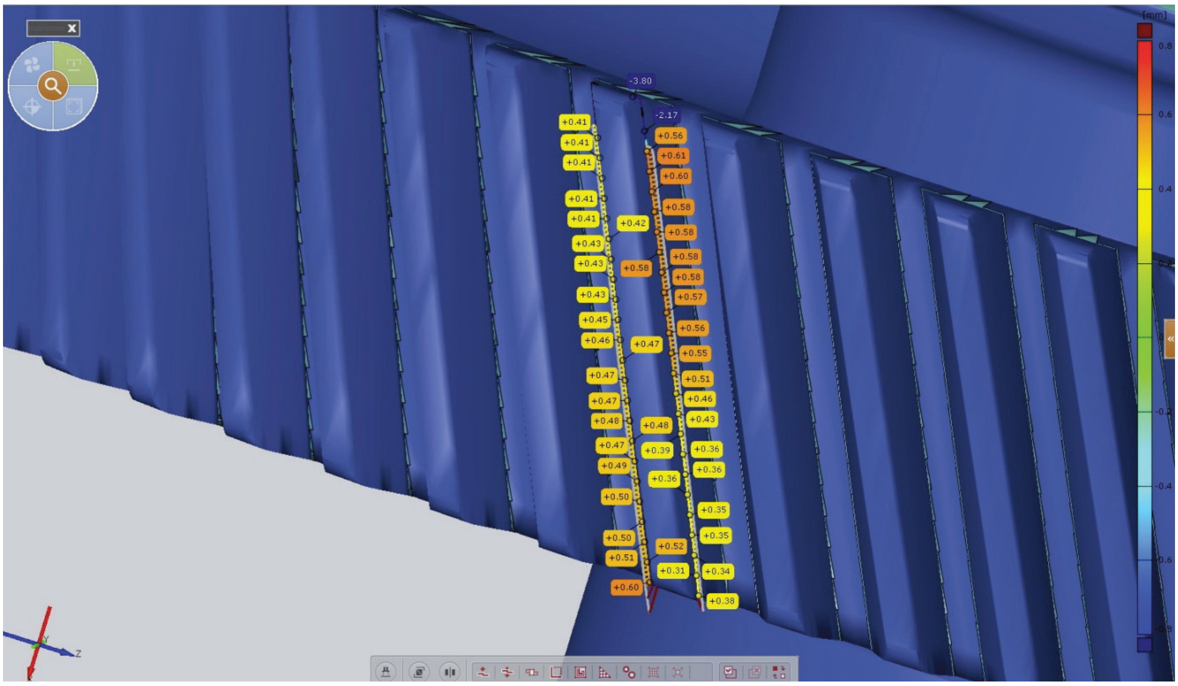

Fig. 11. The detailed analysis of tooth line deviations- position 1

However, with actual machining allowance that has been done, the error of the position of teeth lines is possible to correct. In this connection, as well as on the outline and the diameter of the gear blank, as a result of finishing after heat treatment, there is a possibility of varying the thickness of the improved layer along the width of the rim.

4. Conclusions

The carried out analysis of accuracy done by means of Atos II TripleScan 3D scanner of the test spur gear of dual-power path gearing after roughing and before heat treatment, allowed a quick determination of the actual accuracy of fabrication.

Making gears, which have a 3D-CAD model, make it possible to apply a measurement strategy based on referring the actual geometry to a nominal model.

As a result of the carried out measurements and the process of inspection aiming at verifying the correctness of mapping of the assumed parameters, the received reports define too big allowances for after-machining. In addition, they result in conclusions concerning non-uniformity of scale representation and tooth line of the gear.

Combining individual errors, on the basis of the tests one can come to conclusion that the execution errors in the test gear are possible to eliminate during the final treatment. Furthermore, it should be noted that the gear crafted as part of the test was to enable checking roughing process and detecting possible deformations resulting from heat treatment.

The 3D geometry of the test wheel obtained in the process of scanning will serve as a reference model to determine the possible deformations of geometry of the hardened and tempered gear. The test gear will be subject to a scanning process again and to an analysis with respect to the geometry obtained directly after roughing machining.

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., Markowska, O., Tutak, M., *Automatyzacja i robotyzacja pomiarów współrzędnościowych*, Stal Metale & Nowe Technologie, 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., Zaborniak, M., *Przekładnie zębate o nietypowym zazębieniu – modelowanie, prototypowanie, badania stanowiskowe Rozdział 8. Analiza procesu technologicznego szybkiego prototypowania kół zębatych o specjalnych zarysach w aspekcie dokładności wykonania*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2009.

[4] 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.

[5] Dziubek, T., Zaborniak, M., *Application of chosen contact and non-contact methods of measuring gears*, Western Scientific Centre of Ukrainian Transport Academy, Lvov 2009.

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

[7] Jakubiec, W., Malinowski, J., *Metrologia wielkości geometrycznych*, WNT, Warszawa 1993

[8] 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.

[9] Marciniec, A., Dziubek, T., Zaborniak, M., *Zastosowanie współrzędnościowej techniki pomiarowej i systemów CAD do pomiaru wybranych odchyłek walcowych kół zębatych o zębach śrubowych wykonywanych technikami szybkiego prototypowania*, Konferencja naukowo-techniczna Koła Zębate, Zeszyty Naukowe Politechniki Rzeszowskiej, 2008.

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