THE DETERMINATION OF ACCURACY OF TESTING GEAR WHEEL FOR AERONAUTICAL DUAL-POWER PATH GEAR AFTER HEAT TREATMENT

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Summary

Manufacture of aircraft gearbox elements requires control of gear geometric parameters at different stages of technological process.

The aim of this study is to present develop and execute the analysis accuracy of the geometry of the gear of aeronautical dual-power path gear after the roughing operation using coordinated optical scanner ATOS II Triple Scan. Research was carried out in order to detect errors occurring in the machining process and to determine the value of founded the machining allowance finishing in relation to the CAD model.

On this basis, it is possible to determine the accuracy of the gear wheel as the workpiece after 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: error detection, gear, diagnostics, aircraft gearbox, coordinate measuring technique

OKREŚLENIE DOKŁADNOŚCI TESTOWEGO KOŁA ZĘBATEGO LOTNICZEJ PRZEKŁADNI DWUDROŻNEJ PO OBRÓBCE CIEPLNEJ

Streszczenie

Produkcja elementów przekładni lotniczych wymaga kontroli parametrów geometrycznych kół zębatych na różnych etapach procesu technologicznego. Celem niniejszej pracy jest przedstawienie opracowania i wykonania analizy dokładność geometrii koła przekładni dwudrożnej po obróbce zgrubnej przy użyciu współrzędnościowego skanera optycznego ATOS II Triple Scan. Badania przeprowadzono w celu wykrycia błędów powstałych w procesie obróbki skrawaniem oraz określenia wartości założonych naddatków na obróbkę wykańczającą w odniesieniu do modelu CAD.

Na tej podstawie możliwe jest określenie dokładności wykonania koła zębatego, jako półwyrobu po obróbce cieplnej. Otrzymane wyniki będą podstawą do określenia wpływu obróbki cieplnej na zmiany geometrii koła zębatego ze wzorcem odniesienia dla określenia poprawności wykonania obróbki wykańczającej.

Słowa kluczowe: wykrywanie błędów, koła zębate, diagnostyka, przekładnia lotnicza, współrzędnościowa technika pomiarowa

1. INTRODUCTION

The aim of analysis of geometry of testing gear wheel was to present the possibilities of 3D optical scanners. Due to the lack of specialized software dedicated to measuring bevel gears, it was necessary to develop procedures dealing with preparing, the course and analysis of measuring results. Due to taking into account all dependencies, it was possible to analyze accuracy of spur gear of aeronautical dual-power path. Control of the outline as well as the teeth line was included. The developed methodology of measurements concerns the accuracy of product in the context of machining process as well as it deals with determining the size of geometry deformation caused by heat treatment.

2. THE PREPARATION OF MEASURING

The first stage is the preparation of item for measuring. It has great impact on the accuracy and of reliability of measuring process with the use of optical measuring devices. This step is particularly important when the geometry of solids of revolution, which are gears, is subject to verification.

Applying the control of spur gear of aeronautical dual-power path gear, which based on the acquisition of geometry using a 3D optical scanner and analysis conducted with the use of a universal measuring software, requires to prepare the measurement model so that the complete geometry will be ensured.

During research, it was observed that in the case of rotating parts, it is necessary to place reference points so that they uniquely define the scanned fragments of geometry, which enables to connect them properly (fig. 1).

Figure 1. The measured gear with reference points marked on it

That is why the markers, especially located in a toothed rim, cannot be arrange in an orderly manner. This can cause that individual fragments of obtained geometry might be matched incorrectly. The fragments of surface may overlay on each other as a result of incorrect identification of the reference points and the specificity of the geometry of the tooth rim.

Placing markers, which clearly specify the individual parts of surface, eliminate the inadvertent similarity of the geometry of various parts, and thus increases the accuracy of the measurement process.

Another aspect dealing with the preparation of measured model, was measuring with the use of a turntable in two positions relative to measured wheel. This was done to ensure the possibility of obtaining the complete geometry of the wheel, which is not possible from one location. Therefore to obtain digitization of contact surface of wheel with the measuring table and the geometry located in a given position being outside the measuring area of cameras, it is necessary to measure in two independent series.

However, this requires to arrange reference points so that at least three of them are visible in both series of measuring (fig. 2). This allows to connect individual geometries obtained in two independent measurement series.

The final stage of the preparation of the measurement process deals with covering the surface of measured wheel with anti-reflection layer of powdered chalk (fig 3). This prevents from appearing undesired reflections on scanned surfaces thereby increasing the efficiency of the measurement process.

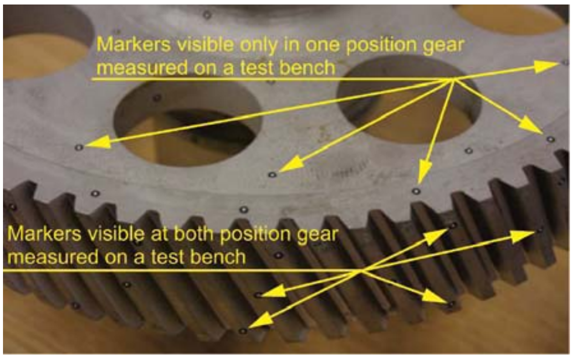

Fig. 2. Deploying reference points on tooth rim

Fig. 3. Measuring gears with anti-reflective covering

Due to the fact that this operation is done only when reference points are applied to the measured near, it is necessary to clean them. It was found that this procedure is much more convenient directly on the test bench, in the light of the projector and measurement area of camera. This enables to observe on the screen which points should be improved. This operation greatly accelerate the preparation process and eliminates errors.

3. MEASURING GEAOMETRY OF GEARS AND DATA PROCESSING

To ensure reproducibility and precision of manufactured gears, makes us use advanced control techniques. This requires to properly plan the measurement process, the methodology and the analysis of the acquired data. This is particularly important in the case of using universal measuring device during measuring the geometry of gears.

3D ATOS II Trilpe Scan was applied during the process of measuring the spur gear of aeronautical dual-power path gearing. A developed measurement methodology provided measuring in two positions of gear with respect to measuring table (fig. 4). Due to such measurement strategy and the opportunities offered by V7,5 ATOS Professional software, an efficient and accurate methodology of obtaining a full geometry of gear was achieved.

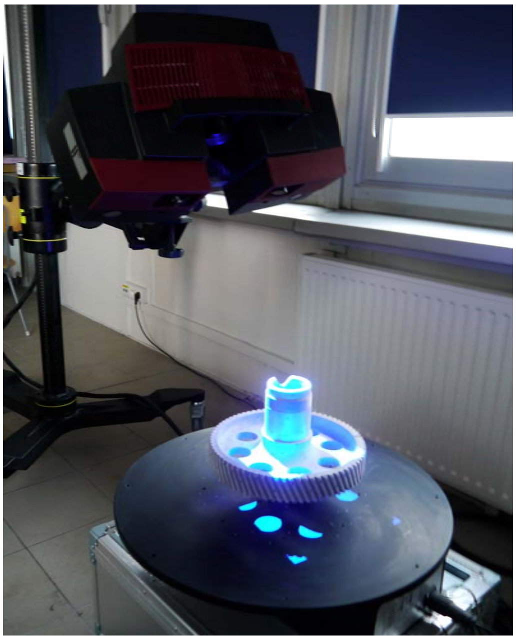

Fig. 4. Measuring the gear wheel for aeronautical dual-power path gearing by means of optical 3D scanner ATOS II Triple Scan.

The developed methodology assumes that the measuring process is carried out in several positions of the measuring system. That is the reason why the measurement was conducted in two independent measurement series (fig. 5, 6).

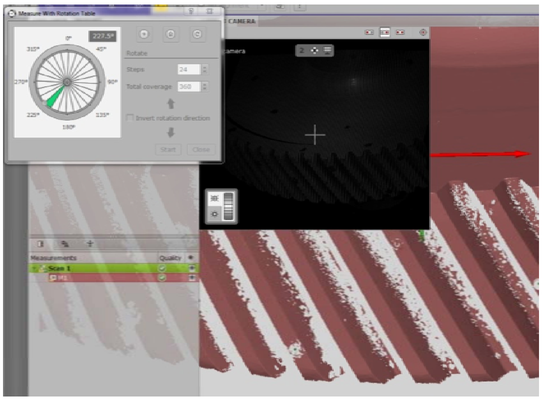

Fig. 5. Geometry of gear obtained in the first position on a measuring table

The adopted measurement strategy requires that the measurement data which have been acquired during two independent measurement series (fig. 6), are compiled on the basis of the reference points (fig. 7) and then they created a surface model of the test gear.

To perform such an operation, at least three reference points have to be visible, which are of detected in two independent measurement series. The more reference points are detected, the less errors associated with deviations of transformation (Fig. 7).

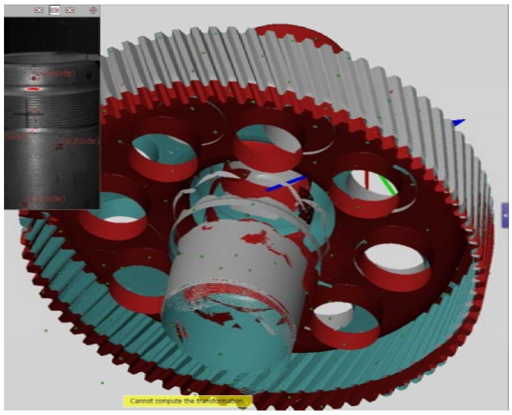

Fig. 6. Geometry of gear obtained in two independent measurement series

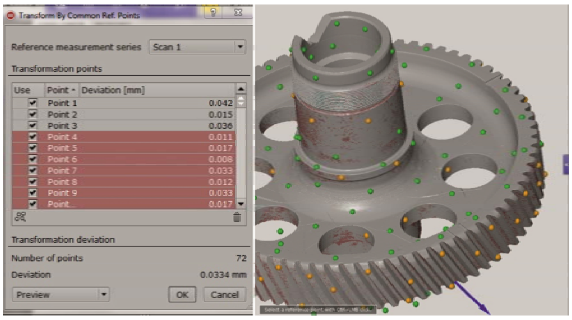

Fig. 7. Connection of geometry obtained in two independent measurement series

3.1. The process of defining the coordinate system

The next step is basing the coordinate system in relation to the acquired geometry. This is the result of the specific nature of the software which algorithms during the measurement process define it freely. Firstly, the geometry of measured element is obtained, and then the coordinate system is defined according to full measurement data,. The advantage of such operation is the ability to change the position of coordinate system without re-measurement.

Defining the coordinate system on an acquired model, from which all irregularities were removed and adding all missing parts is connected with associating it with the coordinate system on the base surfaces (fig. 8).

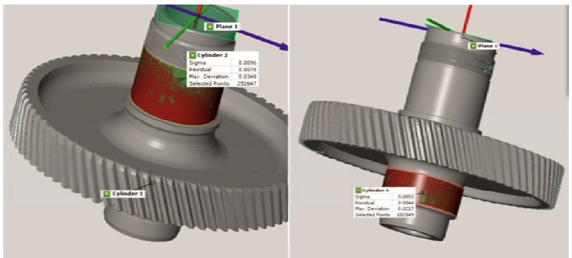

Fig. 8. Defining geometry in order to determine the position of the coordinate system

In the next step, you need to add a reference model in the form of 3D-CAD model to such prepared geometry. Then, both models are subjected to the procedure of basing - standard in relation to the controlled geometry (fig. 9).

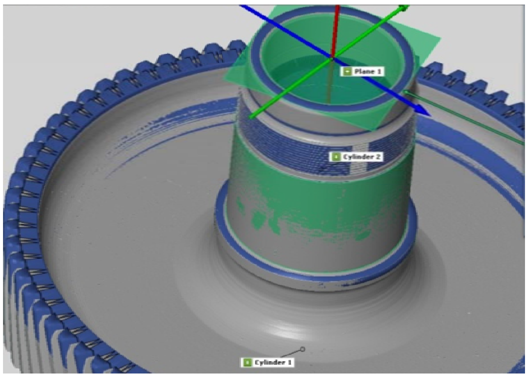

Fig. 9. Connecting standard model 3D-CAD with obtained geometry of gear

When the preparation for measurement, the digitalization of geometry and data processing including describing the coordinate system and connecting models are properly made, you can conduct the analysis of the obtained geometry.

4. THE ANALYSIS OF THE MEASUREMENT RESULTS

Universal software of optical scanner ATOS II Triple Scan allows you to analyze the accuracy of parts. The results are presented both in a quantitative manner, as well as in the form of color maps of deviations. The application of 3D optical scanner and developed methodology allowed for metrologically-correct measurement of geometric features that determine the accuracy of aeronautical dual-power path gear and the impact on the geometry changes resulting from heat treatment.

Due to the defined procedures, you can determine the accuracy and the size of the gear deformation. You can also assess the accuracy of mapping of the side surface of teeth and control the profile and the tooth line. Additionally, you can also assess the run-out of tooth rim if you interpret the results of measuring properly.

4.1. A global analysis

As a result of the imposition of the surface geometry of the spur gear on a 3D-CAD model, a global analysis is performed, which allows for visual assessment of the accuracy.

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 (fig. 10 and 11). Such a picture of deviations visualizes critical places of the measured gear to be subject to detailed analysis.

The results showed the geometry deformation resulting from heat treatment process. The presented results indicate that the gear might have been heated non-uniformly, which causes the deformation of the wheel disc and the tooth rim.

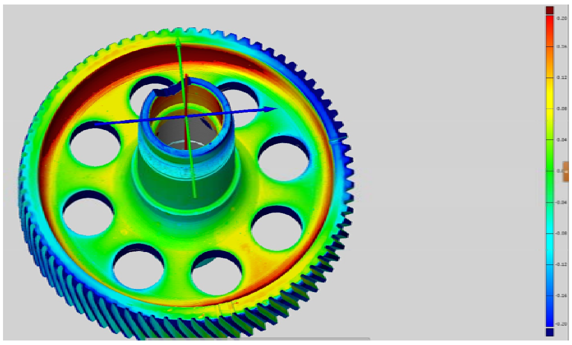

Fig. 10. The global analysis of deviations of the gear surfaces on the CAD model- page 1

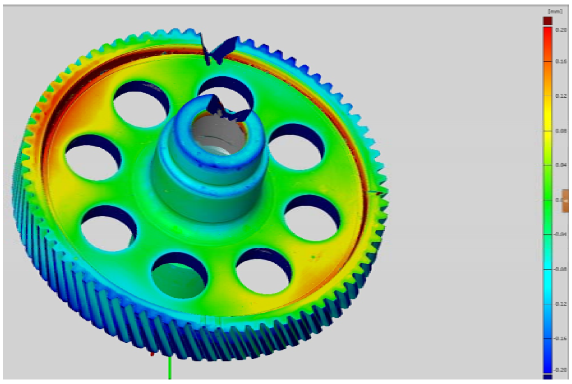

Fig. 11. The global analysis of deviations of the gear surfaces on the CAD model- page 2

4.2. An analysis of tooth side surface

During study, it was found that apart from the global analysis, the accuracy of tooth side surface should be verified. Arrangement shown in figure 12 has also been adopted to carry out thorough analysis of the profile and the teeth line. Due to such defined geometry, you can connect various types of deviations, and consequently assess the accuracy of gear.

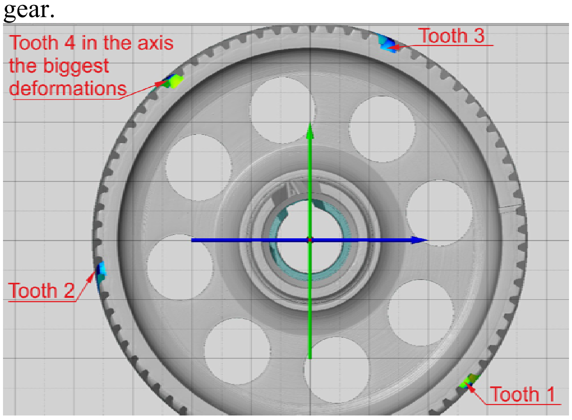

Fig. 12. The principle of distribution of teeth on a toothed rim which are subject to analysis

Through the selection of representative parts of the teeth surface and reference to model, the visual and quantitative analysis of the deviations of the teeth side surface was obtained (fig. 13).

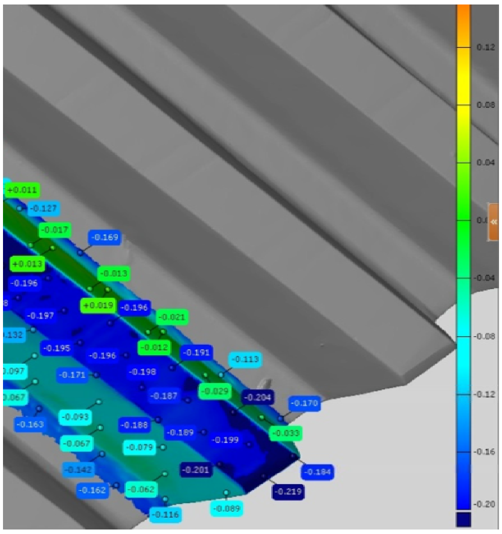

Fig. 13. An Analysis of deviation of the side surface of the tooth with inspection points

Such type of verification of the accuracy is possible for the whole ring, but it is requires more time to analyze. Hence, it was adopted a strategy dealing with applying firstly global assessment of the accuracy, and then you choose selectively places with the highest values of critical deviations.

4.3. An analysis of profile deviation

V7,5 ATOS Professional software enables you to generate a section through the measurement data and CAD construction data. The selected points can be accompanied by information about the value of the deviation, and if they are within the specified tolerance. On the basis of the results of the global assessment, the profile in 5 sections was inspected (fig. 14).

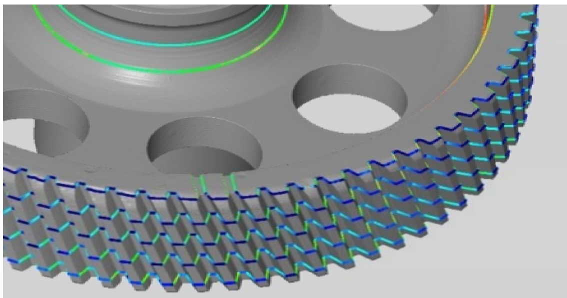

Fig. 14. An analysis of deviations of teeth profile in the section

The analysis illustrate the global deviations of profile for the entire gear rim (fig. 15). There is also possibility to assess thoroughly deviations in the form of quantitative visualization (fig. 16).

If you deeply control, due to reducing the assessed area, you can more accurately assess the size of the deviations. The present analysis can serve both as a verification of the accuracy, as well as, can be used to determine the amount of allowances on the finishing when the measurement process is used between the various stages of manufacture.

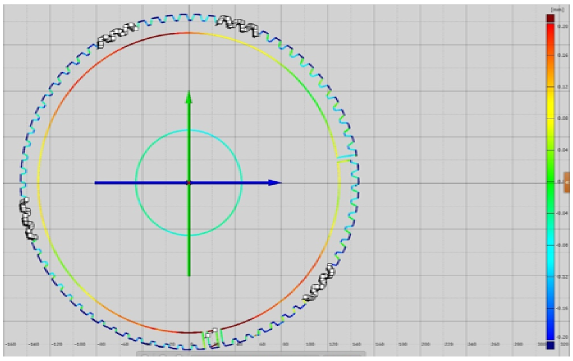

Fig. 15. Global analysis of the profile in one section

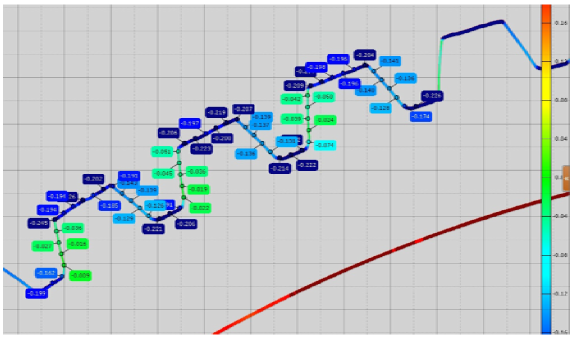

Fig. 16. Detailed analysis of profile deviations

The obtained measurement data confirmed the results of the preliminary global analysis. In addition, it showed that despite of distortion arising during the heat treatment it is possible to obtain the correct geometry of gear on the finishing stage, since the resulting deviations are in the assumed allowances on final machining.

4.4. An analysis of deviation of teeth line

Similarly to with control of the profile, while determining the methodology of measurement of the tooth line, it was assumed that it is possible to verify through creating the appropriate section and then refer it to the standard 3D-CAD. However, in this case there is no direct command that provides obtaining automatic measurement results. For this reason, it was developed the method which deals with generating geometry resulting from the intersection of the measured gear with a suitably defined cylinder with base diameter (fig. 17).

This allows you to specify the value of the line deviation from the nominal outline presented in the form of global assessment of deviations, and a detailed analysis shown in figure 18.

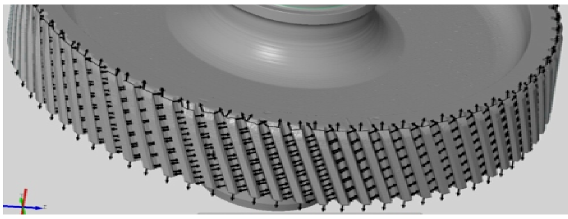

Fig. 17. Creating geometry in order to conduct analysis of deviations of tooth outline

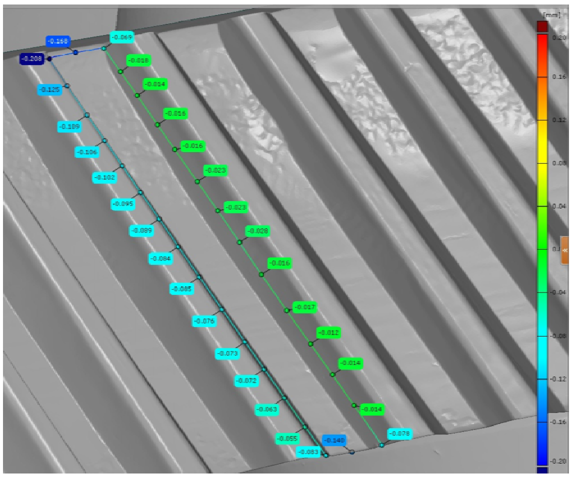

Fig. 18. Detailed analysis of deviations

5. CONCLUSIONS

Due to the use of ATOS II Triple Scan optical scanner during measuring, in order to obtain the desired results, it was necessary to develop a methodology conceding the measurement process and the assessment of accuracy.

Prepared methodology enables you to quickly and efficiently assess the accuracy of product or the geometry deformation of the spur gears. It presents the geometry irregularities visually and allows for easy determination of their size.

As a result of the analysis, they showed the geometry deformations of the plate and the toothed-wheel rim. These results show the influence of heat treatment on the changes gear geometry. On the basis of deviation maps, the value deformation was defined, which allows you classify the gear to further stages of the manufacturing process. Performed diagnostics indicate that it is possible to correct the errors deformation of toothed-wheel rim during the finishing process.

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