OPTICAL MEASUREMENT OF AIRCRAFT ENGINE TURBINE BLADES

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Abstract

Manufacturing of aircraft engine turbine blades requires control of blade geometric parameters at different stages of technological process. Acceleration and automation of measurement process can affect the duration of the finished item production.

Modern technologies for measurement of aircraft engine turbine blades are based on numerical machines - measurement process is based on processing of numerical data obtained by measurement using coordinate measuring machines. The paper presents the opportunity of automation of aircraft engine turbine blades measurements using scanner ATOS II Triple Scan with blue light source technology.

Coordinate measuring technique allows to specify full methodology for designation of complex dimensions of physical objects and transform them into a computer program space of coordinate measuring devices.

Presented paper includes capabilities of device used in the study to improve the measurement process in the technological and economical aspects. Another issue described in the paper is impact of measurement performance in automatic mode on the quality of performance – the numerical model of surface, from the standpoint of accuracy and number of collected data points in time.

The paper includes an analysis of conditions related to the measurement works, such as the process of preparing the model, measurement equipment and data processing capacity. As the result methodology for automated scanning measurements of aircraft engine turbine blades will be presented.

Keywords: *aircraft engines turbine blades, optical measurements, coordinate measuring technique*

1. Introduction

Analysis of accuracy of aircraft engines turbine blades at various stages of technological process requires control of geometric parameters using coordinate measuring methods [1].

Development of coordinate measuring methods is associated with development of computer-based CAD/CAE and RP methods [2-5]. Measurement process is based on computing of measurement data, so that it is possible to determine dimensions of measured object in three-dimensional numerical space. Measurement procedures are based on determination of coordinates of the measured points. Currently, rapid development of optical – non-contact measurement methods using coordinate data processing can be noted [6-9]. These methods allow to perform measurements with high accuracy, significant decrease of measuring time and a software and hardware automation.

2. ATOS Triple Scan Coordinate Scanner

ATOS Triple Scan Blue Light Coordinate Optical Scanner by GOM Company allows performing measurements of the surface objects with complex shapes, such as blades of aircraft engines. ATOS Optical coordinate stereoscopic system is based on two measuring cameras. Moreover, the system consists of projector, tripod, a scanner control unit and a computer. Work stand of the measurement system with a turntable shown in Fig. 1.

Acceleration of the ATOS scanner measurement process is possible due to use of hardware and software automation. Hardware automation is based on measured object mount in holder with additional rotary axes. For stationary objects it is also possible to install the measuring head on the robot arm. First stage of automation is to use stand with one rotation axis. It is a solution that significantly accelerate the measurement process.

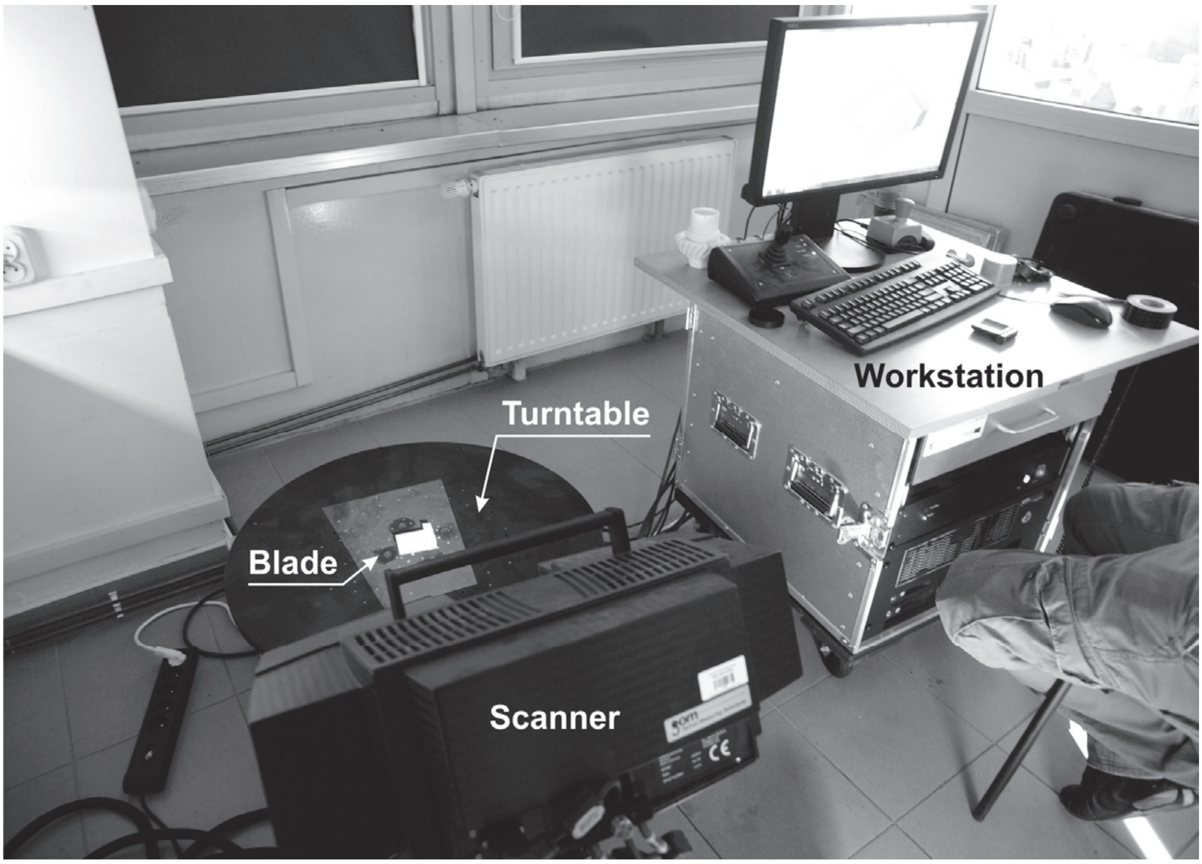

Fig. 1. ATOS II Triple Scan Blue Light measuring system

3. Object and scanner preparation for measurement

Preparation of an object for measurement involves markers fixing and, for reflective objects, imposition of anti-reflective coating. Markers placed on test object or its surrounding such as scanner turntable are used as reference points.

Uncoded reference points are used to determine coordinates of measuring object and combining consecutive measurements. During the measurements, they are automatically detected and numbered sequentially. Reference point size depends on the size of used measurement area.

Before the measurements, calibration of the ATOS system is needed. It is carried out using a calibration plate dependent on used measurement area. Before performing an actual measurement, it is also needed to prepare measuring system with a turntable. For this purpose, the reference points are being placed on the table, and then their distribution measurement is performed. After that, file with the measured data of table reference points is saved as a model and used as a base for the implementation of relevant measures. Thanks to this operation, the need to deploy a large number of reference points on the measured wheel was eliminated, which was normally necessary during the measurement in order to obtain the full geometry of the object (Fig. 2).

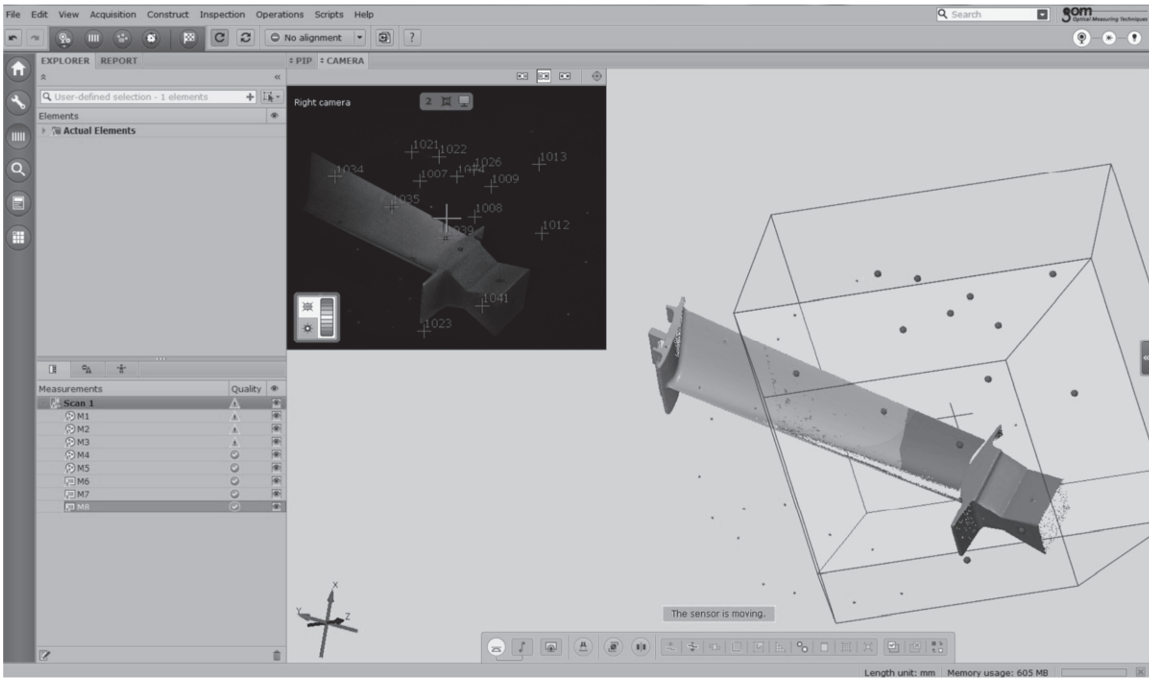

Fig. 2. Image of measurement blade

The turntable fitted to the ATOS optical scanner enables automatic measurement of the blade, which is held at assumed progressive steps. The number of steps in which the table makes full rotation is dependent on the complexity of measured object geometry. In the present case, this relationship was related to the number of gear teeth measured and on this basis a number of measurement steps has been defined.

During the measurement, collection of measured blade geometry, takes place automatically. After each angular position change of the table measuring system automatically enforces rotation and conducts scan of the surface in this position. This kind series measurement process is being terminated after full table turn.

Next step is mutual submission of all scan results. The software used in the scanning system – ATOS Professional, allows to combine scanned images for obtaining complete scanned surface (Fig. 3). As a result of the scanned gear surface poligonisation, millions of data points are replaced with triangle mesh. Measurement data obtained in this way are imposed on the nominal CAD model blades.

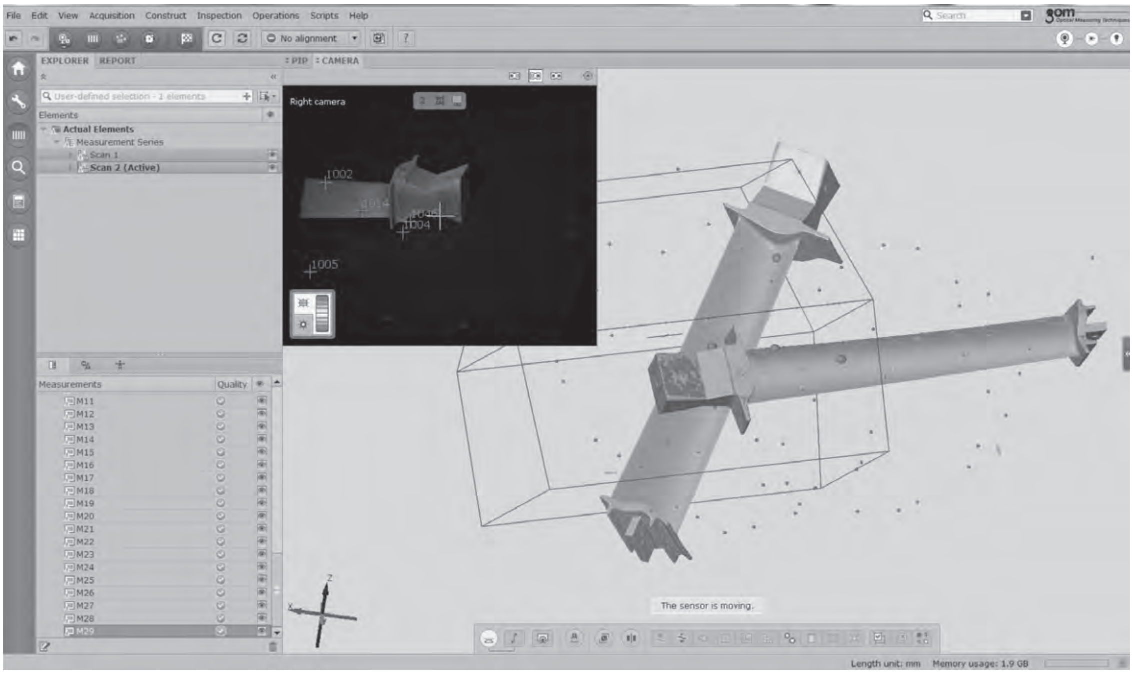

Fig. 3. Combination of measurement results

4. Analysis of measurements results

GOM Software Application Inspection Module allows subsequent performance of the accuracy analysis of the obtained measured element with respect to the nominal model. It allows to analyse whole element what gives a complete picture of the accuracy of its implementation. In addition, coordinate measuring system offers the possibility of using different CAD model adjustments systems: based on the geometrical elements, best-fit and RPS (Reference Point System).

With respect to the nominal profile deviations of all individual measuring points are calculated. The concentration of collected points is relatively large and deviations are visualized as a colour map. Complex analysis of the measured blade has been performed and presented in Fig. 4. After such an analysis, inspection points and dimensions are defined and included in the measurement plan. Critical areas can be specified and documented for further analysis (Fig. 5).

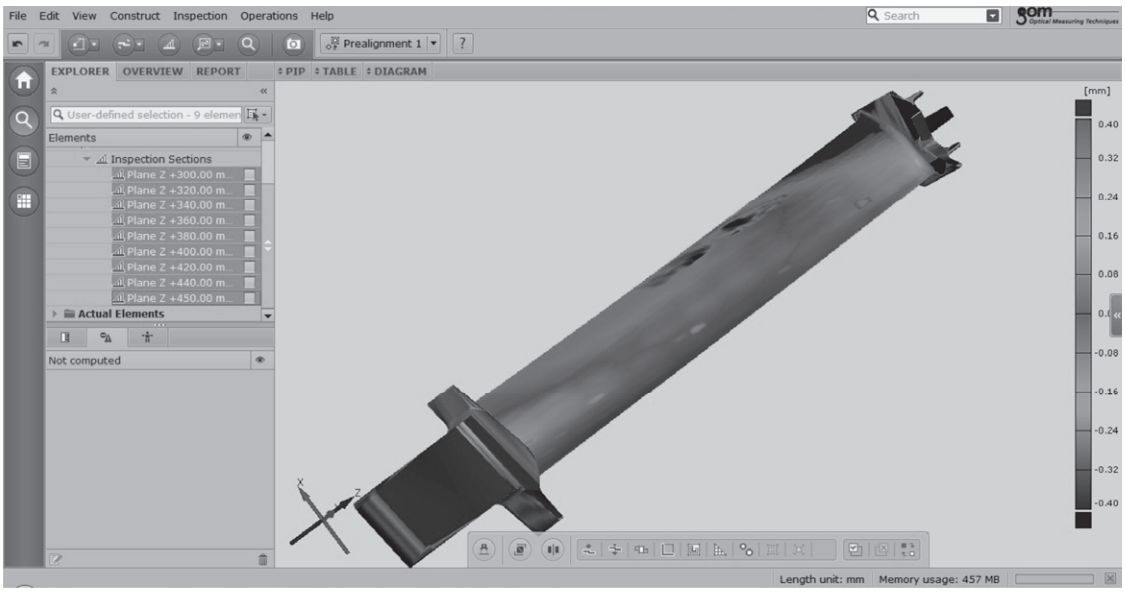

Fig. 4. Analysis of the blade surface deviations with respect to the CAD model

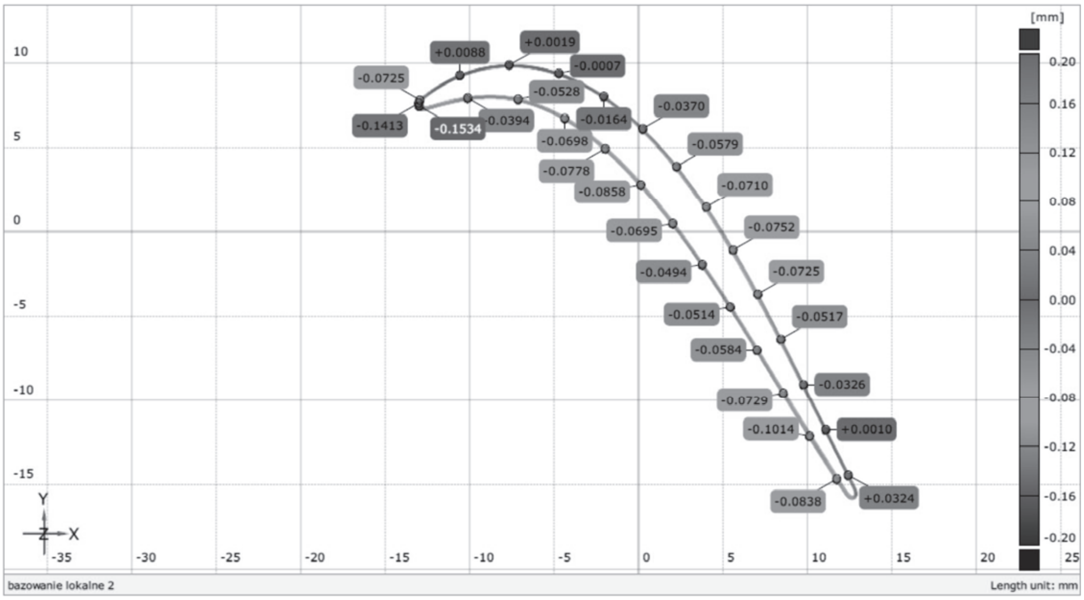

Fig. 5. Detailed analysis of the deviations of outline profile for selected values

6. Conclusions

Measurements of aircraft engine blades and their automation using GOM's ATOS system allows significant acceleration of the measurement process. The automation does not eliminate the need for adequate preparation for the measurement model. However, this provides the opportunity to reduce the number of points fixed to the object by using the reference element which is the surface of the turntable.

During the measurements, the appropriate set of light intensity and anti-reflective model surface coating provides proper markers amount recognition of the corresponding system.

The accuracy of the ATOS system optical measurement method depends on: cameras resolution, stability, the number and rate of images recovery, markers visibility on the surface of the scanned object, calibration procedure and used software. New measurement technology using Blue Light allows more accurate measurements for systems to compare with white light. The Blue Light Technology also allows to reduce the effect of ambient light on measurements.

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References

[1] Budzik, G., *Geometrical Accuracy of Aircraft Engine Turbine Blades*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2013.

[2] Budzik, G., *Possibilities of Using Vacuum Casting Process for Manufacturing Cast Models of Turbocharger Impeller*, Journal of KONES Powertrain and Transport, Vol. 14, No. 3, pp. 125-130, Warszawa 2007.

[3] Hu, D., Wang, R., Tao, Z., *Probabilistic design for turbine disk at high temperature*, Aircraft Engineering and Aerospace Technology, Vol. 83, Is. 4, pp. 199-207, 2011.

[4] Hu D., Wang R., *Combined fatigue experiments on full scale turbine components*, Aircraft Engineering and Aerospace Technology, Vol. 85, Is. 1, pp. 4-9, 2013.

[5] Lin, T., Lee, J., Lwin, T., *Integrated approach for rotor blade manufacturing cost estimate*, Aircraft Engineering and Aerospace Technology, Vol. 83, Is. 4, pp. 235-244, 2011.
[6] Onyszko, A., Kubiak, K., Bogdanowicz, W., Sieniawski, J., *X-ray topography and crystal orientation study of nickel-based CMSX-4 superalloy single crystal*, Crystal Research and Technology 45, 12 pp. 1326-1332, 2010.
[7] Piccione, E., Bernardini, G., Gennaretti, M., *Structural-aeroelastic finite element modeling for advanced-geometry rotor blades*, Aircraft Engineering and Aerospace Technology, Vol. 84, Is. 6, pp. 367-375, 2013.
[8] Ratajczyk, E., *Współrzędnościowa technika pomiarowa*, Oficyna Wydaw. Politechniki Warszawskiej, Warszawa 2005.
[9] Witek, L., Orkisz, M., Wygonik, P., et al. *Fracture analysis of a turbine casing*, Engineering Failure Analysis, Elsevier, Vol. 18, Is. 3 pp. 914-923.