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Optical coordinate scanners applied for the inspection of large scale housings produced in foundry technology

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Abstract
The paper presents possibilities of the dimensional and geometry measurement of the large scale casting details with a coordinate measuring technique. In particular, the analysis has been devoted to the measurement strategy in case of the measurement of large scale detail (larger than 1000 mm) made in foundry technology, with the 3D optical scanner. The attention was paid on the possibility created by the advanced software attached to the scanner for measurement data processing. Preparation to the geometrical accuracy analysis of the measured objects consisted of the identification of particular geometrical features based on the large number of probing points, as well as the creation of the coordinate systems derived from the best-fitting algorithms which calculate the inscribed or circumscribed geometrical elements. Analysis of accuracy in every probing point has been performed through the comparison of their coordinates with nominal values set by 3D model. Application of the 3D optical coordinate scanner with advanced measurement software for the manufacturing accuracy inspection is very useful in case of large scale details produced with foundry technologies and allows to carry out full accuracy analysis of the examined detail.

Key words: coordinate measuring technique, 3D optical scanners, optical coordinate measurement, large scale measurement, foundry of the large scale details

1. Introduction

Large scale details produced in foundry technology have got usually large distances between the measured points of the inspected feature. The features and the examined points reflect the manufacturing accuracy of the detail. Moreover, their accuracy is a crucial characteristics for future functionality and assembleability, and, hence, usefulness of the inspected detail in a final construction or device. The examples are constructions and subassemblies in motor industry, ship or aerospace industry.

Metrological description of the critical characteristics which set conditions on the correctness and accuracy of the large scale details and subassemblies, especially those produced in foundry technologies, depends on the applied measuring techniques and devices. The applied measurement strategy is directed to the identification of the specified dimensions and their deviations from the nominal values.

In the recent decades, one of the most rapidly developing branches of metrology is the coordinate measuring technique. New solutions like advanced construction of the measuring machines, newly developed materials used for their parts, measurement software combined with the control devices, ultra-precise incremental gauges with positioning devices, and measurement heads and probes ensure the extremely accurate measurement of both small and large scale details. Implementation of the non-contact measuring heads in the coordinate measuring technique substantially expanded measuring abilities of the typical coordinate measuring machines. Non-contact measurement is performed generally by the CCD cameras and triangular optical devices.

Further development of the coordinate measuring technique is directed towards wider application of the optical measuring heads, as well as devices based on white light and photogrametry.

2. Optical measurement of large scale details produced in foundry technology

The most modern measuring technique with its most advanced technical and metrological solutions enable to perform measurement of both very small details and very large ones, with dimensions over 10000 mm [1, 2, 3, 4]. The examples of such large scale details could be a car bodies, airplanes, space shuttles or tankers. The housings produced in foundry technology sometimes exceed 1000 mm and then may be considered as a large scale details. To measure this kind of details, one must consider appropriate measurement strategy which ensure required accuracy of the obtained measurement results.

- Measurement Strategy A

3D scanning simple and fast; the measured detail is placed in the measuring area of the optical coordinate system or it is a little larger (Fig. 1).

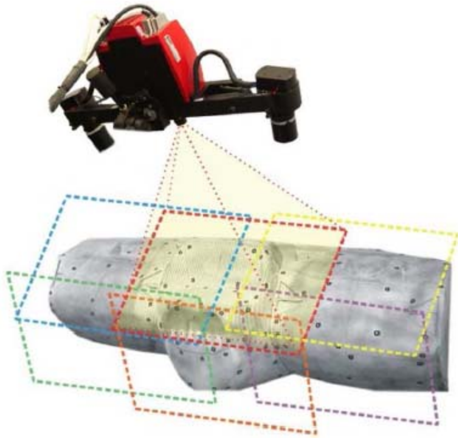
- Measurement Strategy B

In that case, the measured detail underwent scanning partially (in chosen areas corresponding with measurement space of the device), until all the data are collected. In contradiction to the Measurement Strategy A, the complete scanning of the detail is possible here only through the performance of a series of single measurements (Fig. 2).

- Measurement Strategy C

The reference points of the measured detail should be preliminary registered with a photogrametry system. At the very beginning of the project, the coordinates *XYZ* of non-coded reference points registered by photogrametry system are imported to the computer. This method is very useful especially when measuring very large objects like a car, airplane or a large housing in scale 1:1 (Fig. 3).

Fig. 1. Measurement Strategy A [5]



Rys. 2. Measurement Strategy B [5]

3. Metrological characteristics of the optical scanner ATOS II 400 GOM

Division of Metrology and Measurement System (Institute of Mechanical Technology, Poznan University of Technology) runs a measurement laboratory equipped with a 3D coordinate optical scanner GOM ATOS II 400. Its metrological characteristics for all measurement spaces (ranges) are presented in the Table 1. The scanner is equipped with a measuring objectives (corresponding with certain measuring spaces), and combined with the photogrametric system TRITOP it allows to measure objects of any dimensions. The only limitation of large scale measurement is the accuracy of identification of probing points and accuracy of determination of various critical characteristics of the geometrical features of the inspected detail. The accurate measurement of a large scale details, however, is possible because of combination of the coordinate optical scanner and the photogrametric device into one system.

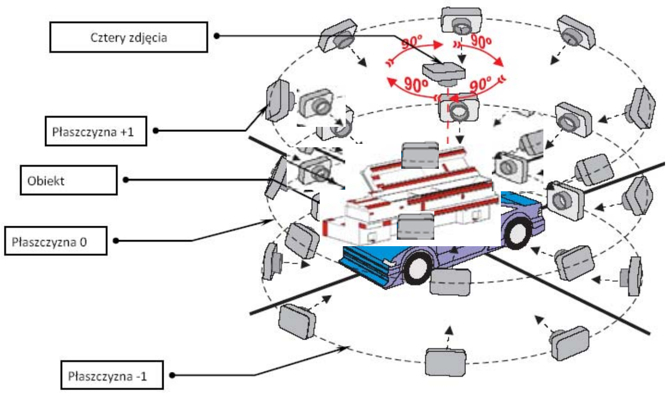


Fig. 3. Measurement Strategy C. Application of the photogrametric system for the identification of the coded and non-coded reference points

Table 1. Metrological characteristics of the measurement space (ranges) of 3D coordinate scanner [5]

Sensor	Measuring volume (L x W x H in mm^3)	Calibration object	Measuring point distance
ATOS II 400	1700 x 1360 x 1360	Cross 1700	1.33 mm
	1200 x 960 x 960	Cross 1200	0.94 mm
	800 x 640 x 640	Cross 800	0.62 mm
	550 x 440 x 440	Cross 550	0.43 mm
	350 x 280 x 280	Panel 350x280	0.27 mm
	250 x 200 x 200	Panel 250x200	0.20 mm
	175 x 140 x 135	Panel 175x140	0.14 mm
	135 x 108 x 95	Panel 135x108	0.11 mm

The accuracy of the particular points identification is bounded directly with the applied measuring space, distance between the single probing points, the method of measurement responsible for the registration of the cloud of points corresponding with the measured object (Fig. 4), and with the method of the data processing in the polygonization process necessary to transform the cloud of points into the virtual object defined by the polygonal grid of the triangles (Fig. 5).

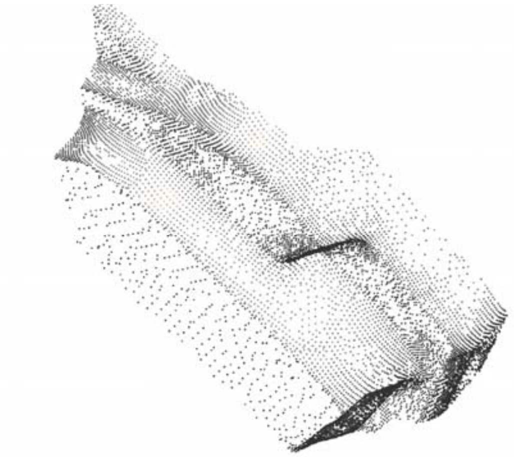


Fig. 4. Cloud of points corresponding with the measured detail

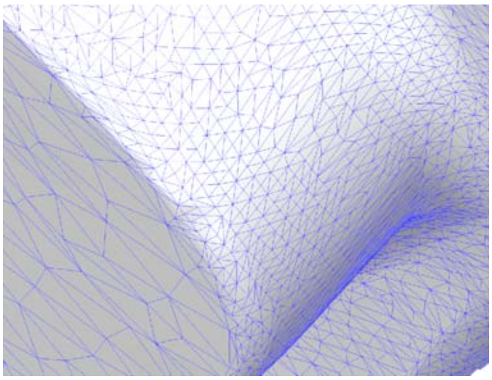


Fig. 5. Grid of triangles after polygonization process

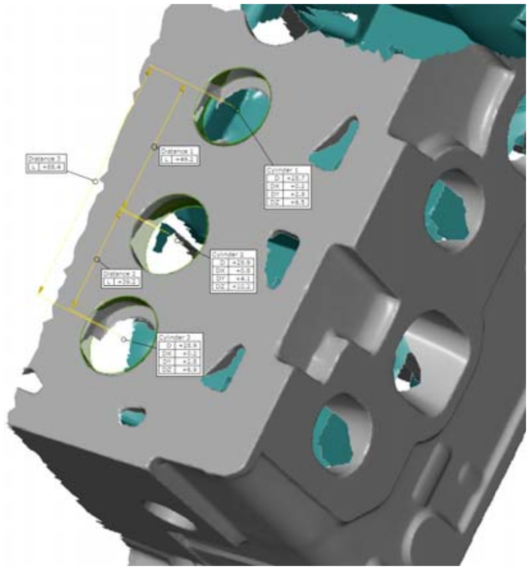


Fig. 6. Example of the measurement results for the characteristics of geometrical features (diameters of the orifices, their localization and distances between them in the defined coordinate system)

3. Possibility of optimization of the cut layer thickness based on the results of optical measurement of the details

In the factories where the large scale castings of complicated forms are used in the manufacturing process, one of the first technological operations is lofting. It helps to evaluate how accurate is the produced casting and how large are the allowances left for further machining [6, 7, 8, 9, 10].

Lofting is a hand-made time-consuming process which may take even several working shifts when the detail is of very complicated form. When the details produced in foundry technology are very large and complicated, often only the first of series of details is being marked-off. It is based on assumption that the foundry technology is repeatable and it is not necessary to evaluate each of subsequent castings. As a result, much time is saved. In practice, however, very often the defects of casting are identified in the machining department. In that case, the machining is postponed until the construction department makes a final decision on further treatment of the detail.

The application of the 3D coordinate optical scanner leads to the creation of the spatial model of the examined casting. The analysis of the model is to be compared with its constructional documentation in order to evaluate the accuracy of manufacturing.

After the verification of the correctness of examined casting, optimization of the machining allowances is performed. That process covers fitting of the obtained 3D model to the constructional model (after machining) with minimal volume of the material to be removed. The fitting process is performed in the virtual space. The optimization result points out the localization of the base zero point on the examined casting. When the machining is carried out in reference to that point, it ensure the minimum volume of the removed material.

The next technological step is the minimization of the idle movement of the cutting tool towards the machined surface. To achieve that, for each measured casting the safe planes covering the groups of the machined surfaces, appropriately distanced from the raw surface of the examined casting. The value of distance should be minimal, but safe. Application of the 3D coordinate optical scanner allows to evaluate the correctness of the examined casting immediately, before it is directed to the further machining.

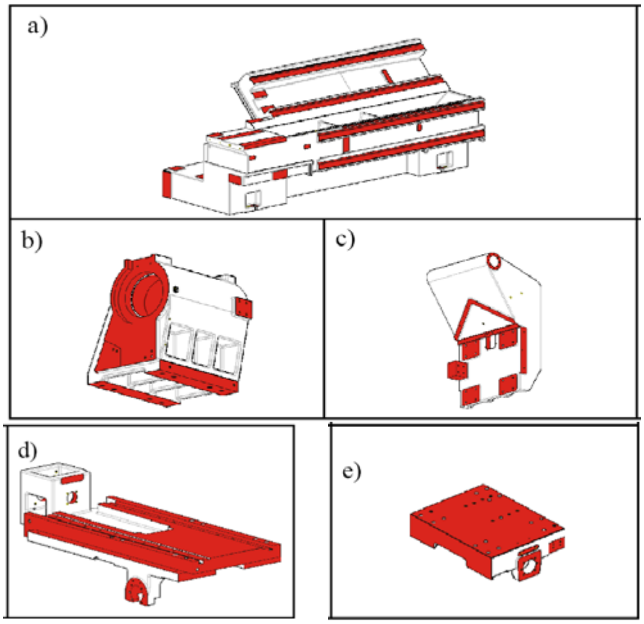


Fig. 7. The castings destined to be mounted into the CNC lathe; the red surfaces are to be machuned: a) cradle, b) Odlewy wchodzące w skład średniej wielkości tokarki sterowanej numerycznie, kolorem czerwonym oznaczono powierzchnie obrabiane: a) łoże, b) fixed headstock, c) tailstock, d) slide Z, e) slide X

At present, verification of the casting is often performed not in the casting house where it was made, but in the place where it is to be machined. Sometimes it is a different factory located remotely from the casting house.

4. Examination of the housings produced in foundry technology

The housings were examined with the coordinate optical system ATOS II 400. The housings were preliminary machined, i.e. initial machining bases were marked in order to enable the further technological process (extremely thin layer was removed only to mark the base surfaces) [11, 12, 13, 14, 15].

After the scanning, the geometrical simulation of the fitting was performed with various algorithms and base surfaces. As a result, the allowances were pointed out in the certain localizations throughout the examined housing. The results of the various analyses are presented in the Figures 8, 9 and 10.

The analysis and the simulations of the raw casting fitting to the machined casting (treated as a nominal housing) enabled to find out the most optimal position and values of the machining allowance. The basing on the best-fitted model enabled to achieve steady allowances in the range from +1.5 mm to + 2.5 mm (Fig. 10 and 11).

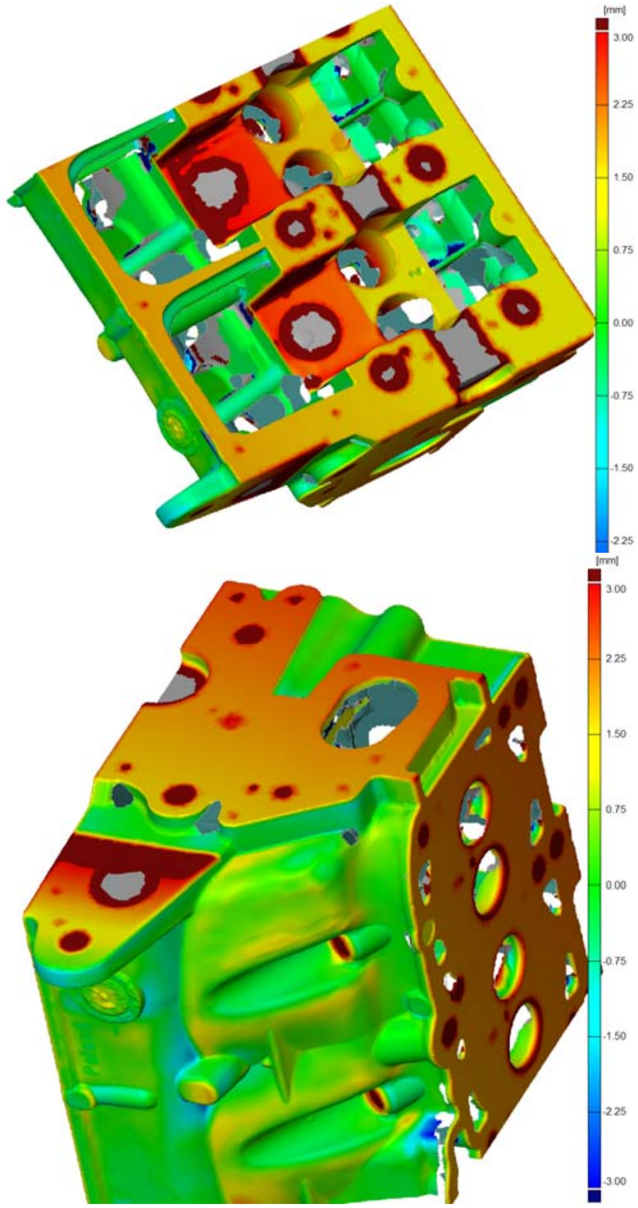


Fig. 8. Distribution of the deviations (values of the allowances) in the best-fitting simulation

The basing on the initially machined technological surfaces of the casting enabled to minimize the deviations on the basic surfaces (calculated from the algorithm of adjacent surfaces) and to localize them appropriately on the machined surfaces (thickness up to 4 mm).

Coordinate optical scanner combined with the specialized measurement software enables to identify the thickness of the allowance layer in the large scale housings made in foundry technology. The measurement system is fully mobile, and the measurement could be performed directly in the casting house. This allows to detect a waster casting before it is transported to the machining department for further treatment.

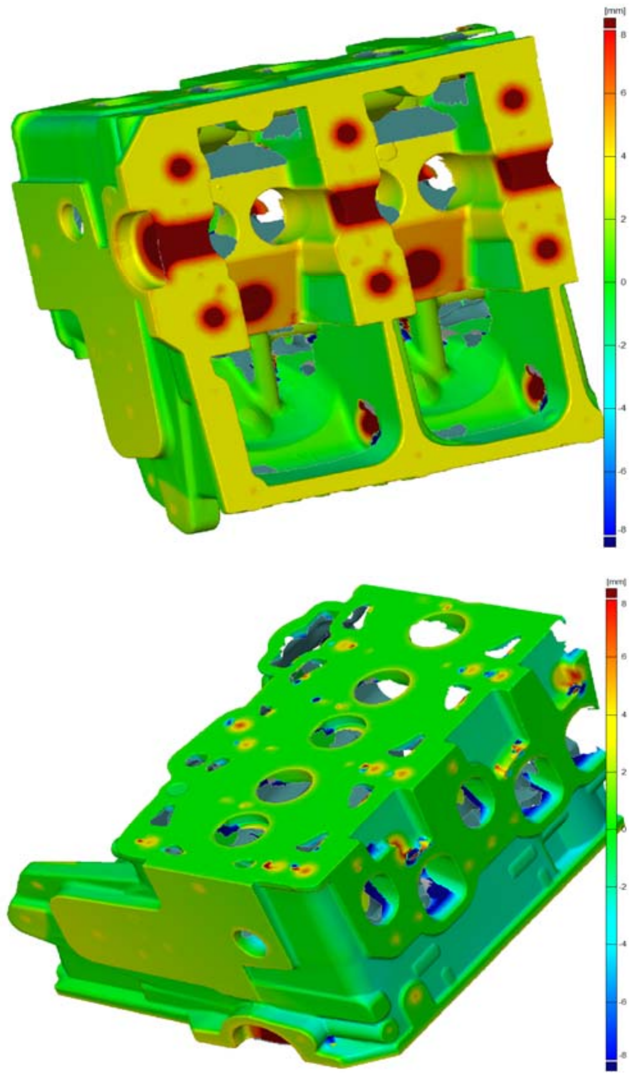


Fig. 9. Distribution of the deviations (technological allowances) for the best-fitting according to the adjacent surfaces

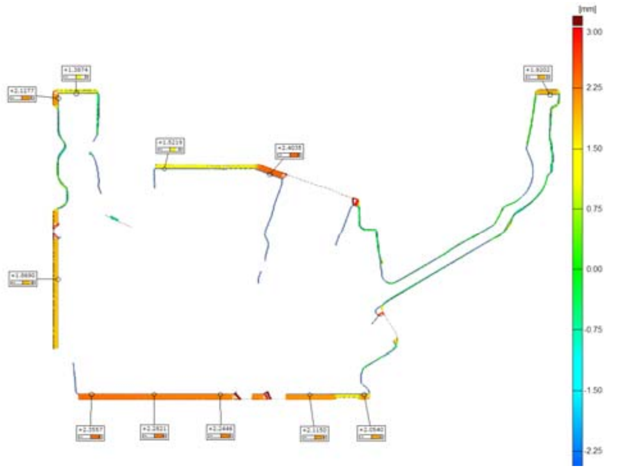


Fig. 10. The values of the technological allowances in the certain intersection of the examined housing, according to the best-fitting algorithm

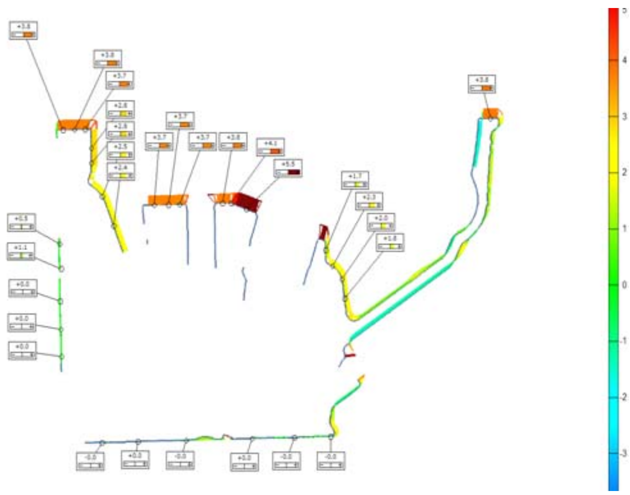


Fig. 11. The values of the technological allowances in the certain intersection of the examined housing, according to the best-fitting algorithm (the adjacent surfaces)

4. Conclusions

Optical coordinate measuring technique allows the measurement of the large scale and complicated form housings produced in foundry technology, because of its most modern and innovative constructional and metrological solutions. The investigations performed in the Division of Metrology and Measurement System (Institute of Mechanical Technology, Poznan University of Technology), as well as in many leading enterprises, lead to the conclusion that the optical measurement systems are the excellent devices for the key characteristics identification and geometrical features analysis of the details produced in foundry technologies.

Coordinate measurement systems enable to identify the geometrical features of the large scale objects and to evaluate the manufacturing accuracy. Moreover, the measurement data could be processed in order to perform the geometrical analysis of the technological allowances. The operator can minimize the overall thickness (volume) of the removed material and, hence, to reduce the costs of the further cutting process.

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