RESEARCH PAPERS
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA
SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

2016 Volume 24, Number 38

REDUCTION OF MILLING TIME BY USING CAQ TECHNOLOGIES

Rudolf ZAUJEC, Peter POKORNÝ, Vladimír ŠIMNA, Tomáš VOPÁT,
Ján URMINSKÝ, Petra BODIŠOVÁ

SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA,
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA,
INSTITUTE OF PRODUCTION TECHNOLOGIES,
ULICA JÁNA BOTTU 2781/25, 917 24 TRNAVA, SLOVAK REPUBLIC
e-mail: rudolf.zaujec@stuba.sk, peter_pokorny@stuba.sk, vladimir.simna@stuba.sk,
tomas.vopat@stuba.sk, jan.urminsky@stuba.sk, petra.bodisova@stuba.sk

Abstract

The paper is focused on reducing machining time by using 3D optical scanner of ATOS Triplescan II. Workpiece was a forging die, which was renovated by hard facing. The contribution deals with comparing the CAM simulation of roughing process according to the STL model imported from ATOS, and simulation without thus-defined workpiece. The results indicate a significant improvement of machining time based on CAQ technology and usage of the ATOS device for measuring the errors of weld deposit.

Key words

simulation, scan, machining, CAM, weld, deposit, deviation

INTRODUCTION

Nowadays, the quality control methods implemented into continuous production processes is based on coordinate measurements. Modern optical 3D scanners are more frequently used than the standard measurement methods. The digitization devices are based on obtaining the surface coordinate points by scanning the surface illuminated by structured light. The spatial coordinates of points forming the surface of the scanned object are determined by active triangulation. The digital model of the object is obtained by polygonising the cloud of points that are obtained. In order to scan reflective surfaces and transparent objects, antireflection layers are applied to the surface of the measured object. The final deformation can then be visualized by color deviation maps. This paper evaluates the suitability of the GOM ATOS 3D optical scanner for measuring the deformations of weld joints and for improvement of machining process (1–4).

The resultant quality of the free-form surface is attained by the 3-axis or 5-axis milling processes, an innovative technology which combines metal removal, CAD/CAM software, programming of CNC machine tools, as well as advanced cutting tool edge design and tool material of the ball end milling cutters. For planning free-form milling operations, it is necessary to combine the product and technology innovation, which requires mastering a broader range of skills, in contrast to the traditional process of milling. Research in free-form milling, therefore, must include the approaches, such as free-form surface design, performance of ball milling cutters, planning the milling strategies, choice of cutting conditions, measurability of free-form surfaces to check their quality parameters, as well as the metrics to assess the machined surface quality (5). However, we focused on roughing milling operations, because they can considerably reduce the resulting machining time. Currently, CAD/CAM software is able to generate very economical machining strategies, if we choose the correct input parameters, such as the STL model of workpiece in this particular case.

SCANNING PROCESS OF FORGING DIE

The scanning process was carried out on the ATOS Triple Scan II device. Calibration of the device was performed before scanning. The calibration is necessary when changing the measuring volume, because in this process the camera lens are changed. For scanning process, it is not necessary; without calibration, we reduce accuracy. In our case, we used the measuring volume MV - 320. Time of the whole scanning process of forging die was 10 minutes, including cleaning the part and emplacement of reference points (0.8 mm). This indicates that, in an hour of scanning, we are able to measure approximately six parts. In implemented scanning was based on the literature (6–9). Fig. 1 shows a deviation color map of the forging die after renovation by weld deposit.

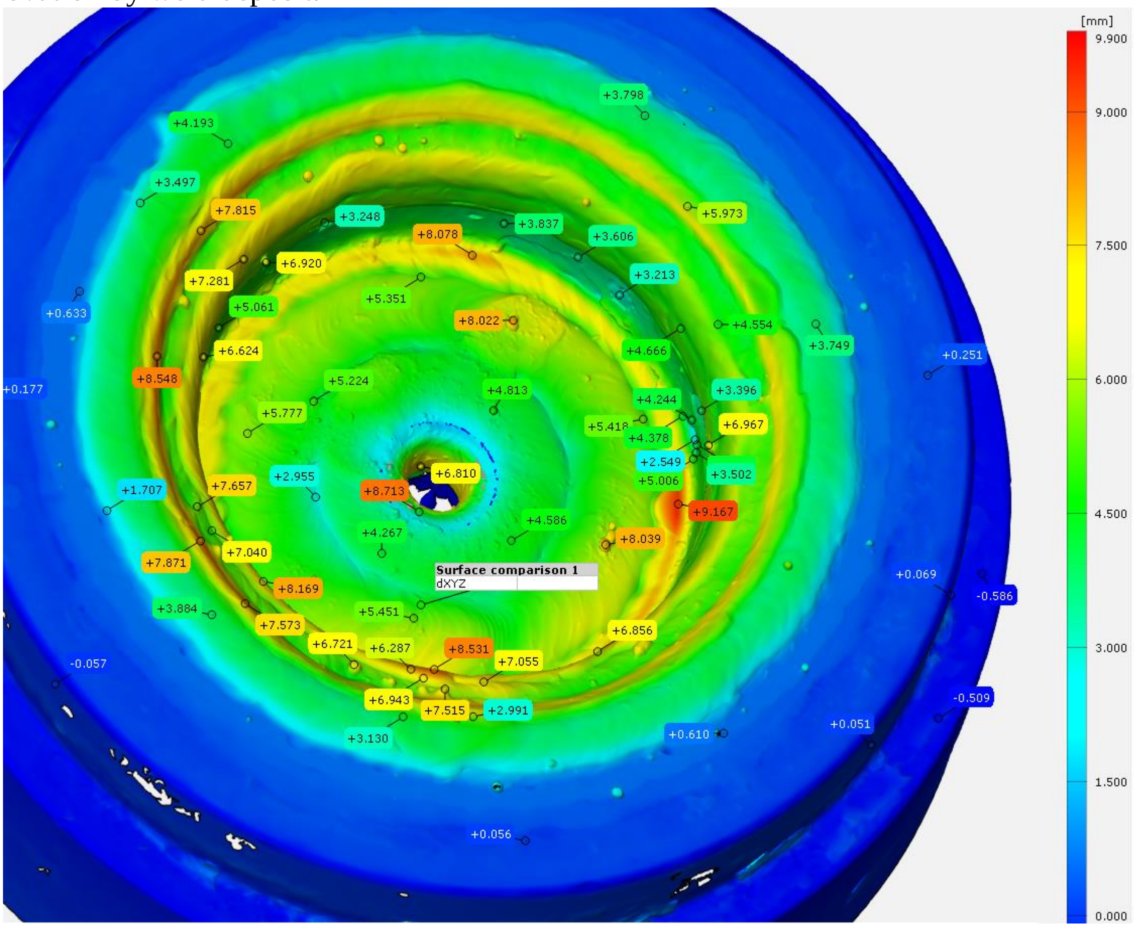

***Fig. 1** Color map of deviations of the welded layer of material*

These deviations are compared with the CAD part models. Weld deposit of material (Oerlikon Fluxofil 54) should be 4 mm according to the manufacturing requirement; however, the Figure shows that the deviations raised up to 9.167 mm in some places of the forging die. This non-uniform layer of a hard material with the alloying elements of Cr, Mn, Mo and Si can significantly damage the cutting tool.

In this particular case, we used the scan to obtain surface irregularities of the workpiece to start the machining process. However, the scan can be used under practical conditions for the detection of weld defects, as seen in Fig. 2. The defect on the dimensional parts is sometimes hard to pin down, and it was discovered only after obtaining a color map of deviations. The layer can be extended down to the base material, and therefore we can find it after the welding of the defective workpiece, and thus prevent further steps of renovations of the forging die.

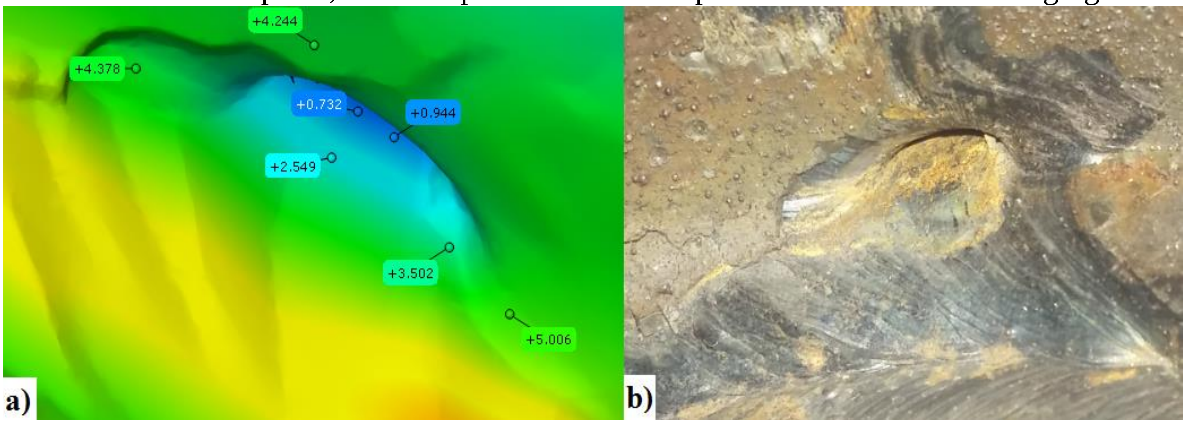

Fig. 2 *Weld defect on the forging die, a) scanned part, b) real forging die*

CAM SIMULATIONS OF MILLING OF FORGING DIE

In our case, the CAM software of PowerMill 2017 was used to create a simulation of milling. In Fig. 3 a), we can see the roughing strategy according to the STL model which was created in the V7.5 GOM Inspect software. Toolpaths in Fig. 3 a) clearly indicate that they were generated by unevenness in the welding process, and the cutting tool movements were performed economically.

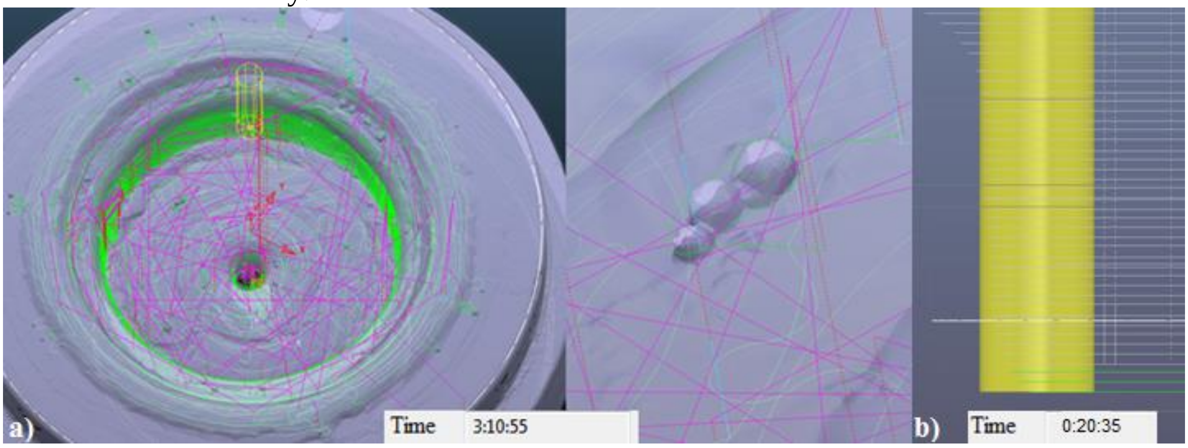

Fig. 3 *Roughing strategies according to the STL model*
a) Roughing strategy in detail, b) The rest of the roughing operation (green lines)

The total machining time according to the software statistics was 3h 10m: 55s. The rest of the roughing operation must be added to this time (see Fig.3 b) at the lower part of forging die where a bevel was. Statistical information for this operation was 20m: 35s. The total time for roughing allowance 0.3 mm for finishing is therefore 3h: 31m: 30s. The cutting conditions specified in the program are the same for all generated CAM strategies as shown in Tab. 1. In

Fig. 4, you can see a very realistic simulation of the milling process of weld deposit which constituted the allowance for machining.

Fig. 4 *Simulation of milling process according STL model*

Table 1 Cutting condition for simulations of milling

YG-1 H3021317-12 face mill with diameter of D12					
v_c [m.min^{-1}]	n [min^{-1}]	v_f [mm.min^{-1}]	f_z [mm]	a_p [mm]	a_e [mm]
100	2653	265	0.05	1	10

Below, represented is the example of the programmed toolpaths in PowerMill 2017 without the data from the scanning of forging die. We created toolpaths with constant allowance of 10 mm in the cavity die, and 5 mm on the face surface for the precise comparison of the situation with imported STL model. From practical perspective, it is extremely difficult to estimate or measure the height of the greatest deviation on the welded parts. This kind of measurement should be undertaken directly on the CNC machine, but we must count with certain downtime. The roughing strategy shown in Fig. 5a) was created based on the cutting conditions specified in Tab.1. Face milling of forging die was used, as the most effectively method of programing of toolpaths (Fig. 5b). If machining also the rake surface of forging die with the D12 cutting tool as before, the total roughing time will be 5h: 58 m: 51s. Therefore, the SANDVIK Coromant 490-063Q22-14M – D63 face mill with cutting conditions: v_c = 275 m.min^{-1}, n = 1389 min^{-1}, f_z = 0.1 mm, a_p = 2 mm, a_e = 55 mm was selected for the face roughing.

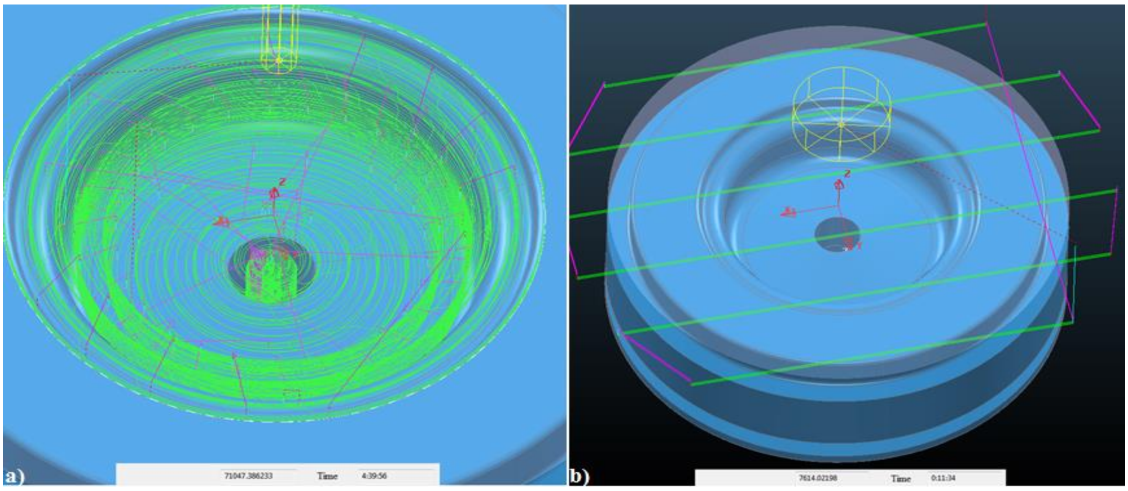

Fig. 5 *Roughing strategies for constant allowance, a) cavity roughing with D12, b) face roughing with D63*

At this stage, programmed toolpaths are the same so it is possible to compare the time demands of strategies with the constant allowance and the allowance according STL. The total time of toolpaths was 4h: 51m: 30s as seen in Fig. 5. Fig. 6 illustrates the forging die after simulation in CAM software. The method of machining according to the STL model with reduced milling time was used in real manufacturing (see Fig. 7).

Fig. 6 *Final shape after simulation of roughing with constant allowance*

Fig. 7 *Final shape after roughing according to the STL model (real forging die)*

Thus, if proposed method of scanning the components (STL model) and the method with the same constant allowance are compared, then difference in the milling time will be 1h: 20m in favour of STL. Also, we take into account the cost of scanning process - 10 minutes per a component.

CONCLUSION

The aim of the paper was to compare the simulation results of roughing for the selected shape of forging die based on the scanning data and without the data. Simulations were carried out for the processes of milling and turning, since in practical production both machining methods of forging dies are found. For milling, the difference in time of machining on the exactly same shape was 1h: 20m. That time does not comprise the difficulties of obtaining the highest deviation before machining of hard facing without STL data from scanning. During the milling of forging dies, it is, of course, possible to shorten these times using higher cutting speeds and the tools with more flutes. In practical production, roughing on conventional lathes in the earmarked time of approximately two hours predominates on this specific type of a forging die, which could be achieved by using the cutting speed in milling of around 150 $m.min^{-1}$.

The same principle can be applied also for CNC turning. The generation of toolpaths will be performed by the same method as for milling. It is needless to say that the time deviance in turning would not be as large, because the process takes much less time. The highest time deviation would be eliminated by this method during CNC alignment of parts. However, this process evidently seems to be appropriate for the forging dies that are milled.

The scanning process of renovation weld deposit for forging dies can be also used to detect different errors of the weld deposit. In our case, we also detected the error that was unnoticed by naked eye. The data could also serve to improve the welding process and achieve potential savings in terms of material.

Acknowledgement

The article was written within the project of VEGA 1/0477/14. Research of influence of selected characteristics of machining process on achieved quality of machined surface and problem free assembly using high technologies. The article was also written within cooperation with HKS Forge s.r.o. and EG Technological Institute.

References:

1. ATOS TipleScan: User Manual – Hardware. https://support.gom.com, 47 p. [cit. 2014-11-01]
2. ATOS V7 Hardware – Benutzerinformation – ATOS I, ATOS I SO. https://support.gom.com, 64 p. [cit. 2014-11-01]
3. ATOS V7.5 SR2 Manual Advanced – Scanning with ATOS – Advanced/Units A-C. https://support.gom.com, 44 p. [cit. 2014-11-01]
4. ATOS V7.5 SR2 Manual Basic – Scanning with ATOS – Basic/Units A-J. https://support.gom.com, 104 p. [cit. 2014-11-01]
5. BEŇO J., MAŇKOVÁ I., IŽOL P., VRABEĽ, M., 2016. An approach to the evaluation of multivariate data during ball end milling free-form surface fragments. *Measurement*, Volume 84, pp. 7-20, ISSN 0263-2241.
6. [6] SANZ, J. L., 1989. Advances in Machine Vision. s.l.:Springer Series in Perception Engineering, ISBN-13: 978-0387968223.
7. MASUBUCHI, K., 1980. *Analysis of Welded Structures, Residual Stresses, distortion, and theri Consequences*. Oxford, England: Pergamon Press Ltd. Headington Hill Hall. ISBN 0-08-022714-7.
8. LUHMANN, T., ROBSON, S., KYLE, S. & HARLEY, I., 2006. *Close Range Photogrammetry, Principles, Methods and Applications.* Scotland, UK. ISBN 1-870325-50-8.
9. CHEN, B. Q., GARBATOV, Y. & SOARES, C. G., MAY., 2011. Measurement of Weld-Induced Deformations in Three-Dimensional Structures Based on Photogrammetry Technique. *Journal of Ship Production and Design*, 27(2), 2158/2866/11/2702-005.

ORCID:

Vladimír Šimna 0000-0001-7489-2441
Tomáš Vopát 0000-0002-6489-9014