THE POSSIBILITY OF USING NON-CONTACT SCANNING TECHNIQUES IN THE ANALYSIS OF THE WEAR FORGING TOOLS

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Abstract

The paper concerns the possibility of the use of modern non-contact measurement techniques in a die forges, like application a measuring arms with integrated linear scanners to analyze wear of forging instrumentation. In particular, to assess the progress of tool wear forging - punch used in the second forging operation of the forging type cover. The presented detailed analysis examines the possibility of using 3D reverse engineering techniques for direct quality control and changes in surface layer geometry of the forging tools, based on the measurement of geometry changes for cyclically collected forgings. The research was divided into two phases. The first step was to analyse tool wear based on direct scanning of their surfaces, then develop a wear-loss curve of the geometric material. In the second step, a selected area of cyclic retrieved forgings from the forging process was scanned for use of an intermediate scanning method - reverse 3D scanning. On this basis, an analysis of the progressive material growth on the selected surface of forgings was made, which was also a loss of material on the punches. The performed analyses showed a good agreement of the geometrical properties of the surfaces (of the selected forgings representing the proceeding wear of the tool) and the geometrical defect of the working impression of the tool, based on the direct measurements during the production process. The obtained results allow for a fast analysis of the forging tool life with respect to the quality and the quantity (of material defect), which, in consequence, leads to significant economical savings.

Keywords: Quality control, scanning, forging tools, forging

1. INTRODUCTION

In modern industrial metrology new trends are noticed, which are mainly related to the possibility of using portable measuring systems such as optical scanners or linear scanners mounted on mobiled measuring arms. This type of non-contact measurement methods, due to their unique capabilities, are used in the analysis of defects in the contour and surface shape [1], which is difficult and time-consuming to evaluate by other measurement techniques. In most cases, they are used only to control the final quality of the products [2], [3]. Unfortunately, modern measuring techniques based on this type of device (such as scanners) are occasionally used to evaluate the state of tools which produce a given product or similar applications [2, [4 - 6]. In additional, it is also worth noting that non-contact measurement technology is currently less accurate than standard contact measurement techniques. However, in some applications, it offers unique capabilities, such as in the regenerative processes surfacing tools [7], [8] w here the error measurement of the shape of the designated surface is used. Currently, non-contact measurement techniques enable efficient quality control of medium and large size forgings, or large-size forging tools, and their measurement can take place directly on production, which is not irrelevant in the economic sense [9].

Die forging processes are one of the most difficult manufacturing processes to perform. Despite the fact that the technology is relatively well-known, proper manufacturing of forgings with complicated shapes, that will meet requirements concerning accuracy and quality posed by customers, require much experience from process engineers and operators. Wearing of forging tools and other instrumentation causes a change of the manufactured product's geometry, and any surface defects on tools (cracks, losses) are reflected on the forged product, affecting the quality of the ready product [10]. The main and most common destructive mechanisms include abrasive wear, mechanical cracking, plastic deformation and thermal and thermal-mechanical fatigue [[11]].

Due to the production costs of forging tools caused to the complex shape of the forged products can be noted the appearance of increased industry interest in research related to increasing the durability of forging tools by measuring and analyzing the progress of their consumption, using non-contact measurement techniques using measuring arms and 3D scanners. This interest prompts to analyze scanning techniques in terms of their usability and development in the forging industry, including: the analysis of tool geometry changes in the forging process and the continuous assessment of the state of the forging tool on the basis of cyclically collected and scanned forgings as well as for more advanced analyses and applications.

The aim of the study is the design and development of contactless measuring method - using a spatial scan of the arm with integrated line scanner for analysis and evaluation of the progress of tool wear forging - punch used in the second forging operation of the forging type cover.

2. MEASURING METHOD AND DESCRIPTION OF THE MEASURING STATION

The hot forging of the forge forgings has been selected for the study. This process is carried out in three operations on the P-1800T press. The tools in the analyzed process are made of WCL steel (**Figure 1a**). After heat treatment, tools for the second and third operations are nitrided.

The research focused on the second forging operation (preliminary forging). Detailed geometric analysis of the treated punch in the upper insert (**Figure 1b**), for it the durability in the analyzed process is the from all tools and selected part of forging forming by this punch (**Figure 1c**).

The ROMER Absolute ARM 7520si with an integrated RS3 scanner and Polyworks software, enabling scanning in Real Time Quality Meshing technology, was selected for tests of applying a contactless measuring method to scan tools and forgings over the course of the forging process. To conduct measurements for the purposes of the developed measurement technology, a laboratory measuring station was built, as presented in **Figure 1d-e**.

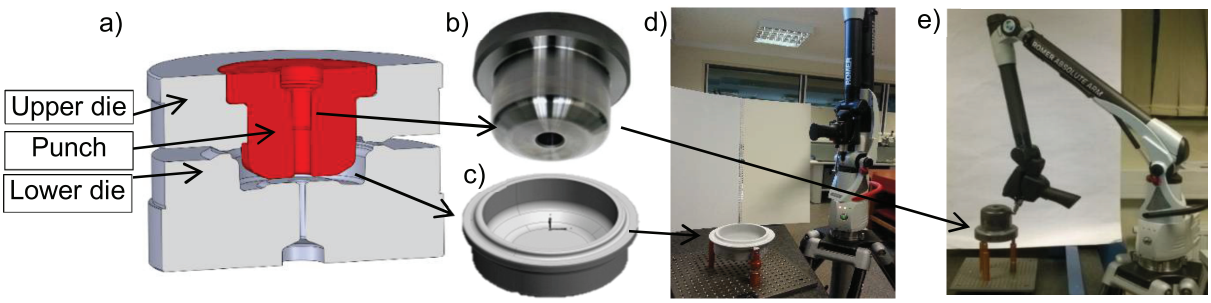

Figure 1 The view of: a) a set of tools used in second operation, b) the analyzed punch, c) the forging, d) measuring stand with the measuring arm and laser scanner to measure tools and e) to measure of forgings

This device makes it possible to perform contact measurements using an additional measuring probe as well as contactless measurements which provides the capability of collecting up to 460,000 points/s for 4600 points on a line at a linear frequency of 100 Hz with a declared 2-sigma accuracy of 30 µm.

3. ANALYSIS OF WEAR TOOL

In the first step of the study, the authors conducted measurements the wear of the analyzed punch after an increasing number of forgings, comparing the scans obtained for the increasingly worn tools with the scanned image of the new tool (**Figure 2**). The presented results of superimposed images of worn tools (after increasing number of forgings), indicate the progressive wear.

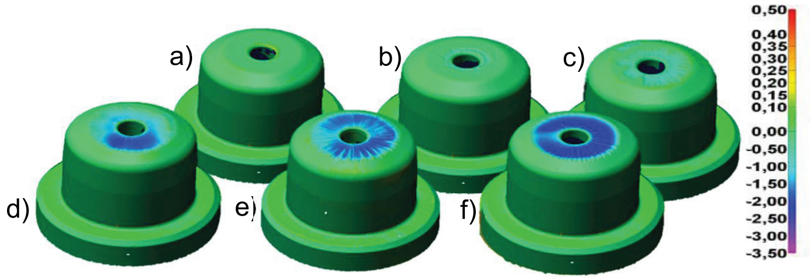

Figure 2 Results of scanning selected punches after different forgings different number of forgings: a) 1000, b) 2500, c) 3000, d) 7000 e) 9000, f) 12500

In the initial period for the tool after a small number of forgings up to 2000 pieces, no material loss was observed. However, since 2500 forgings can be seen clearly wear in the central part of punch. For the punch after 13000 forgings loss on the forehead was more than 2.5 mm. As you can see, for most tools, the wear on the forehead is clearly unbalanced.

The analysis shown in **Figure 2** may not be sufficient, therefore, based on the collected tool scans with increasing numbers of forgings, can be develop wear characteristics, the so-called wear curve for this tool, as a function of the increasing number of forgings from 0 to 12500 pieces. In the developed graph (**Figure 3**), which resembles the classic wear curve (Lorenza), we can observe interesting dependencies and distinguish several ranges (periods) of wear. Wherein, the presented analysis concerns the volume loss of all working surfaces of the selected tools, which may cause some differences in relation to the individual scans of **Figure 3**.

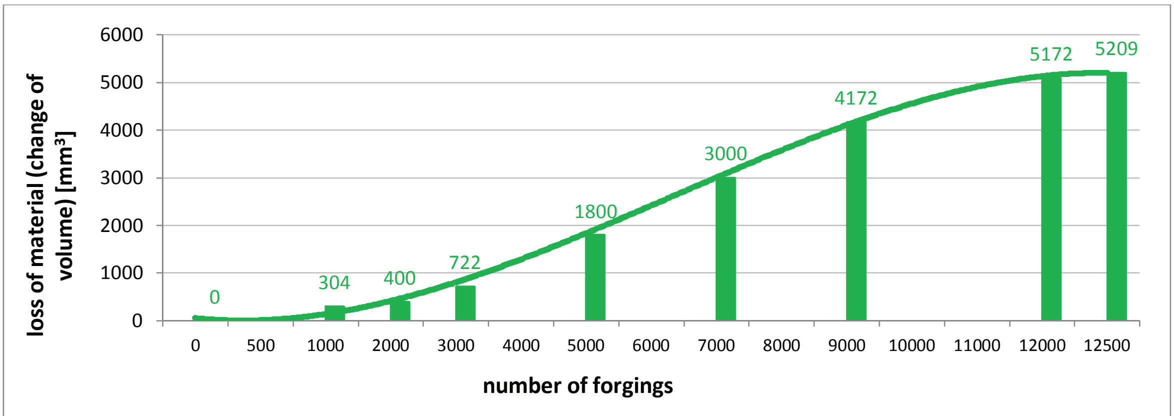

Figure 3 The loss of material (volume change) from the punch as a function of the number of forgings

By analyzing the graph (**Figure 3**), it can be observed that the loss of material for the selected tool - based on the scans grows very slowly at the beginning of the forging process to about 1000 pieces of forgings. Then over 1500 pieces begin the so-called normal state of exploitation characterized by an approximately stabilized intensity level of the main destructive mechanisms, which in the analyzed case amounts to about 11000 units. The volume change for this range of forgings is between 350 and 5172 mm3, but for the number of forgings from 11500 pieces to the end of the tool life (over 12500) the volume change is only 100 mm3. On this basis, it can be inferred that the stabilized wear of the tool being analyzed is up to the maximum of exploitation (12500 pieces) and ends as a result of exceeding the permissible tool shape change due to its withdrawal from further production.

4. APPLICATION OF SPATIAL SCANNING METHOD

The next step in the research was to use the innovative 3D scanning method to develop tool wear characteristics using 3d reverse scanning. Its application consists in using the observed similarity (reflection) of the work surface of the tool on the selected forgings surface, where the loss of tool material equals the increase of material on the forgings. This method avoids the necessity of interfering with the forging process and consists in measuring (measuring) with the scanner, the progressive wear of the selected forging tool (its material loss), on the basis of shape changes, cyclically collected from the forging process (their material increase). **Figures 4a-b** shows the surface of the tool before and after the operation with the corresponding surfaces of forgings. **Figure 4c** shows examples of measured material loss on the tool and corresponding material surpluses occurring on the analyzed forging.

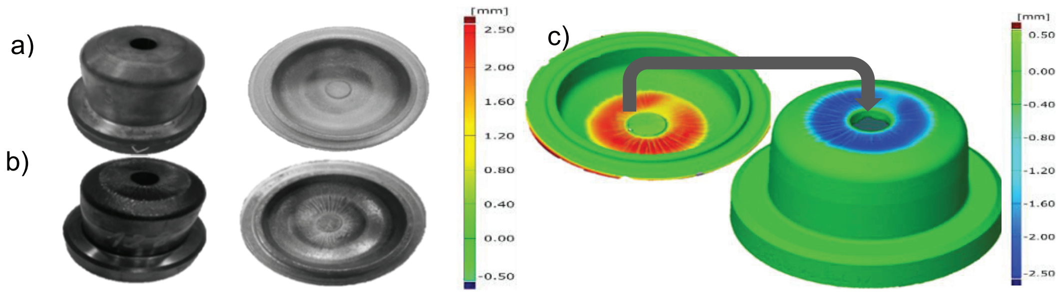

Figure 4 The view of: a) new punch - before work with forging at the beginning of process, b) worn - after 13,000 pieces with forgings from the end of tool life, c) idea of 3D scanning method - comparison of punch scans and last forging

Figure 5 shows the results of the punch wear analysis for the increasing number of forgings, by using the tool image reflection on the surface of subsequent forgings and comparing them to the "unused" 100 forging. They indicate the progressive wear of the tool, which is located in the middle part, near the ejector hole in the forging face area, and is in the initial phase of the irregular forging process. At the end of the punch life, radial grooves (**Figure 5**) are visible.

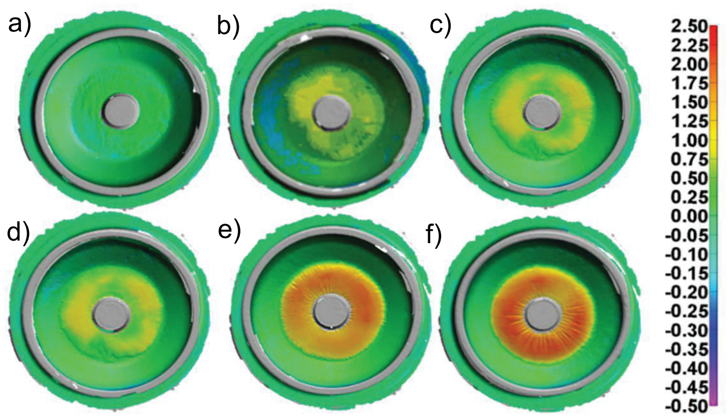

Figure 5 Comparison of scans of inner parts of forgings, in the form of quantitative changes of their shape after: a) 2000, b) 4000, c) 6000, d)8000, e) 10 000, f) 12 000 forgings

The presented results in the form of the error of the shape of the forgings collected cyclically allow only on simplified analysis, which determine the areas of the tool where the wear is occurring and the places with the maximum loss of material. Such recovery of the wear pattern allows for an analysis with an equal interval of the forgings to be taken. It means the development the classical wear curve for a tool based on forgings.

5. COMPARISON OF THE WEAR CURVE DETERMINED ON THE BASIS OF SCANNED TOOLS AND REVERSE 3D SCANNING

Figure 6 shows a comparison of the Lorenz curve determined based on the scanned tools after increasing exploitation (**Figure 2**) and on the basis of the inverse scan method by measuring systematically collected forgings (the scans are shown in **Figure 5**).

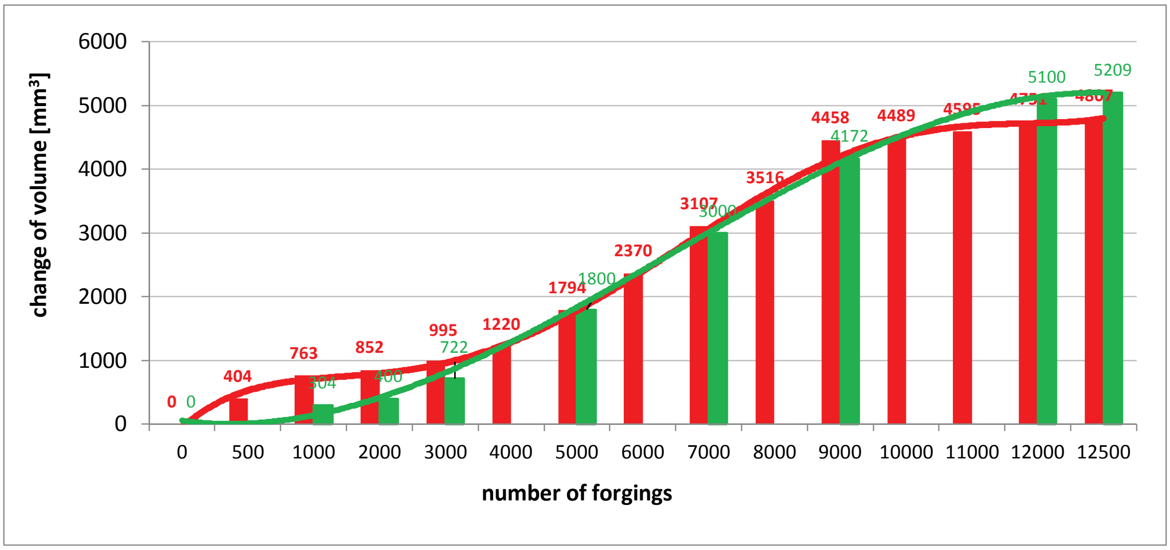

Figure 6 Comparison of tool wear scans (green) and forgings (red)

The comparison of both charts presented in **Figure 6**, which allow for determination of dependencies describing tool wear over the course of forging (determination of tool life), indicates high coincidence between their results. The greatest divergences can be observed at the very beginning, i.e. from 0 to 2500 forgings, and within the range from 9000 to 1300 forgings. Differences in the initial range are most probably the result of stabilization of the process (the entire system), meaning stabilization of the proper tool working temperature and of optimal lubricating and cooling conditions - tribological conditions. However differences in the later period can be explained by the studies conducted by the authors which demonstrated that for this period the loss of the tool is greater than the increase in the forging material. These studies have shown that in order to maintain geometry of forgings within tolerable tolerances, blacksmiths have made conscious correction of the size of the closure between the upper and lower tool. Other causes of slight differences between the two curves may be due to the fact that the forgings for the Lorenz curve were taken (every 1000) from exactly one forging process for which the average durability is 13,000 forgings. On the other hand, the tools chosen to determine wear were taken from several of the same processes, but with increasing numbers of forged forgings. This was dictated by the need to maintain similar process conditions (elimination of tool cooling for scanning analysis and reheating before continuing the production process). Other, less significant causes of slight discrepancies may be the measuring accuracy of the scanner itself (+-0.035) and oxidation and scaling of measured forgings, which were cleaned before measurement, as well as errors arising from the computation algorithm in volume analysis.

Being aware of the above presented comparison confirms that the determination of the wear on the basis of the scan forgings periodically collected during the manufacturing process (without interference), the method is efficient and economically justifiable. It should also be emphasized that the determination of wear on the basis of scanning tools is a non-practical method, which often causes difficulties in the continuity of production, its interruption, as well changes in technological and tribological conditions.

6. SUMMARY

The paper presents the method of analysis of the wear of forging tools, based on the innovative use of data obtained during the measurement of non-contact measuring method. The presented method allows the analysis of tool wear and forging instruments by recreating the wear progress of forging tools based on measuring the change in the geometry of the final product. It should be emphasized that the described method allows to conduct indirect control quality and change the geometry of forging tools (without dismantling) by direct measurement of the geometry changes cyclically collected forgings. The results of the research presented in this paper confirm that the wear characteristics obtained from the measurement (scanning) of the forgings are comparable to the curve obtained from the tool scans. This allows practical use of the developed indirect measurement technology on the basis of scanning for analysis of wear progression and thus current control of the state of the forging equipment. This will have its impact on the financial benefits resulting from the lack of downtime due to unforeseen failure of forging instruments and make quick decisions about a possible replacement of the spent forging tools. Disclosed in paper advantages and disadvantages of the proposed new approach to data analysis in the determination of the progress of wear of forging tools using 3D scanning will allow to create new opportunities for the description of phenomena consumption in the process of forging die, and will also shorten the design time of forging tools with increased wear resistance.

REFERENCES

[1] KUŞ, A. Implementation of 3D optical scanning technology for automotive applications. Sensors, 2009, vol. 9, pp. 1967-1979.

[2] MARTON, E., PIZZOLON, F. Dimensional control during forging. Innovative 3D laser measuring systems, Forge Applications, 2010, Vol. 1.

[3] WECKENMANN, A., WEICKMANN, J. Optical inspection of formed sheet metal parts applying fringe projection systems and virtual fixation. Metrology and Measurement Systems, 2006, vol. 13, no. 4, pp. 321-334.

[4] LULKIEWICZ, J., SZKUDELSKI, S., PACHUTKO, B. Kompleksowe badania matryc kuźniczych. Projektowanie i Konstrukcje Inżynierskie, 2015, vol. 3, no. 90, pp. 16-19.

[5] MACHÁCEK, P., TOMÍCEK, J. Application of laser scanning in reverse engineering and prototype manufacturing. WTP, 2010, vol. 1, no. 21, pp. 35-44.

[6] PACHUTKO, B., ZIÓŁKIEWICZ, S. Investigation of the wear processes of dies for forging building anchors basing on metallographic examinations. Obróbka Plastyczna Metali, 2012, vol. 23, no. 4, pp. 277-293.

[7] Kontrola jakości odkuwek i matryc - archiwizacja i regeneracja matryc. ITA-POLSKA, http://www.ita-polska.com.pl.

[8] Measurement of a forging die for tooling corrections. AICON 3D SYSTEM, http://www.aicon3d.com/fileadmin/user_upload/produkte/en/breuckmann_Scanner/01_PDF_IuT/Forging_die_measurement_Web.pdf.

[9] GRONOSTAJSKI Z., HAWRYLUK M., KASZUBA M., ZIEMBA J. Application of a measuring arm with an integrated laser scanner in the analysis of the shape changes of forging instrumen-tation during production. Eksploatacja i Niezawodnosc - Maintenance and Reliability, 2016; vol. 18, no. 2, pp. 194-200.

[10] GRONOSTAJSKI, Z., HAWRYLUK, M., JAKUBIK, J., KASZUBA, M., MISUN, G., SADOWSKI, P. Solution examples of selected issues related to die forging. Archives of Metallurgy and Materials, 2015, vol. 60, no. 4, pp. 2767-2775.

[11] GRONOSTAJSKI, Z., KASZUBA, M., HAWRYLUK, M., ZWIERZCHOWSKI, M. A review of the degradation mechanisms of the hot forging tools. Archives of Civil and Mechanical Engineering, 2014, vol. 14, no. 4, pp. 528-539.