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APPLICATION OF 3D SCANNING AND RAPID PROTOTYPING IN DESIGNING METAL SHEET FORMING PROCESSES

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Abstract

The procedure of designing sheet metal forming processes for elements which geometrical features are determined experimentally at stand tests has been presented in the paper. The designing procedure is aided by 3D scanning and rapid prototyping. There are the following successive stages: producing a physical model of the element, 3D scanning, geometrization of the scanned record of the element's surface, dimensional analysis of the element and preparing a model which has been geometrically elaborated, making a prototype of that model, preparing a general outline of technology to be applied, preparing technical documentation in CAD/CAM format, numerical simulation of the technological process, elaborating programmes which contain steering codes for producing the tools for m forming process and finishing process of the element.

Key words: 3D scanning, rapid prototyping, metal sheet forming process

1. INTRODUCTION

A tubular diffuser selected for the analysis has been presented in figure 1a. The diffuser is a component of the diffuser module (figure 1b). It is a part of turbofan engines and consists of many tubular elements - in the analysed model there are 21 single diffusers.

There are some crucial points in the designing process and producing a multi-element unit of a diffuser since it requires high precision of representing geometrical features of the element (appropriate selection of a shape of single tubes and keeping high quality of their inside surface) which ensure laminar flow of working gas inside. The speed of gas which gets into a diffuser is almost as high as the speed of sound. Determining geometrical features of a diffuser which would secure proper gas flow in such conditions is possible only in experimental way during stand tests. Transferring geometrical features of a master diffuser which was made in stand tests into picture documents calls for such tools that would provide precise record of the element's geometry which was determined experimentally. It needs to be kept in mind that the prepared picture documents are essential for elaborating technology of producing the element. In the case of very complicated shapes of the construction element it is difficult to make the tools for metal forming. 3D scanning and rapid prototyping techniques seem to be quite effective methods which can support making picture documentation and elaborating production technology.

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a)

b)

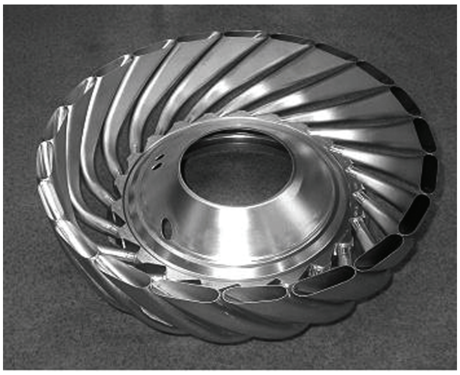

Fig 1. Photographs of tubular diffuser: a) single, b) complete module (Materialy Zakladu Przetworstwa Metali PZL „WSK Rzeszow", 2008).

2. THE PROCEDURE OF DESIGNING PRODUCTION TECHNOLOGY OF THE ELEMENTS AIDED BY 3D SCANNING AND RAPID PROTOTYPING TECHNIQUE

The elaborated procedure of designing production technology of any elements using 3D scanning techniques and rapid prototyping technology is a multistage one. At each stage the applied programmes and tools ought to be compatible because of the used software.

The application of 3D scanning for representing the outside surface of physical model of the element is the first stage of the procedure. 3D no-touch scanner has to be used for digitizing geometrical features of the element obtained experimentally (Golebiewska-Kurzawska et al., 2010(b)). If the element, for which the production technology is designed, has been made in any sheet metal forming process, e.g. stamping, than it is enough to transfer the outside surface in order to determine its geometrical features. The inside surface of the element is determined by thickness of the blank.

Data obtained in scanning process in the form of coordinates of the cloud of points of tubular diffuser must be elaborated according to specially prepared methodology of geometrization. The aim of geometrization is to eliminate the errors resulting from resolution of a scanner, digitizing noise and deviation of geometrical features of the real element from its design form which has been defined by nominal dimensions and permissible variation. CAD programme, e.g. Solid Works can be used for geometrization.

Correctness of the record of geometrical features of the diffuser's surface after geometrization can be verified by making dimensional analysis of the data obtained directly after the completed process of 3D scanning of coordinates of the cloud of points as well as the data after the process of geometrization of coordinates of the surface which has been spanned on geometrized cloud of points. The analysis of dimensional variations has been done by putting the models which are to be compared on top of each other using Geomagic Quality programme. It is possible to use other programmes, however Geomagic Quality has been chosen because it enables to process the data quite effectively. Dimensional analysis (comparative) allows to get the most important information about any possible divergence between the model obtained after geometrization and the initial one - the obtained results allow to check the correctness of the applied method of geometrization. In the case of the analysed diffuser, the applied method is based on accommodating any section obtained in the process of scanning to the design form of the diffuser assuming that:

a) centre of gravity of the sections overlap,
b) surface of the sections is equal,
c) axis of the symmetry of sections overlap.

The two above mentioned conditions have been presented in the form of a system of equations:

$$\pi R^2 + 2Rb = S \tag{1}$$

$$\frac{\pi}{2} \cdot \frac{3}{4\pi} \cdot R^3 + \frac{Rb^2}{2} = \frac{s}{2} \cdot y_s \tag{2}$$

where:

S – measured area of the profile's section acquired in the process of scanning,

y_s – position of the centre of gravity of the top half of a real profile determined by SW programme.

The solution of equations (1) and (2) gives the dimensions of geometrized cross-sections which represent the profiles of sections after the scanning procedure. Next stage is to make a prototype of a physical model of the element applying the technique of rapid prototyping, e.g. (SLS) selective laser sintering (Bis and Markiewicz, 2008; Cholewa et al., 2009(a); 2009(b); 2009(c); Mutwil and Golebiewska-Kurzawska, 2010; Mutwil et al., 2010; Sydor, 2009). It is necessary in the following designing procedure to select the technology of producing and designing the appropriate sequence of technological operations, to make the right choice of equipment and parameters of the process taking into account the quantity of production series as well as minimizing the production costs of a diffuser.

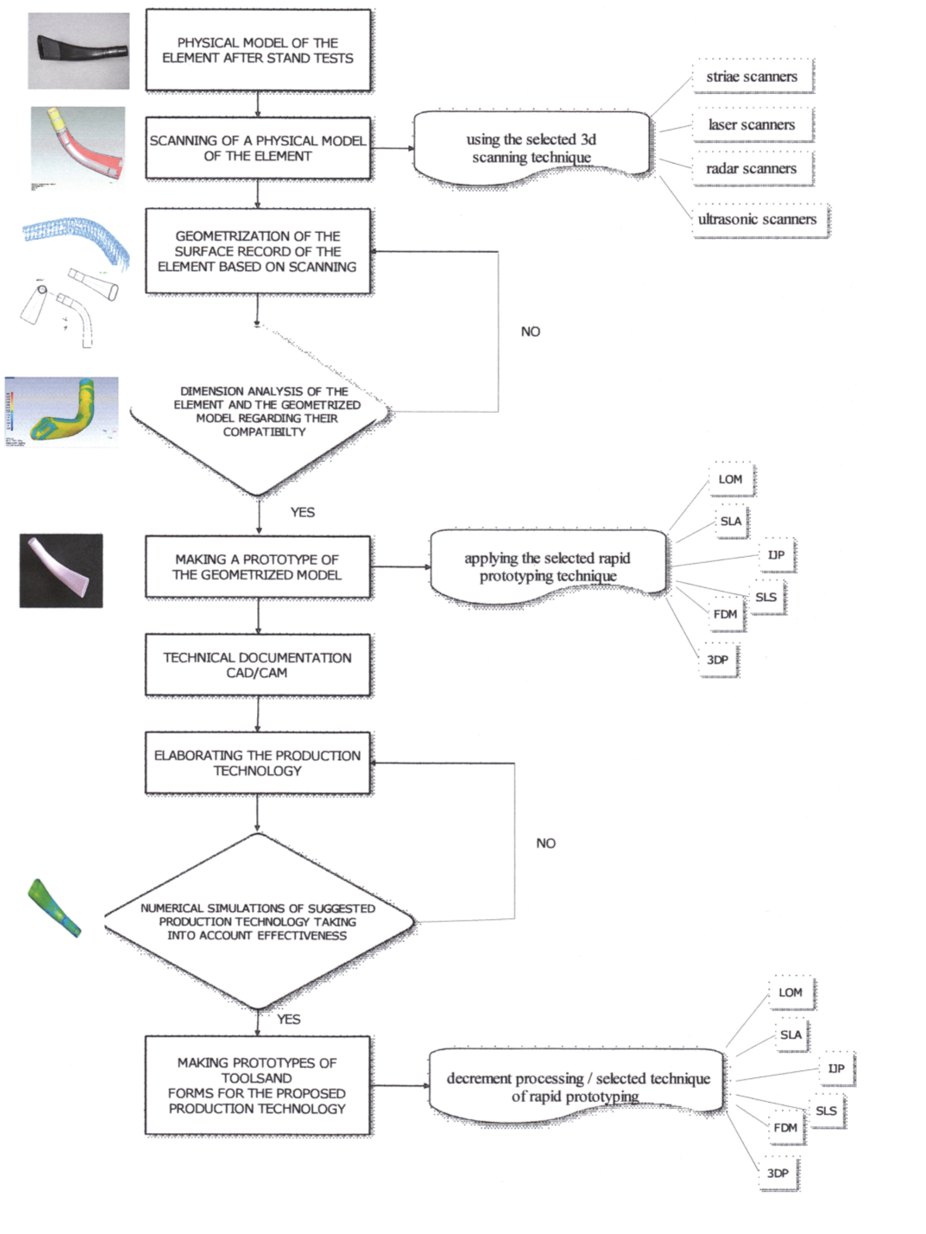

Fig. 2. Chart of designing the procedure of production technology for making elements, aided by 3D scanning and rapid prototyping techniques (Golebiewska-Kurzawska et al., 2010(a)).

The suggested production technology needs to be verified applying numerical simulations, e.g. in Eta/Dynaform 5.6 programme. The carried out simulations enable to determine the possibilities of using the designed technology in industry. Three-dimensional models which were made on the basis of geometrized files coming from 3D scanning should be used in simulations. In order to verify the designed tools and the selected material used as a charge, rapid prototyping technique ought to be applied, e.g. three-dimensional printing (Golebiewska-Kurzawska et al., 2010(a)). Respective stages of realizing the proposed procedure have been shown in figure 2.

3. SUMMARY

The procedure which uses 3D scanning and rapid prototyping technique presented in the paper can be an effective supporting tool for designing the construction and technology of producing elements for which geometrical features are determined experimentally (e.g. during stand tests).

The application of elements and the quantity of production series define the use of different production techniques and this can be done using:

– rapid prototyping techniques applied directly for making a final product (however this is rather rare, most likely in one piece production or small series production),
– prepared technical documentation in CAD format for making the tools by rapid prototyping technique – short tool life makes it possible only for small series production,
– prepared technical documentation in CAD format for making long life tools made of tool steel by numerically controlled machines – particularly recommended for series production or multi series production.

The prepared technical documentation in CAD format can also be used for controlling machine tools put into service for final processing of a finished product. The above presented designing procedure for production technology enables to elaborate the technology for making a product which is based on technical documentation in CAD/CAM format. 3D scanning of a physical model in the form of a prototype made during stand tests has been used.

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ZASTOSOWANIE TECHNIK SKANOWANIA PRZESTRZENNEGO I SZYBKIEGO PROTOTYPOWANIA DO WSPOMAGANIA PROJEKTOWANIA PROCESU KSZTAŁTOWANIA BLACH

Streszczenie

W artykule przestawiono procedurę projektowania procesu kształtowania blach dla wyrobów, których cechy geometryczne wyznaczane są doświadczalnie, w próbach stanowiskowych. Procedura projektowania wspomagana jest technikami skanowania przestrzennego i szybkiego prototypowania. Kolejnymi etapami projektowania są: wykonanie modelu fizycznego wyrobu, skanowanie przestrzenne, geometryzacja uzyskanego ze skanowania zapisu powierzchni wyrobu, analiza wymiarowa wyrobu i opracowanie modelu zgeometryzowanego, wykonanie prototypu modelu zgeometryzowanego, ustalenie ramowej technologii wytwarzania, przygotowanie dokumentacji technicznej w formacie CAD/CAM, symulacja numeryczna ustalonego procesu technologicznego, opracowanie programów zawierających kody sterujące do wykonania narzędzi do procesu kształtowania plastycznego oraz obróbki wykańczającej wyrobu.

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