ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering

Tome XII [2014] – Fascicule 4 [November]
ISSN: 1584-2673 [CD-Rom, online]

a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

1. Juraj HUDÁK, 2. Miroslav TOMÁŠ, 3. Dagmar DRAGANOVSKÁ, 4. Peter IŽOL

THE USEOF A PHOTOGRAMMETRIC METHOD IN ASSESSMENT OF TIN CAR BODY PRODUCTION

1-4. Technical University of Košice, Faculty of Mechanical Engineering, Department of Technologies and Materials, Mäsiarska 74, 040 01 Košice, SLOVAKIA

Abstract: The paper deals with assessment of tin car body production byphotogrammetric method.The optical 3D forming analysis system ARGUSwas used at experimental work when the tin car body production has been proposed. Two methods of car body production were evaluated - the first one used deep drawing in open die and the second one used deep drawingin closed die with elastomer Fibroflex applied at the bottom of the die. The tin steel sheet TS 245 with thickness 0.28 mm had been used as an experimental material. The shapes of pressings were evaluated using the photogrammetric 3D measuring system ARGUS. Besides, the wall thickness change and the strain distribution on the surface of pressings were evaluated as well. These values had been compared for both method of the tin car body production.

Keywords: photogrammetry, tin car body, deep drawing, rubber pad forming

1. INTRODUCTION

The deep drawing technology represents shape-changing operation by plastic deformation to produce hollow, symmetric or asymmetric in shape products. The drawn parts represent variety of either simple or complicated in shape components. Therefore, proper design of tooling meets requirements to spare time and costs of design by using CAD systems. Despite the complicated shape of drawn parts, they often result from only one motion of forming machine in very short portion of operating time [1,2].

By the conventional stamping methods such as deep drawing in solid stamping dies, unconventional methods also take place in industry: the rubber pad forming by Guerin, Marform and Hidraw methods, rubber pad membrane forming by Verson-Wheelon, Hydroform and Fluidform methods as well as hydromechanical drawing. These are used for production of small series of drawn parts or prototypes as well as large sized drawn parts in aircraft industry. [3]

Considering conventional stampingin solid stamping dies, the new CNC controlled systems are involved to production process and they enable regulation of forming force and speed of press ram in the whole range of slide motion. These systems such as a multi-segmented flat and tapered blankholders, pulsatory and elastic blankholders, and intelligent multi input multi output (MIMO) systems with numerically controlled blankholder force etc. are either part of machine orstamping die as well.[4]

The important parameter after deep drawing process is the drawn piece’s wall thickness change as a result of stress and strain distribution during the deep drawing. The wall thickness change react precisely when parameters of deep drawing such as blankholder force and friction are changed and anisotropy of steel sheets is considered as well. Thus, measuring the wall thickness change allows finding out the critical areas at deep drawing. [5]

Nowadays, automated measurement systems have been developed, such as optical system ARGUS by GOM mbH, based on photogrammetry and it is now established in the forming practice. Frącz et al [6] used Argus for verification and optimization of the numerical simulation of sheet metal forming process. They have used the system for direct experimental verification of computer simulation results and the selection of boundary conditions in simulations. Slota et al [7] tested the sensitivity of the Argus system to use photo or video camera to take the pictures, use the anti-reflexive spray and comparing the strains computed by numerical simulation and measured ones by Argus system. Chu et al [8] used Argus to measure the maximum effective strain value from the deformed workpiece by analysing the deformation of the grid. By combining the effective stressretrieved from the simulation and effective strain data produced by different punch radii, the flow curve was established. The maximum effective strain observed in the drawn piece made it possible to compare the strains under different deformation process.

In the paper we focus to the research of deep drawing of complicated drawn piece shape by ARGUS optical system. The conventional deep drawing in open die and unconventional deep drawing with elastomers at the bottom of the die will be compared to each other.

2. EXPERIMENTAL MATERIAL AND METHODS

The tin car body is presented in the paper as the object of the research. The tin car (Fig. 1) was designed for the entertainment technical center SteelPARK Creative Factory [9] as a part of the European Capital of the Culture that had been held in Košice in 2013. The aim of the Tin car project was to present tin steel sheet and deep drawing technology to young people as well as explain them the production process from raw material to final product.

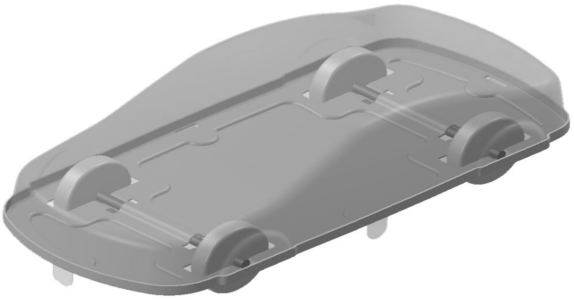


Fig. 1. The tin car (car body in transparent mode)

The tin car consists of tin car body, two axes, four wheels and chassis. One of the main parts is tin car body as a representative of the complex shape of pressings. The tin car body is made by cutting the blank, deep drawing, flange cutting and calibrating. The production steps are shown in Fig. 2. The most complicated step in production is deep drawing due to shaped bottom of the pressing that creates the car body profile.

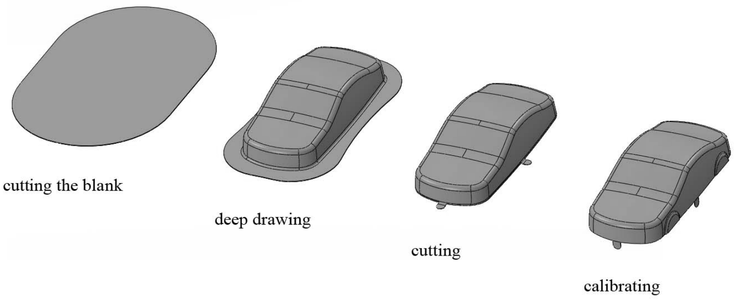


Fig. 2. Production steps of tin car body

The car body is produced in the single action drawing die with spring blankholder. When designed production process and drawing die for tin car body two methods of deep drawing had been verified: the first one used open die (Fig. 3) and the second one used closed die with elastomer’s blocks at the bottom of the die (Fig. 4). The elastomer Fibroflex produced by Fibro with Shore-A-hardness of 80 had been chosen for elastomer blocks with dimensions 10x30-20 at the rear and 10x30-26 at the front of the car.

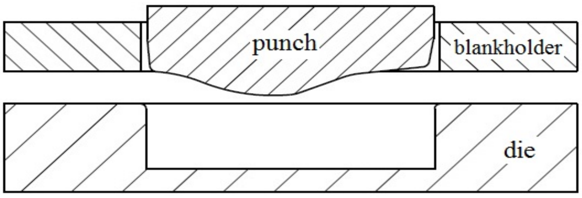


Fig. 3. Scheme of deep drawing in “open die”

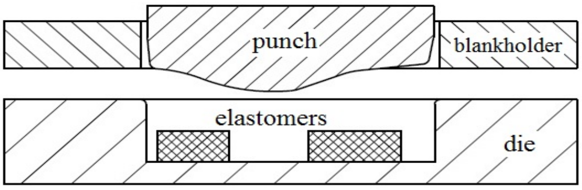


Fig. 4. Scheme of deep drawing in “closed die”

As the aim of the contribution, the strain distribution as well as thickness reduction was researched and compared to each other for both methods of deep drawing.

The tin steel sheet TS 245 with thickness 0.28 mm had been used for the car body production. The mentioned electrolytic tinned steel is produced by U.S.Steel Kosice, s.r.o. and it is commonly used for production of food packages, beverage containers, decorative tins, lids, closures, 2 piece cans, 3 piece cans, ends, crown caps, toys and other products. The material formability parameters are shown in Tab. 1. The mechanical properties have been measured according to STN EN ISO 6892-1, the normal anisotropy ratio according to ISO 10112 and strain hardening exponent according to ISO 10275. The values of material formability parameters have been measured in directions 0°, 45°and 90° to steel sheet's rolling direction on testing machine TiraTEST 2300 equipped with an automatic extensometer to measure the elongation and the second extensometer to measure the width of the specimen during the test.

Table 1. The material formability parameters of TS 245 tin steel sheet, thickness 0.28 mm

direction [°]	$R_{p0,2}$ [MPa]	Rm [MPa]	A_{80} [%]	r [-]	r_m [-]	Δr [-]	n [-]	n_m [-]	Δn [-]
0	250	370	31.1	1.171	0.618	-0.093	0.188	0.195	-0.008
45	245	358	37.8	1.433			0.199		
90	254	367	36.8	1.284			0.194		

The ARGUS photogrammetric system had been used to the strain measuring of drawn pieces. It provides the 3D coordinates of the component's surface as well as the distribution of major and minor strain on the surface and the material thickness reduction. In the Forming Limit Diagram, the measured deformations are compared to the material characteristics [10].

The measurements have been done using ARGUS 5M photogrammetric system, consisting of 5 Mpix camera Baumer TXG50i with picture resolutions 2352x1728 pixels, high precision scale bars with defined length of coded points and set of single coded points. A point pattern of uncoded points with diameter 0.5 mm and distance of 1 mm have been electrochemically etched on the undeformed blank using EU Classic marking system by Östling.

The principle of measuring by ARGUS system is shown in Fig. 5. Change of the camera position in three planes take place during measuring the draw piece. At each camera position the measured draw piece is rotated of 360° in the plane. A group of pictures is taken and then evaluated in the ARGUS software. All results are presented in a fine resolution mesh created from the determination of the 3D coordinates and reflecting the surface of the measured object as it is shown in Fig. 6.

Fig. 5. The principle of measuring using the Argus system

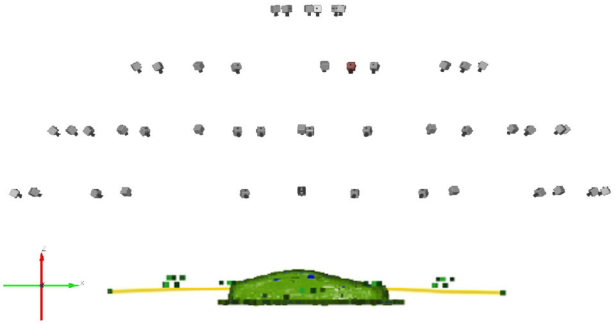


Fig. 6. Recognized positions of camera when taking pictures and created surface mesh

The ARGUS photogrammetric system also had been used to measure the FLC curve of experimental material either to compare measured strain to this material characteristic and determine critical forming areas. Nakajima test(Fig. 7) of specimens with different width (Fig. 8) according to EN ISO 12004-2 has been performed on testing device Erichsen 145-60. The Nakajima test was carried out with the speed of the punch of 60 mm/min. The test was performed on electrochemically etched specimens with measuring circular dots grid of 0.5 mm in diameter and regular spacing of 1 mm. Strain measurement was performed in the central drawpiece zone, close to the fracture of the material (Fig. 8), which occurred in the top of the hemisphere. The results of strain measurement allowed constructing the FLC directly from Argus program (Fig. 9).

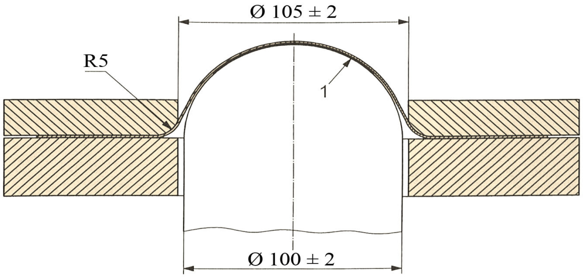


Fig. 7. Scheme of Nakajima test according to EN ISO 12004-2

Fig. 8. Dog bone shaped specimens for Nakajima test to determine FLC curve

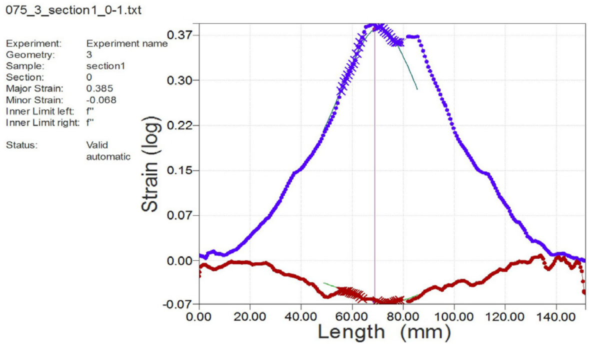


Fig. 9. Evaluation of critical deformation acc. to EN ISO 12004-2 by ARGUS software

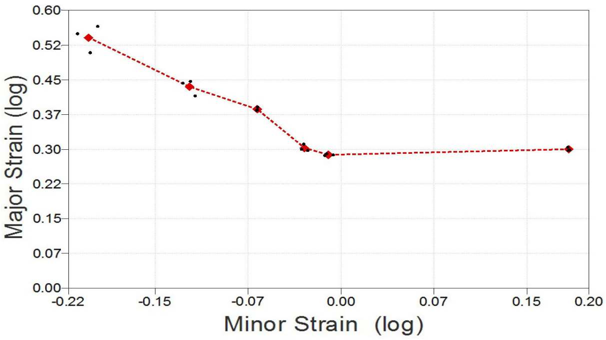


Fig. 10. The forming limit curve experimentally determined using ARGUS software

3. REACHED RESULTS AND DISCUSSION

Based on pictures taken by Argus photogrammetric system, the software calculated coordinates, displacements and strains. These are determined only on the surface of the object. The calculation of the thickness change is based on the assumption of volume constancy of the material during loading [10].

Fig. 11 compares the cumulative effectiveMises strains distribution for both methods of deep drawing. The Misesstrains have been calculated as follows [10]:

$$\varphi_i = \sqrt{\frac{2}{3}} \cdot (\varphi_1^2 + \varphi_2^2 + \varphi \tag{1}$$

The maximal effective Misesstrain was 101.3 % for open die and 83.9 % for closed die closed die with elastomers. The distribution of effective strain was similar for both methods of deep drawing with critical areas at rear corners of the tin car body. Fig. 12 shows the distance of each measured point to the forming limit curve. The better plasticity reserve was for deep drawing in open die with 16.42 % to FLC compared to 11.6 % for closed die forming with elastomers.

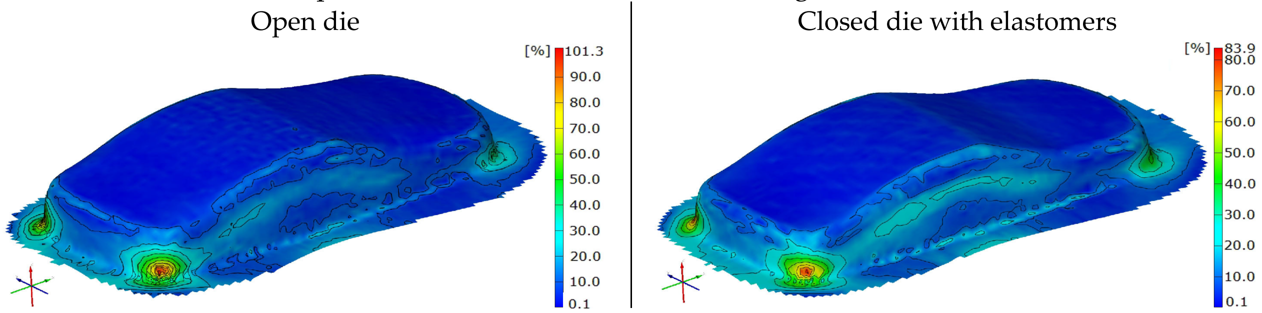


Fig. 11. Comparison of the Mises strains

The material thickness reduction is shown in Fig. 13. When car body was deep drawn in open die the thickness reduces was 8.66 % on the sides in car's window location. The same place of the maximum thickness reduction was when the car body was deep drawn in closed die with elastomers, but the thickness reduction increases to 13.1 %. The corners (areas of lights) at the front and the rear of the car body have been found as second critical areas of thickness reduction slightly lower values of thinning. This was caused by the shaped bottom of the punch, because the car roof touches the blank first while the blank is held down with blankholder.

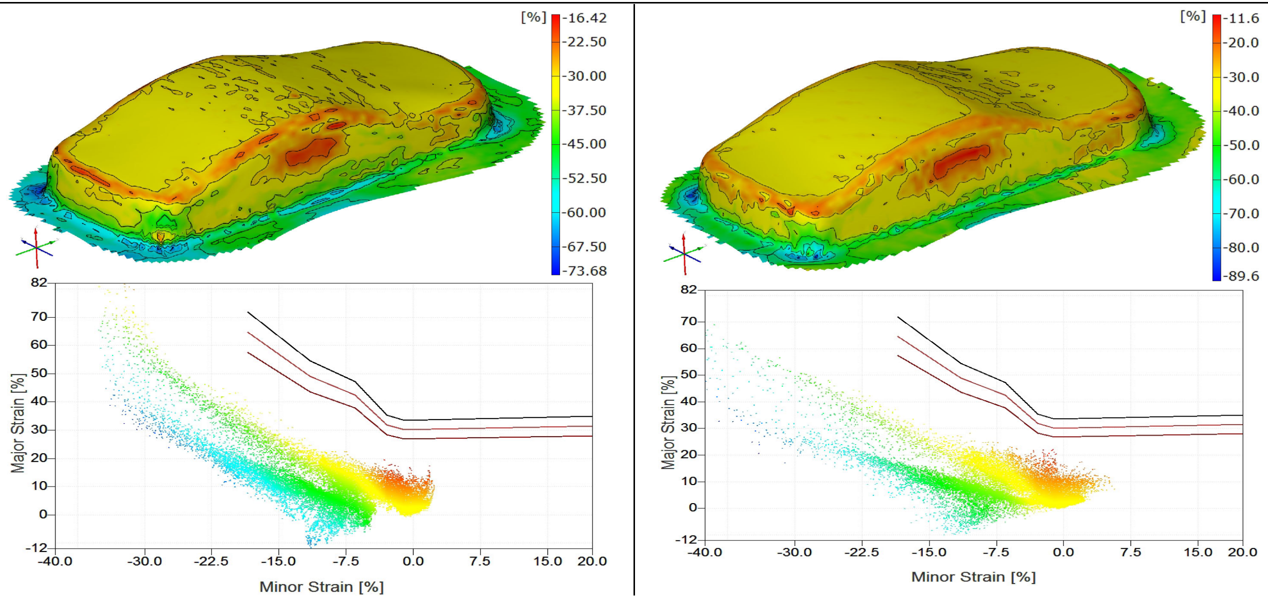


Fig. 12. Comparison of the distance to FLC (plasticity reserve)

Open die

Closed die with elastomers

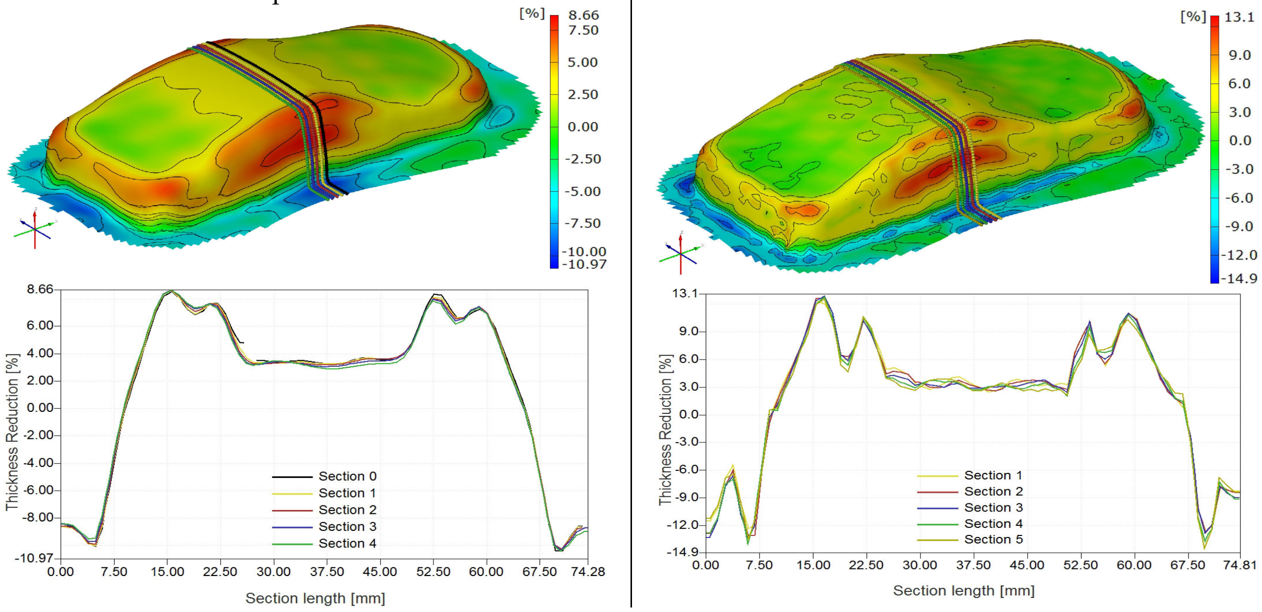
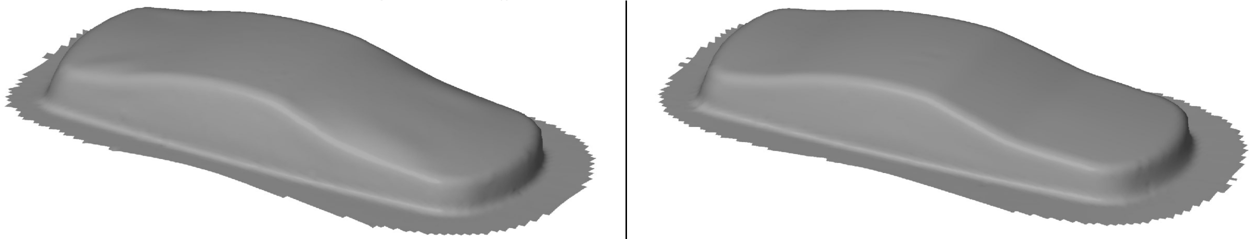


Fig. 13. Comparison of the thickness reduction



3D view

3D view

side view

side view

Fig. 14. Comparison of the surface

The shapes of the drawn pieces are shown in Fig. 14 in 3D and side views. When the car body was deep drawn in open diewith car body contour (in top view) and rounded edge, the final draw piece was not precisely drawn and wrinkles have occurred in the front and in the rear of the car body. Thus, the blocks of elastomer Fibroflex have been applied at the bottom of the die. The elastomers produced the counter pressure during the punch stroke and provided additional pressure and friction between the punch and the blank. These allowed reaching the correct shape of the final drawn piece without any wrinkles.

We assume the same effect should accomplish when the blank would be deep drawn with calibration into die negative to the punch shape, respecting the drawing clearance. However, the production of shaped die is more difficult than open die with car body contour (in top view)and rounded edge.

4. SUMMARY

The deep drawing of tin car body appeared to be more complex problem due to its complex shape, given by shaped bottom of the punch and drafted walls. By applying elastomers at the bottom of the die, the correct shape of the tin car body had been reached. The strain distribution as well as thickness reduction had been compared for both methods of deep drawing. The major and the minor strains are distributed similar for both methods of deep drawing; less difference had been identified in the car roof due to additional pressure of elastomers. The thickness reduction pointed out a good agreement with the values of 8.66 % at deep drawing in open die and 13.1 % at deep drawing in closed die with elastomers. The next work will be focused to numerical simulation of the researched processes and comparing results of strain distribution reached by photogrammetric system ARGUS and numerical simulation as well.

Acknowledgement

Authors express their thanks for projectsVEGA 1/0500/12 “Quality improvement when milling form surfaces by advanced milling tools”, VEGA 1/0824/12 “Study of formability aspects of coated steels sheets and tailored blanks“, VEGA 1/0872/14 “Research and optimization of formability and joinability evaluation of high strength steel and aluminum sheets” supported by Scientific Grant Agency of the Ministry of Education, Science and Research of Slovakia as well as projects APVV-0273-12 “Supporting innovations of autobody components from the steel sheet blanks oriented to the safety, the ecology and the car weight reduction“ andAPVV-0682-11 “Application of progressive tool coatings for increasing the effectiveness and productivity of forming sheets made of modern materials” supported by Slovak Research and Development Agency.

References

[1.] POLLÁK, L.: Forming dies for stamping - products of mechanical engineering industry. In: Proceedings “TOOLS 2004”, 2004, p. 142-145, ISBN 80-227-2043-7
[2.] SPIŠÁK, E. - EVIN,E. - HUDÁK, J.:Forming technology. TU Košice, 1992, ISBN 80-7099-173-9.
[3.] TIŠNOVSKÝ, M. - MÁDLE, L.: Deep drawing on presses, 1sted., SNTL Praha, 1990, ISBN 80-03-00221-4
[4.] TRZEPIECIŃSKI, T.: Advances in sheet metal forming technologies. Zeszytynaukowe Politechniki Rzeszowskiej, Nr 284, Mechanika z. 84,2012, p. 59-70, ISSN 0209-2689
[5.] POLLÁK, L.: Anisotropy and drawability of steel sheets.1sted., Alfa Bratislava, 1978
[6.] FRĄCZ, W. - STACHOWICZ, F. - PIEJA, T.: Aspects of verification and optimization of sheet metal numerical simulations process using the photogrammetric system. Acta Metallurgica Slovaca, Vol. 19No. 1,2013, p. 51-59, ISSN 1338-1156
[7.] SLOTA, J. - JURČIŠIN, M. - GAJDOŠ, I. - SPIŠÁK,E.: The sensitivity of a photogrammetric method in formability analysis. Acta Mechanica et Automatica, Vol.7 No.2,2013, p. 117-123, ISSN 1898-4088
[8.] CHU, Y.Y. - LEE, R.S. - PSYK, V. – TEKKAYA, A.E.: Determination of the flow curve at high strain rates using electromagnetic punch stretching. Journal of Materials Processing Technology, Vol. 212, 2012, p. 1314-1323. ISSN 0924-0136
[9.] Project Steelpark. Information on http://www.sjf.tuke.sk/ktam/Steelpark/index.htm
[10.] ARGUS v6.2 User manual, GOM mbH, Braunschweig, Germany, 2009
[11.] ŠTEFAŇÁK, L.:Numerical simulation of tin car-body production, Graduation theses, Department of Technologies and Materials, Faculty of Mechanical Engineering, Technical University in Košice, 2014

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

5, REVOLUTIEI, 331128, HUNEDOARA, ROMANIA
http://annals.fih.upt.ro