W. MATYSIAK, B. BARIŠIĆ, I. MAMUZIĆ

ISSN 0543-5846
METABK 49(1) 13-17 (2010)
UDC – UDK 621.941:621.983:539.3:519.37 = 111

ELABORATION OF THE TECHNOLOGY OF FORMING A CONICAL PRODUCT OF SHEET METAL

Received – Prispjelo: 2008-09-10
Accepted – Prihvaćeno: 2009-03-17
Original Scientific Paper – Izvorni znanstveni rad

The work presents a general knowledge about spinning draw pieces of sheets, one of multi-operational processes of spinning a sheet metal conical product without machining. The objective of the work was to elaborate both the technology of forming conical products of sheet metal and execution of technological tests as well as to determine the technological parameters for the process of spinning a conical insert. As a result of the investigations, the products with improved mechanical properties, stricter execution tolerance and low roughness have been obtained. The series of 200 prototype conical inserts for the shipbuilding industry have been made.

Key words: spinning, stamping, draw piece

Razrada tehnologije oblikovanja stožastih proizvoda od lima. Rad predstavlja opće saznanja o rotacijskom izvlačenju izradaka od lima, procesu višestrukih operacija procesa rotacijskog izvlačenja stožastog proizvoda lima bez operacija skidanja čestica. Cilj rada bio je razraditi tehnologiju oblikovanja stožastih proizvoda od lima i izvođenje tehnoloških ispitivanja kako bi se utvrdili tehnološki parametri procesa rotacijskog izvlačenja stožastog izratka. Kao rezultat istraživanja dobiveni su proizvodi s poboljšanim mehaničkim svojstvima, striktnijeg izvršenja niskih tolerancija i niže hrapavosti. Napravljena je serija od 200 prototipa stožastih izratka za brodogradnju.

Ključne riječi: rotacijsko izvlačenje, štancanje, izvučeni izradak

INTRODUCTION / GENERAL INFORMATION ON SPINNING

The present work concerns the forming of the sheet metal conical products which, combined with a vulcanized rubber blend form footings for electric power generators.

Conical sheet metal elements are most often formed by the following four methods:

- multi-operational stamping with stiff tools,
- hydro-mechanical stamping,
- spinning,
- flow turning.

In case of stiff tool stamping, traces on the side surfaces after each stamping should be taken into account. Sometimes, they are considered as defects. But in case of a conical insert it could be neglected. For long series production and automatic presses with jaw feeders, this is the most economical technology ever. The hydro-mechanical method is applied up to the drawing coefficient value of 0,38. Moreover, with the material thickness of 3 mm, the method requires very high pressures.

When applying this method to flow turning, a different product is obtained – the one with a thick bottom and thin side wall. The large thickness of the initial sheet should also be considered.

Since the conical product (Figure 1) is supposed to be 3 mm thick, according to the theory of flow turning (1), the thickness of the initial sheet should be 6,6 mm with the side wall inclination angle of 27° because [1]:

$$g = g_0 \sin\alpha \tag{1}$$

$$g_0 = \frac{g_1}{\sin\alpha} = \frac{3}{\sin 27^\circ} \approx 6{,}6 \text{ mm} \tag{2}$$

The forming of sheets with such thicknesses was beyond the possibilities of the force parameters of the MZH-500 spinning and flow turning machine on which the tests have been performed, which was one of the reasons why spinning has been applied. The results of the technical-economical analysis carried out in this work have proved that the choice of the technology was right.

Spinning is applied in short series production, when execution of stamping dies is for economical reasons not advisable and too time-consuming. It is also applicable for making vessel-like parts with convexo-concave shape of the side wall. The accuracy of the spin formed parts ensures the conformity of the product to the design

W. Matysiak, Faculty of Mechanical Engineering and Management, Poznan University of Technology, Poznan, Poland, B. Barisic, Faculty of Engineering, University of Rijeka, Rijeka,Croatia, Ilija Mamuzic, Faculty of Metallurgy, University of Zagreb, Sisak, Croatia

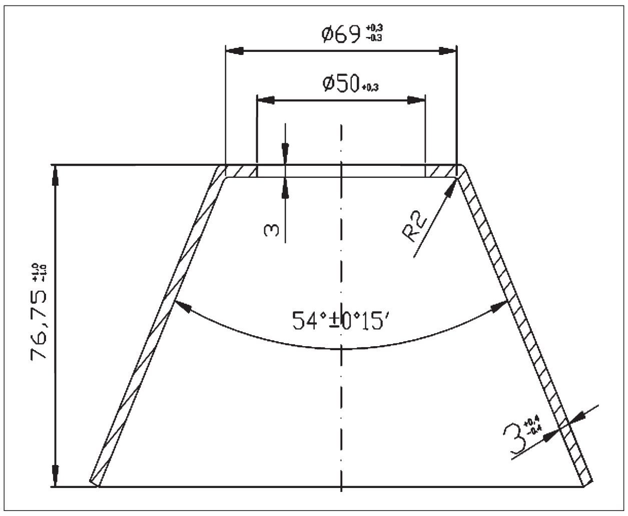

Figure 1. The insert diagram

drawing. If the required product cannot be spin formed in one operation, spinning is performed in several operations on different templates, but with the same smallest diameter of the template. The process of spinning is more complex and less investigated than other metal forming processes, e.g. stamping. The lack of knowledge of the stress and strain state (the mechanisms of transferring the deformation from the tool pressure area to the rest of the blank being formed) makes it difficult to elaborate a spinning technology. The correctness of the elaborated technology and tool design has been proved by the results of conducted technological investigation.

Characteristics of spin formed products

In the course of the spinning process the sheets are usually thinned. Wall thickness varies less with more passes of the spinning roll. In case the number of spinning roll passes is too small, a material crack can take place as a result of thinning. Spinning is mostly applied in the manufacture of lighting industry products with straight or curved side wall shapes. Spinning can also be applied in the making of artistic objects, such as cups, being made as single pieces. Material thinning in those products is not qualified as defective. A characteristic feature of spin formed products is the occurrence of furrows made by the spinning element on the side wall. They represent the travel path of the spinning element on the draw piece generatrix. They may be considered as defects. This requires the application of additional product finishing, e.g. machining.

The surface roughness of spin formed products is usually *R*a = 1,25÷2,5 (with visible traces of the spinning tool or roll). The ultimate structure of the surface depends on the shape of the roll working surface, the travel and the spindle speed and other parameters as, for example the force of the roll pressing. It also depends on the material of the roll. Smoother surfaces of soft steel products will be obtained with the application of plastic rolls whereas less smooth with the application of bronze rolls (usually applied in forming of stainless steel).

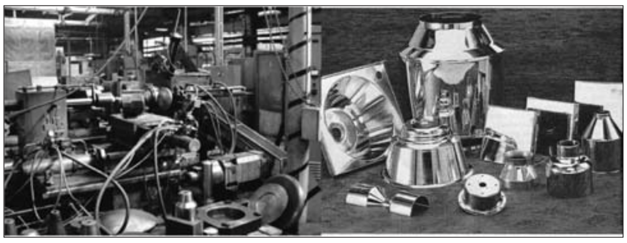

Figure 2a, b. MZH-500 spinning and flow turning machine, examples

Selection of the machine

The spinning operations are performed on specialized machines called spinning lathes (Figure 2a). Examples of application of spinning in the agriculture and automotive industry are presented in Figure 2b.

A spinning lathe support drive can be either mechanical or hydraulic. The spindle is usually mechanically driven. The rolls can be born on one side or on two sides. The way of roll bearing is determined by the shape of the draw piece. When spinning draw pieces with elliptical generatrices rollers born on two sides are usually applied; conversely, when products with straight line generatrices are made rolls born on one side are applied. Ball bearings are usually applied.

A number of references concerning spinning has been taken into account in these investigations [2÷12]. The description of a multi-operational process of spinning conical products without changing the templates, selection of parameters, mathematical apparatus for calculating the forming forces has been searched for. Spinning of conical elements with several templates is presented in [1].

It has turned out that none of the listed books contained precise information on spinning of conical elements. Often, offers of firms with examples of conical products could be found, but there was no data concerning the process itself. This may prove the complexity of the process and purposeful secrecy of investigation results. Most information about spinning and spinning machines could be found in the articles published by the Metal Forming, the Institute in Poznan in the years 1995÷2003 [7, 12].

In [2, 3, 5, 6, 11], a general description of the spinning process could be found as well as arguments for the application of spinning in the automotive industry. Since information on the forces, deformations, spinning process parameters, allowing for the elaboration of the technology of spinning a conical draw piece, could not be found in literature, it was necessary to perform experimental investigation in which the technical parameters of spinning a conical element have been determined.

INVESTIGATION

It has been initially assumed that the basic criterion for the obtained product accuracy will be the tolerance of the side wall inclination angle. The other criterion for the product assessment will be the deviation of the wall thickness which should not exceed ±0,4 mm. The distribution of the draw piece wall thickness while maintaining the inclination angle of 27° with a deviation of ±15° and strict tolerance of the other overall dimensions had to be investigated. The deviation of the cone tolerance will be measured by means of the gauge supplied by the purchaser of the draw pieces and a set of gap gauges.

The initial material for conic element spinning was 08AI deep-drawing steel disks, surface type I, drawing ability G, thickness 3 mm, R_m=308 MPa, elongation A/% = 43,3 (Figure 3a). The chemical composition of the steel is shown in Table 1.

Table 1. **Chemical composition of 08AI steel / mas. %**

C	Mn	Si	P	S	Cr
0,05	0,26	0,01	0,009	0,008	0,02
Ni	**Cu**	**Al**	**N_2**	**Mo**	**As**
0,02	0,02	0,038	0,0040	0,001	0,001

The discs have turned out of squares with the side length of 196 mm in accordance with the elaborated technological process. Prior to the principal investigation, the spinning roll and the template have been fixed to the MZH-500 machine, the rules have been set to zero, the shape of the template has been copied. The copying consisted of the procedure that the hydraulic servomotor pressed the spinning roll to the template with a reduced force and moved the support together with the roll along its outline. Thus, the roll has copied the spatial shape of the spin formed draw piece, the shape of which has been recorded in the form of the point coordinates. Then the data of the template shape has been sent to the program in this manner, by drawing the trajectory (Figure 3b).

EXECUTION OF THE TESTS

Prior to the execution of the tests, the following technological parameters of the spinning process have been selected:

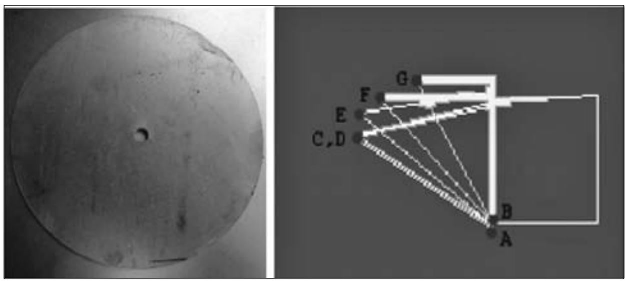

Figure 3a, b. The initial material, trajectory of the spinning roll

Figure 4a, b. Phases of the process – the initial one and the intermediate one

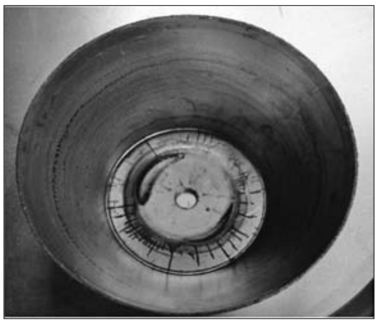

Figure 5. Finished draw piece

- spinning roll trajectory - considering the simple shape and manufacturing possibility, it has been decided that the trajectory should be straight line, the roll should be born on one side,
- the number of spinning passes - the number of passes has been established to be 5,
- the angle between the roll path and the axis of the product being formed – the angles had the following values: 58°, 40°, 31°, 25°, 25°. The last two angles had the same value because the last pass of the roll was a smoothing one. The purpose was not to change the shape of the draw piece, but to improve its surface condition;
- advance of the roll - the advance was established to be 600 mm/min.
- the rotational speed of the object, i.e. of the spindle, was 600 r.p.m
- a roll with the working with the working surface radius of R = 6 mm has been used.

After fixing the disk and starting the spindle, the sheet disk has been formed in subsequent roll passes (Figure 4a, 4b) till the final shape of the draw piece has been obtained (Figure 5).

INVESTIGATION RESULTS

After the technological tests, the following has been done:

- the disk has been taken off and the draw piece visually assessed in comparison with the reference piece supplied by the purchaser,
- the draw piece wall thickness has been measured by means of a sensor gauge.

In the visual assessment of the draw piece, it has turned out that the draw piece has not been correctly

Figure 6. A defective draw piece

Figure 7a, b. Checking of the insert and gap

pressed to the template. This has caused defects inside the draw piece, marked in Figure 6.

The excess of the admissible values of deformations has given rise to folds and loss of material stability.

The correctness of the draw piece has also been checked by means of the pattern supplied by the purchaser (Figure 7a).

In the case of two draw pieces, it has been found that the bottom edge of the gauge has not been resting on the draw piece bottom. The gap between the side edges and the draw piece wall has been measured by means of a set of feeler gauges (Figure 7b).

It has been found that the gap had the dimension of 0,55 mm. Therefore, the total clearance has been about 1,1 mm. The height of some draw pieces was smaller than the one required (Figure 8a). On the draw piece side wall, some furrows could be seen. This was an effect of the wrong selection for the spinning roll travel (too large), Figure 8b.

As result of the measurements, it has been found that the products were not in conformance with the draw piece drawing. Therefore, a correction of the trajectory has been introduced and the technological parameters changed:

– the roll trajectory has been determined to remain rectilinear,
– the number of spinning passes has been maintained the same, i.e. 5,
– the angels between the roll path and the product axis have been changed – after tests and calculations, the angles had the following values: 60°, 42°, 33°, 27°, 27°,
– the roll feed has been fixed to 500 mm/min.,
– the rotational speed of the product being formed, i.e. of the spindle, has been fixed to 750 r.p.m.,
– the radius of the spinning roll has been changed from R = 6 mm to R = 10 mm.

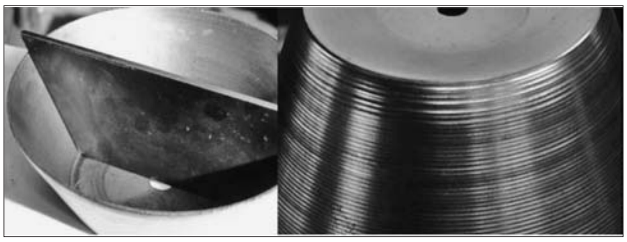

Figure 8a, b. Checking the insert height, draw piece with furrows on the surface

Then, the disk has been fixed in the holder by the means of a hydraulically moved tailstock with a thrust plate. The disk has been pressed with a force of 3 kN and subsequent technological tests have been performed.

After technological tests of ten draw pieces:

– the draw pieces have been taken off and visually assessed with comparison to the pattern supplied by the purchaser,
– the thickness of the draw piece wall has been measured by means of the above mentioned sensor gauge.

The measurements have shown that the maximum thickness difference for the insert was 0,29 mm, while the arithmetical average of the wall thickness was 2,86 mm. The measurement of the gap between the draw piece generatrix and the gauge has shown that its value was 0,2 mm on each side. After performing technological tests, the draw piece has been cut and the hardness distribution in it examined.

CONCLUSIONS

1. The performed tests have proved that it is possible to make a conical element of 3 mm thick 08 AI metal sheet with spinning technology.
2. During the tests, a relationship between the radius of the roll working surface and the roughness of the draw piece surface has been observed.
3. The dimensions of the draw pieces were in conformance with those given in the design drawing of the product.
4. The deviation of the circularity of the side wall has not exceeded 0,15 mm.
5. The metal on the draw piece generatrix has undergone strain hardening as compared to the metal on the product bottom, which has not been subjected to plastic forming.

REFERENCES

[1] W. P. Romanowski, Handbook of cold metal forming., WNT, Warsaw 1961.
[2] Metal spinning in automotive industry, Sheet Metal Ind., 72(1995)4, 31÷32.
[3] K. Da-Chang A study of quasi-superplastic spinning of 2091 Al-Li sheet. J. Mat. Proc. Technol., 51(1995), 1÷4, 79÷86.

[4] V. S. Ryzikov, Technology of narrowing tube type blanks by spinning. Metal Forming, 6(1995)2/3, 45÷46.
[5] Spinning., Sheet metal Ind. 73(1996), 8, 31.
[6] A. Zaboklicki, New prospects of manufacturing techniques: laser aided processes, Metal Forming, 8(1997)3, 61÷67.
[7] T. Cielecki, T. Drenger, J. Wiśniewski, The development of metal spinning ans shear and flow forming in the Metal Forming Institute, Poznań, Metal Forming, International Scientific and Technical Conference, Poznań-Kiekrz, 28÷30 September 1998, INOP, (1998), 67÷72.
[8] Metal forming in a spin., Metallurgia, 66(1999)7, 20÷21.
[9] K. Da-Chang, Study on the deformation mode of conventional spinning of plates., J. Mat. Proc. Technol., 91(1999), 1÷3, 226÷230.
[10] G. Xi-Cheng, Experimental research on a new technology - elipse spinning., J. Mat. Proc. Technol., 94(1999), 197÷200.
[11] Fast spin., Sheet Metal Ind., 77(2000), 2, 16.
[12] T. Cielecki, T. Drenger, J. Wiśniewski, A modern spinning maxchine, 14th Scientific and Technical Conference of Metal Forming on the "Design and Technology of Drawpieces and Die Stampings", Poznań – Czerniejewo, 14÷16 June 2000, INOP, (2000), 81÷85.

Note: The responsible translator for English Language is K. Mance, Faculty of Engineering, Rijeka, Croatia.

FIRST CIRCULAR – CALL FOR PAPERS
Prvo priopćenje – poziv za referate

9th International Symposium of Croatian Metallurgical Society*
9. međunarodni simpozij Hrvatskog metalurškog društva

"Materials and Metallurgy"
"Materijali i metalurgija"

http://public.carnet.hr/metalurg

S H M D '2010.

Šibenik 2010, June 20 - 24, Solaris Holiday Resort****, Croatia

9th International Symposium of Croatian Metallurgical Society „Materials and Metallurgy" will be held as part of:

- **150th anniversery** of THE ESTABLISHMENT OF STEEL INSTITUTE VDEh Düsseldorf, Germany
- **90th anniversery** of THE ESTABLISHMENT OF DNEPROPETROVSK NATIONAL UNIVERSITY, Dnepropetrovsk, Ukraine
- **70th anniversery** of STUDIES OF METALLURGY OF UNIVERSITY OF LJUBLJANA, Slovenia
- **60th anniversery** of THE ESTABLISHMENT OF INSTITUTE OF METALS AND TECHNOLOGY, Ljubljana, Slovenia
- **55th anniversery** of THE ESTABLISHMENT OF INSTITUTE OF MATERIALS RESEARCH Slovak Academy of Sciences, Košice, Slovakia
- **50th anniversery** of THE ESTABLISHMENT OF:
  - TECHNICAL FACULTY, UNIVERSITY OF RIJEKA, Rijeka, Croatia
  - FACULTY OF ELECTRICAL ENGINEERING, MECHANICAL ENGINEERING AND NAVAL ARCHITECTURE, UNIVERSITY OF SPLIT, Split, Croatia
- **20th anniversery** of INTENSE INTERNATIONAL COOPERATION OF CROATIAN METALLURGICAL SOCIETY, Zagreb, Croatia