STRAIN DISTRIBUTION AFTER METAL SPINNING OPERATIONS

Jana ŠUGÁROVÁ, Peter ŠUGÁR, Faculty of Environmental and Manufacturing Technology, Technical University Zvolen, Študentská 26, 960 01 Zvolen, Slovakia

Abstract: *The paper brings the results of strain distribution investigation throughout the part after metal spinning operation by the circle grid analysis method. The results of realized experimental works showed up the increasing of deformation capacity of the sheet metals, compared with the results obtained from the uniaxial, monotonic tensil tests. The reasons of the found out properties of the tested materials are discused in the paper.*
Key words: *forming, spinning, strain, measurement, plasticity*

1. INTRODUCTION

Forming is a manufacturing process, which plays the dominant role in the nowadays competitive industry. One of the most important objectives of modern forming processes is necessity to produce machine components with improved surface layers properties (surface integrity). All surface alterations generated in forming process determine the functional properties of the component.

Relatively old sheet metal forming technology which involves forming of axisymmetric hollow parts with advantageous surface layer properties is metal spinning (conventional spinning, shear spinning and tube spinning). It is old technique where a flat metal disk is pressed against a form while turning in a spinning lathe.

Because the theoretical basis of the spinning process is not sufficient, the experimental study of the strain distribution throughout the part after the operation have been realized. The experimental methods and achieved results are described in the paper.

2. STRAIN DISTRIBUTION AFTER METAL SPINNING

Strain distribution in material of axisymetric hollow parts produced by conventional spinning operations were investigated. The tests were carried out on the parts (experimental samples) with three different shapes, produced from three different materials (together nine experiments).

2.1 Measurement of strain distribution throughout the parts (experimental material and methods)

For the experimental study of the strain distribution throughout the parts, thin sheets with 1 mm thickness with next material composition, were used:

- STN 42 5301 – 11321.1 (0,1%C; 0,45%Mn; 0,035%P; 0,035%S) – material M1,
- STN 42 5315 – 17241.1 (0,12%C; 2%Mn; 1%Si; 18%Cr; 10%Ni; 0,045%P; 0,03%S) – material M2,
- STN 42 4005.11 – Al99,5 (min 99,5% Al; 0,3%Si) – material M3.

For illustration the basic material characteristics (R_m – ultimate tensile strength, $R_{p0,2}$ – 0,2% offset yield strength, A – elongation, r – medium value of anisotropy, Δr – planar anisotropy) presents the Table 1.

Table 1. Mechanical characteristics of experimantal materials

Material -	**M1**	**M2**	**M3**
R_m *[MPa]*	282	626	72
$R_{p0,2}$ *[MPa]*	149	202	51
$R_{p0,2} / R_m$	0,53	0,32	0,71
A *[%]*	45,72	60,35	54,61
r	1,685	1,607	0,738
Δr	0,890	0,475	0,394

Experiments have been realized on the part of hemispherical, oval and conical shape (Figure 1). Basic dimensional charakteristics of the samples shows Table 2.

The circle grid analysis method [3] based on the measurement of circle grid elements before and after deformation process were used for strain distribution analysis. The values of major and minor strains was obtained from the elliptically distorted grid circles. Measurement of circle diameters (d = 2 mm before deformation) were realized on optical microscope MWDC no. 1170 with cross wire, slide table and electrical output of information about position of table in horizontal plane.

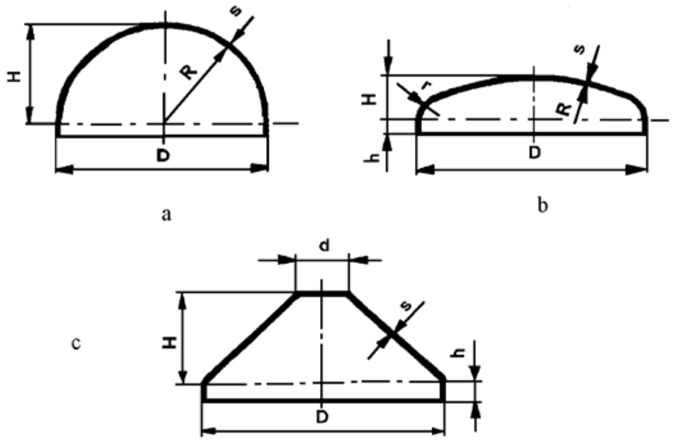

Fig. 1 *Shapes of experimental samples*
a – hemispherical, b – oval, c – conical

Table 2. Dimensional characteristics of samples

Dimension [mm] / **Sample shape**	***D***	***d***	***H***	***h***	***R***	***r***	***s***
hemispherical	142	-	56	-	71	-	1
oval	165	-	15	10	165	4	1
conical	140	100	62	0	-	-	1

3. RESULTS AND DISCUSSION

The results of true major and minor strains measurement throughout conical sheet metal part (material M2) are shown on Figure 2 and Figure 3. The true strains have been evaluated in three directions – 0°, 45°, 90° refer to the rolling direction of the sheet. The results of measurements for the other combination of material and sample shapes are included in publications [4], [5].

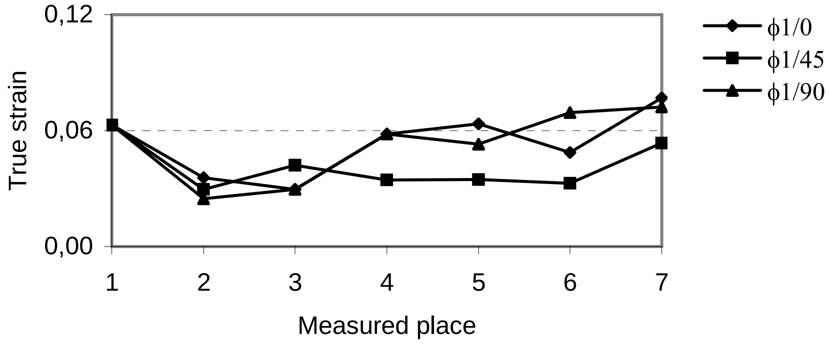

Fig. 2 *Measured true major strains φ_1 (material M2, conical shape)*

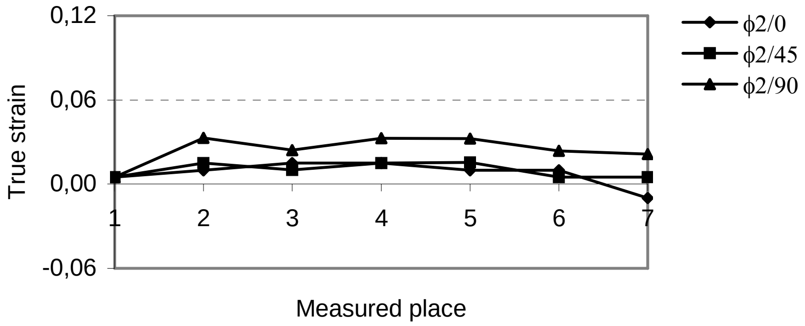

Fig. 3 *Measured true minor strains φ_2 (material M2, conical shape)*

The obtained results have been evaluated in accordance with the publications [1], [2]. On the basis of critical deformation intensity for uniaxial simple tension φ_{ikrit} (obtained from uniaxial tensil test) and local deformation intensity φ_i (calculated from true major and minor strains) the coefficient of local plasticity was calculated. The coefficient value $\eta > 1$, usually indicates the material failure.

$$\eta = \frac{\varphi_i}{\varphi_{ikrit}} \tag{1}$$

Experimentally determined and calculated coefficients of local plasticity are summarized in Table 3.

Table 3. Coefficients of local plasticity (CLP)

Sample shape	η		
	M1	**M2**	**M3**
hemispherical	1,86	1,76	1,79
oval	1,36	1,33	1,39
conical	1,76	1,63	1,72

The results of carried out experiments lead to the next conclusions:

- Several times higher strains (η > 1) have been found compared with strain values acquired from the uniaxial, monotonic tensil test and material has not failured. It is a sign, that the very advantageous stress state exists in deformed material what is a result of special plastic deformation mechanism accompanied with imaginary deformation increasing due to triaxial compression with high portion of hydrostatic compression.
- Very favourable stress state of material after metal spinning operation results from the triaxial compression under roller. It secure very good material formability, in case of very hard forming material, too. Compressing stresses close crevices and the surface layer quality is better compared with the quality of surface layers prouced by drawing.
- Comparison of the strains in directions – 0^o, 45^o, 90^o refer to the rolling direction of the sheet comfirmed the assumption about minimal influence of material anisotropy on the spinning process. For metal spinning process is typical deformation only in small (local) volume of material.

4. CONCLUSION

The paper brought the results of experimental investigation which is a part of complex research project focused on the metal spinning energy-force parameters evaluation. Energy – force parameters are input information of the process plan generation, because they provide a framework for estimating the environmental impact cause by manufacturing process.

5. REFERENCES

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