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ANALYSIS OF SURFACE LAYERS MICROHARDNESS OF METAL SPUN PARTS

SUGAR, P[eter] & SUGAROVA, J[ana]

Abstract: *The paper analyses a microhardness of the formed parts surface layer produced by conventional metal spinning. The relationship between mandrel (material) rotation frequency and material microhardness changes in the process of hollow, axially symmetric sheet metal parts production is studied. The thin sheets with 1 mm thickness, steel S235JRG2 (according to standard EN 1002511), was used for experimental study of microhardness in the formed part places with different strain degree – conical part and radius between bottom and conical wall of the formed part.*

Key words: *forming, spinning, microstructure, microhardness*

1. INTRODUCTION

Bending of materials involving rotation called metal spinning, also known as spin forming (Ger.: Metalldrücken), constitutes a part of basic surface-forming operations along with drawing, bending and cutting. It is a method for manufacturing hollow axially symmetric sheet parts and dimensionally undeployable structures which, due to the way new surfaces of the product are generated, is similar to manufacturing of pottery on potter's wheel dating back to Ancient Egypt era 3000 years BCE (Palten & Palten, 2002). The core of the process consists in gradual shaping of a pre-sized metal disc according to a model (mandrel). From the technological point of view the material is exposed to plastic deformation provoked by bending moment; indeed, it is not simple bending but a compound material bending with local shaping. In other words, it is incremental forming based on gradual bending of material in rotation with additional reduction force of the spinning tool (Šugárová, 2008).

There are three types of metal spinning techniques. The process, in which the thickness of workpiece is almost unchanged, is called conventional or multipass spinning. In conventional spinning, it is assumed that the sheet thickness is constant and the hoop strain is compressive, the radial strain is tensile and the thickness strain is zero. The second process where the hoop strain is zero, is named pure shear forming, also named power spinning (Bewlay & Furrer, 2006) or spin forging (Quigley &Monaghan, 2000). The third metal spinning techniques is named tube spinning or flow forming.

The possibilities for the use of spinning technologies are very rich. They are applied with production of mechanical parts for the area of food processing, agriculture, lighting and ventilating systems, aviation, marine, and last but not least in motorcar industries, where metal spinning technologies find ample use especially in production of wheel disks, nozzles, sleeves and other similar mechanical parts.

Great flexibility in re-setting of production is an important feature that makes of the metal spinning technology an alternative to less flexible part manufacturing processes by drawing. Another advantage of the process resides in the relatively favourable degrees of final stress and deformation of the material due to the mechanism of plastic deformation.

Because metal spinning technology is based on empirical rather than exact knowledge that is indispensable for proper management of process operations with respect to the required final product qualitative parameters. This endeavour is even further strengthened due to ever present large expansion of automation efforts concerning the operations of metal spinning with the use of CNC machines and industrial robots.

The said advantages are the attractions that have been drawing the attention of research, development and manufacturing centres all around the world to metal spinning technology.

Knowledge about the mechanics of spinning has been developed by systematic investigation of the process using both experimental and theoretical techniques. For more detailed analysis of the process, numerical methods are required.

Many experimental techniques have been applied to study the mechanism of deformation and evolution of strains, to investigate failure mechanism and predict failure, to predict forming forces, thickness distribution, roundness tolerance and surface quality. Several gaps exist in the knowledge of spinning mechanics. These gaps are: prediction of metal spun properties (microstructure, residual stresses and springback) and prediction of failure and design of toolpaths. No many studies of microstructure in metal spinning exist (Wong et al., 2003; Music et al., 2010 and other authors).

This article shows partial outcomes of a complex experimental research focused on identification of impact of selected technological parameters of the conventional metal spinning process on formed part surface layers integrity.

2. MICROSTRUCTURE AND MICROHARDNESS OF SPUN PARTS

Plastic deformation of material has a side effect in the process of metal spinning – changes in the structure and consequent changes of features of the material, mainly within its surface and subsurface layers (Šugár & Šugárová, 2009). Besides mechanical properties changes (better solidity, hardness and breakability) some physical properties changes, such as reduction of heat-carrying and electrical conductivity of the material, appear. Those changes are crucial for the usage of the product for they might affect usage infallibility parameters such as surface wear intensity, corrosion resistance, etc.

2.1. Methodology of experiments

An experimental production of samples has carried out to assess the impact of selected technological parameters of the process of metal spinning on changes in structure and properties of the formed material. Steel EN 30-69 (11 375.21 under STN 41 1375) with thickness of s = 1 mm was used for the experiment. The chemical composition and selected forming properties of the material are listed in table 1.

C (%)	Si (%)	P (%)	S (%)
0,130	0,010	0,010	0,014

Tab. 1. Chemical composition of experimental material

R_m (MPa)	$R_{e0,2}$ (MPa)	$R_{e0,2}/R_m$ (-)	A_{80} (%)
389	269	0,690	32,3

Tab. 2. Mechanical properties of experimental material

The experimental research has studied the impact of workpiece rotation frequency on changes in structure and effect of mechanical hardening in areas with different intensity of plastic deformation: M1 (radius between bottom and conical wall of the formed part; R = 10 mm) and M2 (conical shape) (Fig. 1). Formed parts MS1, MS2, MS3 and MS4 were made at different mandrel rotation frequencies: 255, 490, 600 and 890 min^{-1}. The manual metal spinning machine tool was used.

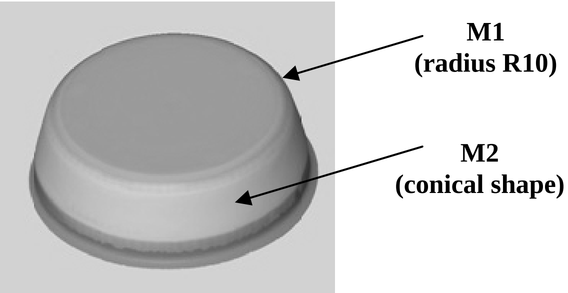

Fig. 1. Formed part and places of measure

Samples taken from areas M1 and M2 in direction of 0^o rolling-wise were subject to subsurface microhardness measure up to depth 25 μm by the Vickers method HV 0.025 in accordance with the standard STN 42 0375 (microhardness measurement machine Indeta Met 1100).

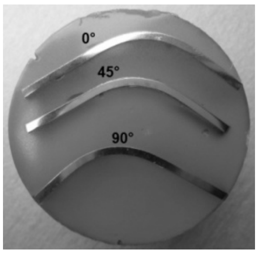

Fig. 2 Samples taken from the area M1 in directions of 0^o rolling-wise

The degree of mechanical hardening (MH) was calculated on the basis of average value of microhardness of spun part (HV_1) and microhardness of origin material (HV_0):

——— (1)

2.1. Results and discussion

The results of average values of mechanical hardening (MH) for all experimental parts and different places of measure (M1 and M2) are presented in the Tab. 3 anf Fig. 3.

Formed part (mandrel rotational frequency)	Place of measure	MH (%)
MS1 (n = 255 min^{-1})	M1	12,55
	M2	15,04
MS2 (n = 490 min^{-1})	M1	3,39
	M2	23,8
MS3 (n = 600 min^{-1})	M1	3,59
	M2	23,11
MS4 (n = 890 min^{-1})	M1	13,55
	M2	33,96

Tab. 3.The degree of mechanical hardening (MH)

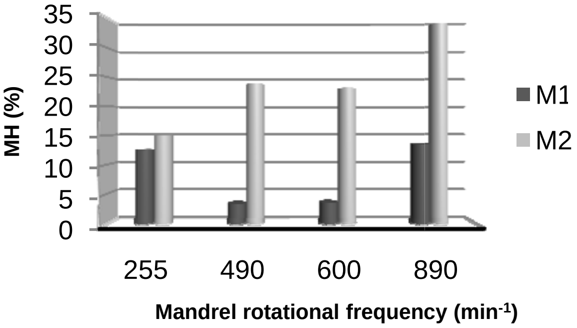

Fig. 3.The degree of mechanical hardening (MH)

3. CONCLUSION

The conventional metal spinning process can be considered as a dynamic stochastic multi-factor system. The outcomes of experimental research documented in this article, and other similar articles of the authors, have confirmed the differences in structure of the material in different areas of the product depending on degree of localised plastic deformation. The changes of structure-sensitive properties (such as microhardness in subsurface layers of material) prove direct dependence on circumferential speed of the workpiece when formed where higher values of mandrel rotation frequency corresponds to higher values of microhardness of the product in the conical part of the workpiece. Mechanical hardening of spun material in the area of radius between bottom and conical wall of the part is minimal for frequency 255 min^{-1} and maximal for mandrel frequency 890 min^{-1}. Because the mechanical hardening of spun material for frequences 490 min^{-1} and 600 min^{-1} is lower then mechanical hardening for the lowest frequency used in the experiment, no unambiguous conclusions can be expressed.

4. ACKNOWLEDGEMENTS

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