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ANALYSING THE PROPERTIES OF SURFACE LAYERS GENERATED BY SHEET METAL FORMING OPERATIONS

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Abstract

The paper brings results of the surface layers properties analysis of a thin wall hollow sheet metal parts, produced by metal spinning and deep drawing. The influence of mandrel (workpiece) frequency of rotation on the spun parts surface layer strainhardening is studied and compared with the quality of the formed part surface layer produced by deep drawing technology.

Key words

surface layer, strainhardening, metal spinning, microhardness

Introduction

Every technological method, which takes part on production of final component, brings in the component specific proprieties that influence its proceeding in whole assembling, i.e. it takes effect on its utility properties. Generated superior parameters of surface layer significantly influence for example wear resistance, fatigue strength, resistant to corrosion etc. These are important aspects, especially regarding the parts that are under dynamic stress or exposed to difficult operative conditions.

Typical parts exposed to such conditions are containers and pressure tanks utilized for holding energy saved in, e.g. compressed gases. Their most important construction elements are the shaped heads (bottoms of the tanks). These are classified as rotary parts, which are for the aspect of shape defined as hollow steel metal components. Heads are components of pressure tank that are manufactured out of boiler-irons, structural steels, aluminium and copper alloys, clad steels and reinforced plastic with carbon fibres [1].

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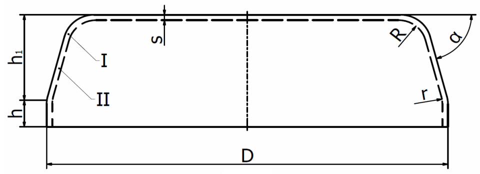
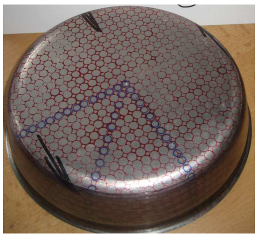
Most applied method of heads manufacturing is deep drawing. However, from the economic aspects and quality indicators is the process of metal spinning better alternative. After application of these operations a typical stress-strain states are generated in material and qualitative proprieties in surface layers [2, 3], which have subsequently effect on the safety index of pressure tanks. Consequential facilities of surface layers determine among others also material strainhardening the experimental analysis of which is the objective of this contribution.

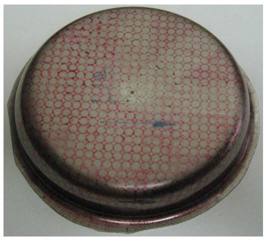
Experimental procedure of measurement and evaluation

For production of hollow sheet metal part, which dimensions parameters are shown in Fig. 1a and listed in Table 1, a thin steel sheet made of EN 10025-94 (ISO 630-80) material with thickness s_0 = 1 mm was used. Chosen basic mechanical proprieties and facilities defining material plasticity are listed in Table 2. The blanks with diameter D_0 = 180 mm were formed by deep drawing (Fig. 1c) and metal spinning (Fig. 1c) processes. Forming was performed by Sandrik company 1895, spol. s.r.o., Hodruša-Hámre, at the technological conditions listed in Table 3.



a





b c

Fig. 1 *Hollow sheet metal part*
a – parts shape and dimensions
b – part manufactured by metal spinning (MS)
c – part manufactured by deep drawing (DD)
I – bottom-wall of part, II – wall of part

FORMED PART DIMENSIONS Table 1

D (mm)	***h*** (mm)	***h_1*** (mm)	***r***	***R***	***α*** (°)	***s*** (mm)
140	30	90	10	10	75	1

VALUES OF CHOSEN MECHANICAL PROPERTIES AND PROPERTIES DEFINING MATERIAL PLASTICITY EN 10025-94 Table 2

R_m (MPa)	$R_{p0,2}$ (MPa)	$R_{p0,2} / R_m$	A_5 (%)	r_s	Δr	n	A_{sh}
340	235	0.69	26	1.174	0.34	0.28	27.38

TECHNOLOGICAL PARAMETERS OF DEEP DRAWING AND METAL SPINNING PROCESSES Table 3

Process of deep drawing			Process of metal spinning		
Blank-holder force F_P (kN)	**Forming force** F_T (kN)	**Forming velocity** v ($m.s^{-1}$)	**Feed ratio** f (mm)	**Mandrel frequency of rotation** n (min^{-1})	**Maximum circumferential velocity** v ($m.min^{-1}$)
20.11	192.31	0.25	0.80	600	263

Presented experimental observation and evaluation of surface layers properties are aimed at the evaluation of material strainhardening, utilizing the method of microhardness measuring according to Vickers, method HV 0.025, under STN 42 0375, measured on INDETA Met 1100 device. The measurement was carried out in direction from the part's surface to its depth on positions that are from the aspect of hollow sheet parts production defined as critical (Fig. 1a), i.e. inter-stage spots of head to wall (I) and conic wall (II). For mathematical formulation of material strainhardening values, the measuring was carried out five times, also on the base material (BM), whereby the measurement was applied in two directions – 0^o and 90^o referring to the rolling direction of the sheet. The measured and calculated values for the base material are listed in Table 4. For metal spinning part, positions I and II are measured, and calculated values are listed in Table 5.

MICROHARDNESS VALUES OF SURFACE LAYER, MEASURED ON BASE MATERIAL (BM) Table 4

Depth of measure (μm)	***5***	***10***	***15***	***20***	***25***	***Mean average***
HV_{BM-0}	***101.9***	***101.8***	***100.2***	***99.3***	***98.9***	***100.43***
HV_{BM-90}	***101.7***	***99.4***	***99.2***	***98.6***	***98.0***	***99.07***

MICROHARDNESS VALUES OF SURFACE LAYER, MEASURED IN POSITION I AND II OF MS PART Table 5

Depth of measure (μm)	***5***	***10***	***15***	***20***	***25***	***Mean average***
HV_{MS-I-0}	***111.4***	***104.9***	***104.1***	***103.2***	***101.2***	***104.96***
$HV_{MS-II-0}$	***130***	***129.8***	***124.5***	***117.1***	***109.8***	***122.24***

Graphic evaluation of microhardness values of sample's surface layer, made by metal spinning, in positions I and II, under consideration of material rolling direction, is shown in Fig. 2.

Graphic evaluation of microhardness values of sample's surface layer, made by deep drawing, in positions I and II, under consideration of material rolling direction, is showed in Fig. 3.

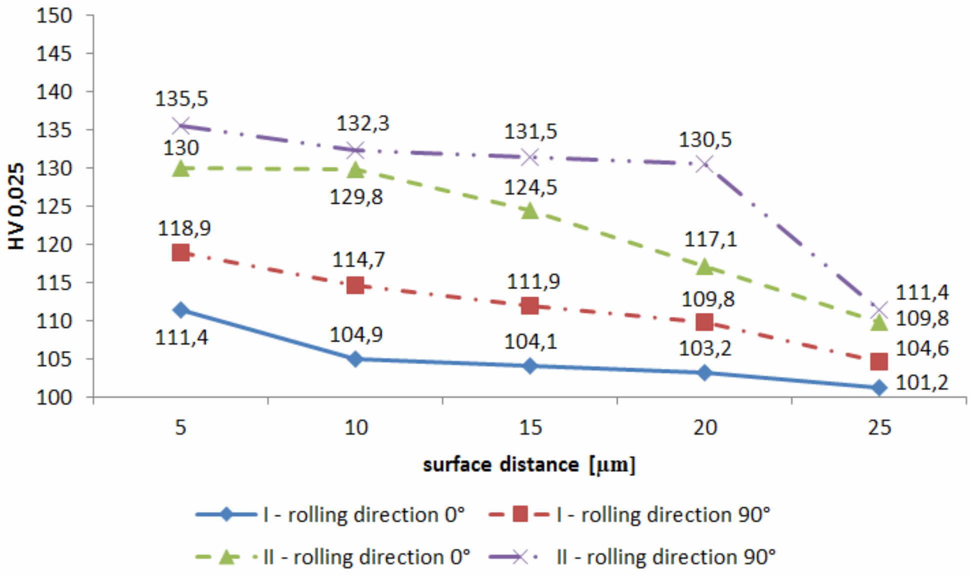


Fig. 2 *Progress of microhardness values in surface layer of MS sample in position I and II, in direction 0° and 90° refer to the rolling of the sheet*

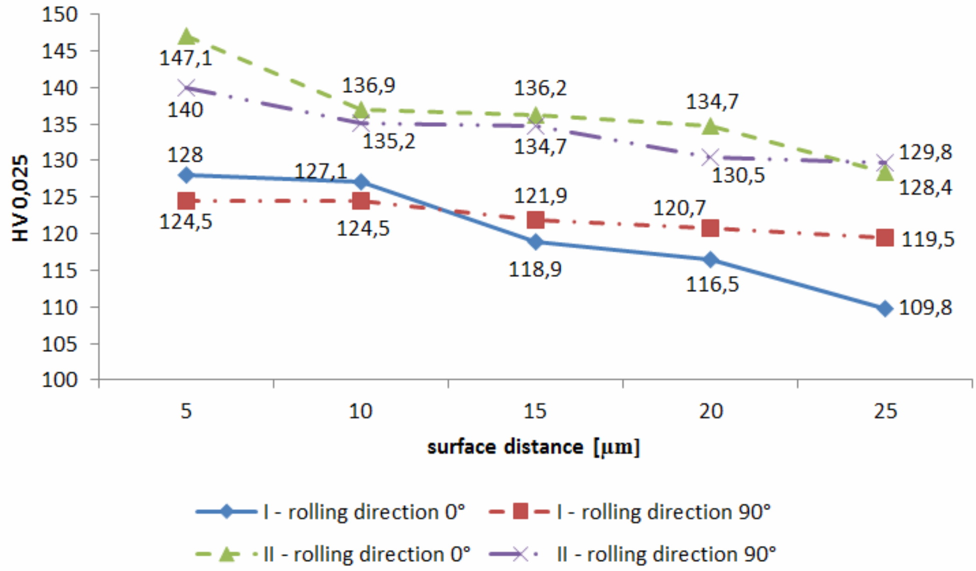


Fig. 3 *Progress of microhardness values in surface layer of DD sample in position I and II, in direction 0° and 90° refer to the rolling of the sheet*

Consequently "relative strainhardening of material" (PSM) was interpreted on MS and DD samples considering BM, whereby the material rolling direction was also regarded. Every sample was evaluated twice. The first calculation was aimed at comparison of base material with the inter-stage of head to wall. The second calculation was aimed at comparison of base material with the conic wall. Median calculation example of MS material, in position I, in the direction of material rolling ($PSM_{MS\text{-}I\text{-}0}$), states formula (1) and example of MS material, in position II, in the direction of material rolling ($PSM_{MS\text{-}II\text{-}0}$), states formula (2). Calculations of PSM for maximum values of microhardness, for the same directions and positions, are shown in formulas (3) and (4).

$$PSM_{MS-I-0} = \frac{HV_{MS-I-0} - HV_{BM-0}}{HV_{BM-0}} 100 = \frac{104.96 - 100.43}{100.43} 100 = 4.51 = 5 \ [\%] \tag{1}$$

$$PSM_{MS-II-0} = \frac{HV_{MS-II-0} - HV_{BM-0}}{HV_{BM-0}} 100 = \frac{122.24 - 100.43}{100.43} 100 = 21.72 = 22 \ [\%] \tag{2}$$

$$PSM_{MS-I-0-\max} = \frac{HV_{MS-I-0-\max} - HV_{BM-0}}{HV_{BM-0}} 100 = \frac{111.4 - 100.43}{100.43} 100 = 10.92 = 11 \ [\%] \tag{3}$$

$$PSM_{MS-II-0-\max} = \frac{HV_{MS-II-0-\max} - HV_{BM-0}}{HV_{BM-0}} 100 = \frac{130 - 100.43}{100.43} 100 = 29.44 = 29 \ [\%] \tag{4}$$

The presented procedure evaluates the values of PSM for all microhardness values, measured in direction of material rolling. Equal computation was applied for the direction 90^{o} referring to the rolling direction of the sheet. Saturation and comparison of single PSM values of DD and MS samples are shown in Figs. 4 and 5.

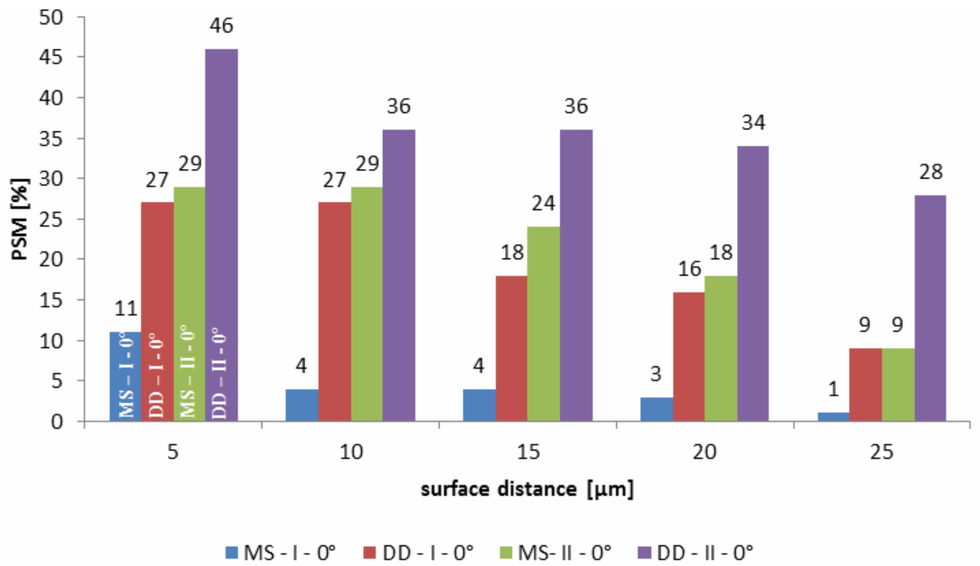


***Fig. 4** Comparison of PSM values of DD and MS samples in positions I and II, in direction of material rolling*

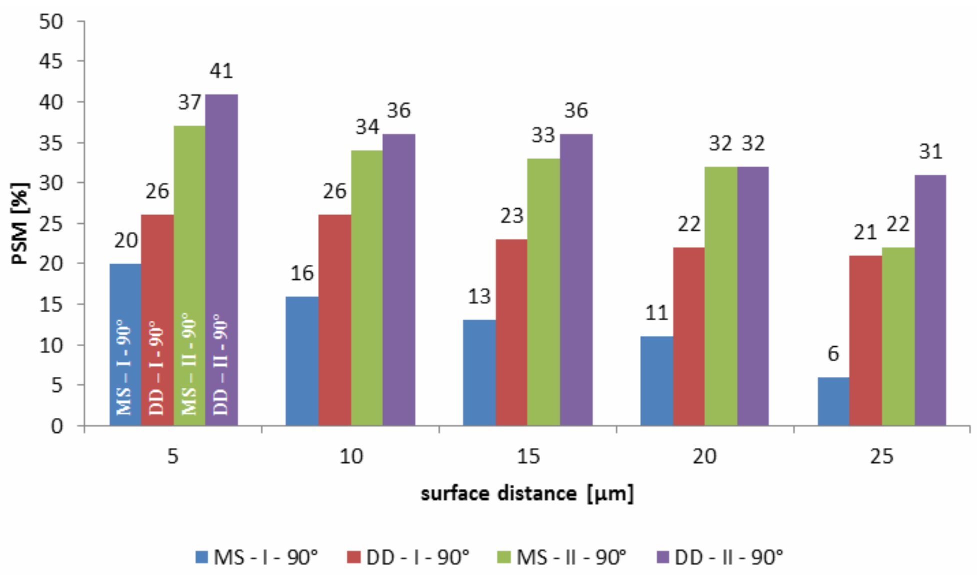


Fig. 5 *Comparison of PSM values of DD and MS samples in positions I and II, in direction 90° referring to the rolling direction of the sheet*

Conclusion

The published results suggest that the maximum values of PSM in both directions, referring to the direction of rolling, are on DD sample, whereby its average value in position I-0 is 19.4 %, in I-90 it's 23.8 %, in II-0 the average PSM value is 36 % and in II-90 it is 35.2 %. The average PSM value of MS sample in positions I-0 is 4.6 %, in I-90 it is 13.2 %, in II-0 the average PSM value is 21.8 % and in II-90 it's 29.8 %. These values are at average higher in position I over 12.7 % and in position II over 9.8 %. Likewise interesting is the fact that the PSM values distinction in single measuring positions of DD and MS samples (Figs. 4 and 5) are moving in the same values. Namely, on DD sample, it is 14 % and on MS, it is 16.9 %, which we can consider as relatively equal values for both forming processes.

Based on observation of strainhardening values and their average PSM surface layers values of deep drawing and metal spinning samples it is possible to state that the different stress-strain conditions, parallel in material, generated different values of material strainhardening. In the DD sample, the values were about 10 % higher. Equal values of PSM are possible to achieve by putting a calibration process into the manufacturing process, or modifying the technological parameters, i.e. choosing higher frequencies of mandrel rotation, or higher feed ratio of forming tool.

Besides propitious values of material strainhardening on surface layers, typical stress-strain condition of material after spinning, effects also wear intensity positively, increases corrosion resistance and also some other values of mechanical properties and properties defining formability of materials, e.g. increases fracture limit [4], which is an important aspect in process of exploitation.

Further we can state, that the final important properties of surface layers are influenced by initial direction of material rolling, since the values of PSM after spinning are almost equal to those made by deep drawing in perpendicular direction to the direction of material rolling

(6%, 4%). However difference between both directions values is higher (16%, 17%); therefore we can predict, in theoretical line, places of potential failure in components exploitation process.

Following the experimental measurement carried out and its evaluation, it is possible to state, that the technology of metal spinning is likely to produce components with suitable surface staining as technology of deep drawing, whereby the character of material deformation in spinning process determines other facilities that are more convenient from the aspect of their working qualities.

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