METAL SPUN AND DEEP DRAWN PART’S SURFACE LAYERS PROPERTIES EVALUATION

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Abstract: Contribution states the experimental analysis of surface layers properties of thin-walled hollow sheet metal parts, manufactured by forming processes – deep drawing and metal spinning. It brings the results of the part’s surface layer microhardness measurement after conventional metal spinning and deep drawing operation and the comparation of the strain-hardening effects of these processes.

Key words: surface layer, strain-hardening, metal spinning, microhardness

1. INTRODUCTION

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

Typical parts exposed to such conditions are containers and pressure tanks, 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, aluminum and copper alloys, clad steels and reinforced plastic with carbon fibers [1].

Most applied method of heads manufacturing is deep drawing. However, from the economic aspects and quality indicators, the process of metal spinning is better alternative. After application of this technology a typical stress-strain states are generated in material and qualitative properties in surface layers [2, 3, 4], which have subsequently effect on the safety index of pressure tanks. Consequential facilities of surface layers determine, among other things, also material strain-hardening. Experimental analysis and comparation of above mentioned processes, from the surface layer strain-hardening, is the objective of this paper.

2. EXPERIMENT

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

![Fig. 1 Hollow sheet metal part shape and dimensions](image)

I – bottom-wall of part, II – wall of part
Presented experimental observation and evaluation of surface layers properties is aimed at evaluation of material strain-hardening utilizing method of micro-hardness 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 part’s surface to its depth on positions, that are from aspect of hollow sheet parts production, defined as critical (Fig. 1), i.e. inter-stage spots of head to wall (I) and conic wall (II). For math formulation of material strain-hardening values was the measuring carried out five times, also on the base material (BM), whereby the measurement was applied in directions 0° and 90° refer to the rolling direction of the sheet. Measured and calculated values for base material are listed in Table 4.

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 showed 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.

<table>
<thead>
<tr>
<th>Surface distance (μm)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>Mean average</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV_{BM0}</td>
<td>101.9</td>
<td>101.8</td>
<td>100.2</td>
<td>99.3</td>
<td>98.9</td>
<td>101</td>
</tr>
<tr>
<td>HV_{BM90}</td>
<td>101.7</td>
<td>99.4</td>
<td>99.2</td>
<td>98.6</td>
<td>98</td>
<td>101.14</td>
</tr>
</tbody>
</table>

Table 4. Microhardness values of surface layer – base material (BM)

![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 direction](image1)

![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 direction](image2)
Consequently “relative material straining” (RMS) was interpreted on MS and DD samples considering BM, whereby the material rolling direction of the sheet 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 direction 90° refer to the rolling direction (RMSMS/I/90), states formula (1) and example of MS material, in position II, in the direction 90° with respect to the rolling direction of material (RMSMS/II/90), states formula (2). Calculations of RMS for maximum values of microhardness, for those same directions and positions, are showed in formulas (3) and (4).

Presented procedure evaluates values of PMS for all microhardness values, measured in direction of material rolling. Equal computation was applied for the direction of 90° refer to the rolling direction. Saturation and comparison of single RMS values of DD and MS samples are showed in Fig. 4 and 5.

\[
RMS_{MS/I/90} = \frac{HV_{MS/I/90} - HV_{BM/90}}{HV_{BM/90}} \times 100 = \frac{123.26 - 101.14}{101.14} \times 100 = 21.87 \% 
\]

(1)

\[
RMS_{MS/II/90} = \frac{HV_{MS/II/90} - HV_{BM/90}}{HV_{BM/90}} \times 100 = \frac{128.92 - 101.14}{101.14} \times 100 = 27.47 \% 
\]

(2)

\[
RMS_{MS/I/90\text{ max}} = \frac{HV_{MS/I/90\text{ max}} - HV_{BM/90}}{HV_{BM/90}} \times 100 = \frac{130.5 - 101.14}{101.14} \times 100 = 29.03 \% 
\]

(3)

\[
RMS_{MS/II/90\text{ max}} = \frac{HV_{MS/II/90\text{ max}} - HV_{BM/90}}{HV_{BM/90}} \times 100 = \frac{142.3 - 101.14}{101.14} \times 100 = 40.7 \% 
\]

(4)

Fig. 4  Comparison of RMS values of DD and MS samples in positions I and II
3. CONCLUSIONS

From published results follow that the maximum values of RMS in both directions of material rolling is on DD sample, whereby its average value in position I-0 is 35.31%, in I-90 it’s 32.73%, in II-0 the average RMS value is 18.87% and in II-90 it’s 20.43%. The average RMS value of MS sample in positions I-0 is 12%, in I-90 it’s 21.87%, in II-0 the average RMS value is 31.51% and in II-90 it’s 27.47%.

Based on observation of strain-hardening values and their average RMS 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 strain-hardening. In the DD sample were higher values of mechanical hardening. Higher values of RMS for metal spun parts are possible to achieve by calibration, or by modification of technological parameters, i.e. choosing higher frequencies of mandrel speed, or higher feed ratio of spinning tool.

Besides propitious values of material strain-hardening 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, which is 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 RMS after spinning are almost equal to those made by deep drawing in direction 90° refer to the sheet metal rolling direction. However difference between the directions of material rolling values is higher, therefore we can predict, in theoretical line, places of potential failure in components exploitation process.

Following the carried out experimental measurement and its evaluation it is possible to state, that the metal spinning is more suitable for producing components with favorable manner of surface strain-hardening as technology of deep drawing. The character of material deformation in the process of metal spinning determines other part’s facilities, which are more convenient from the utilization point of view.

4. REFERENCES


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