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CHANGE OF EARS CREATION OF AHSS STEELS AFTER HEAT TREATMENT OF ZINC COATING

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The article deals with the normal anisotropy, the earring evaluation of deep-drawing steels DC06, micro-alloyed steel H220 and steel with transformation induced plasticity TRIP RAK 40/70 and deals with the influence of annealing temperature to ears creation of H220 steel and TRIP RAK 40/70 steel. The evaluation of normal anisotropy has been made by tensile test on TIRA test 2300 according standards STN EN 10002-1+AC1 and STN 42 0321. The evaluation of earring degree has been carried out on the cups, which have been drawn on a hydraulic press Fritz Müller 100.

Key words: multiphase steels, heat treatment, coefficient of normal anisotropy, degree of earing, earring, zinc coating

INTRODUCTION

Deep drawing is an essential part of the automotive industry. This technology is used to make external parts of car bodies from deep drawing steel sheets as well as internal parts of the body from various types of high-strength steels. From the aspect of technology, i.e. manufacture of pressings and car bodies, requirements for very high plasticity and homogeneity of properties are emphasized. The requirements for material properties of individual car parts and components are different [1-4]. Deep-drawing steels DC06, micro-alloyed steel H220 and steel with transformation induced plasticity TRIP RAK 40/70 also fall under the category of automotive sheets.

During sheets treatment by deep drawing have great importance directional values of mechanical properties (anisotropy). The sheets show two types of anisotropy: surface and normal. The surface anisotropy expresses inequality of mechanical properties in different directions of sheet plane. The surface anisotropy has adverse influence during the process of symmetrical cup drawing not only on the creation of ears needed to be removed, but it can also cause thinning of cup wall thickness and cause circularity deviations of cylindrical cups. The normal anisotropy expresses the inequality of properties obtained in sheet plane in respect to properties in perpendicular direction to sheet plane (in thickness direction). So it expresses sheet resistance to thinning at deep drawing [5].

A qualitative expression of the normal anisotropy is the normal anisotropy coefficient r:

$$r = \frac{\varphi_b}{\varphi_a} \quad (1),$$

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where: φ_b is true strain in direction of width and φ_a is true strain in direction of thickness.

If $r = 1$ that the tested sheet is isotropic and the sample deforms equally in direction of width and in direction of thickness. If $r < 1$ that the extension of sample is mainly by deformation of the thickness and vice versa if $r > 1$ that the extension of sample is mainly by deformation of width.

Normal anisotropy coefficient

$$\Delta r = \frac{r_0 - 2r_{45} + r_{90}}{2} \quad (2).$$

According the value of Δr it is possible to determine the inclination of sheet to creation of ears by deep drawing.

The ears are created in the sheet direction in which the value of the normal anisotropy coefficient "r" is maximal. If $\Delta r > 0$ that the ears are created in the direction 0° and 90° in relation to the direction of rolling, if $\Delta r = 0$ that the ears are not created and if $\Delta r < 0$ that the ears are created in the direction 45° in relation to the direction of rolling. The ears are so much bigger whereby the absolute value of Δr is bigger [2, 4, 6, 7].

The value of Δr relates with the degree of earring ΔH calculated from (3). The degree of earring represents the average heights of ears. The earring of cups is characterized as unfavourable property of deep drawing sheets, which is result of surface anisotropy [4].

Degree of earring

$$\Delta H = \frac{1}{2}(H_0 - 2H_{45} + H_{90}) \quad (3),$$

where: H_0, H_{45}, H_{90} are cup heights in the direction 0°, 45°, 90° in relation to the direction of rolling.

Earring coefficient

$$Z = \frac{H_{max} - H_{min}}{H_{min}} \cdot 100 \quad (4),$$

where: H_{max}, H_{min} are maximal and minimal cup heights.

For evaluation of cylindrical cups earring is convenient to use the degree of earring ΔH mainly because it gives average value of height cups. For evaluation of asymmetrical shapes cups is convenient to use the earring coefficient because it gives percentage value of ears for blank specific orientation in tool [2, 4, 6, 8, 9].

EXPERIMENTAL MATERIAL AND METHODS

Experimental material:

- deep-drawing steel DC06BZE75/75PHOL, thickness a_0 = 0,75 mm, marked “DC06 Y”,
- deep-drawing steel DC06BZE75/75PHOL, thickness a_0 = 0,85 mm, marked “DC06 Z”,
- micro-alloyed steel H220 Z100MBO, thickness a_0 = 0,80 mm, marked “M”,
- transformation-induced plasticity steel TRIP RAK40/70 Z100MBO, thickness a_0 = 0,75 mm, marked “T”.

Steel sheets ”M” and “T” were electrolytically galvanized on both sides, the zinc coating weight being 100 g/m^2 (designated as Z100MBO). Deep-drawing steel sheets “DC06 Y” and “DC06 Z” were also zinc-plated on both sides, the zinc coating weight being 75 g/m^2 (designated as BZE75/75PHOL).

Chemical compositions of experimental materials achieved by Spectrometer Belec Compact Port are (in %) materials ”DC06 Y” and ”DC06 Z”: C = 0,02; Mn = 0,25; P = 0,02; S = 0,02; Ti = 0,3; material ”M”: C = 0,004; Mn = 0,415; P = 0,042; S = 0,004; Ti = 0,037; Si = 0,1; Al = 0,035; Cr = 0,031; Cu = 0,011; Ni = 0,017; Nb = 0,026; Mo = 0,005; Zr = 0,007 and material ”T”: C = 0,204; Mn = 1,683; P = 0,018; S = 0,003; Ti = 0,009; Si = 0,2; Al = 1,73; Cr = 0,055; Cu =0,028; Ni=0,018; Nb=0,004; Mo=0,008; Zr=0,007.

Uniaxial tensile test

The test has been made on TIRA test 2300 according standards STN EN 10002-1+AC1 and STN 42 0321. The goal of test is to obtain values of basic mechanical characteristics yield point, ultimate tensile strength, elongation and value of normal anisotropy coefficient. Samples were taken under zero-, 45-, and 90-degree angle in relation to the direction of rolling. The number of test samples taken in each direction was three.

Measured and calculated values of experimental materials from uniaxial tensile test are shown in Tables 1 - 4.

Table 1 **Mechanical properties and normal anisotropy coefficient of DC06 Y steel**

Sample orient.	$R_{P0,2}$ / MPa	R_m / MPa	A / %	Δr
0°	138	277	53,0	0,288
45°	142	282	50,4	
90°	141	277	51,7	

Table 2 **Mechanical properties and normal anisotropy coefficient of DC06 Z steel**

Sample orient.	$R_{P0,2}$ / MPa	R_m / MPa	A / %	Δr
0°	145	292	50,9	0,576
45°	151	298	47,9	
90°	149	290	48,0	

Table 3 **Mechanical properties and normal anisotropy coefficient of M steel**

Sample orient.	$R_{P0,2}$ / MPa	R_m / MPa	A / %	Δr
0°	219	385	34,5	- 0,285
45°	225	368	37,4	
90°	238	383	35,8	

Table 4 **Mechanical properties and normal anisotropy coefficient of T steel**

Sample orient.	$R_{P0,2}$ / MPa	R_m / MPa	A / %	Δr
0°	442	771	27,7	- 0,108
45°	441	762	25,4	
90°	450	766	25,9	

Earring test for cups of inner diameter 69,15 mm

The earring test has been carried out for cylindrical cups with flat bottom. Cups of inner diameter 69,15 mm have been drawn from circular blanks of diameter 119; 123,5; 128; 133; 138 and 144 mm. The test has been evaluated from three tested samples of every kind of steel (”DC06 Y”, ”DC06 Z”, ”M” and ”T”) and of every blank diameter. An experimental drawing tool used for earring test had following parameters:

- punch diameter d_{te} = 71,25 mm,
- die diameter d_{tk} = 69,15 mm,
- die clearance t_m = 1,05 mm,
- punch radius r_{te} = 6,0 mm,
- die radius r_{tk} = 6,0 mm.

From individual blanks diameters have been drawn three cylindrical cups with flat bottom, whose height has been measured in eight measuring points around the perimeter of cup, namely in direction 0° two times, in direction 45° four times and in direction 90° twice. From the measured values (heights of cups) for specific direction and specific cup have been calculated the average values of heights in three measured directions. Furthermore, from the average heights of specific cups have been calculated the average values of cups drawn from the same blank diameter. Next from these values has been calculated the degree of earring ΔH for each tested material, using (3).

Dependence of earring degree on diameter of blank for cups of inner diameter 69,15 mm is shown in Figure 1.

The earring test has been realized for limit contact friction conditions – drawing without lubricant and drawing with lubricant. As a measuring instrument has been used digital slide gauge with accuracy 0,01 mm.

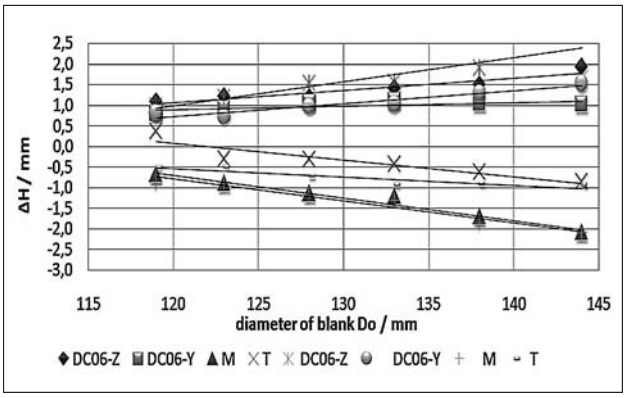

Figure 1 Dependence of earring degree on diameter of blank

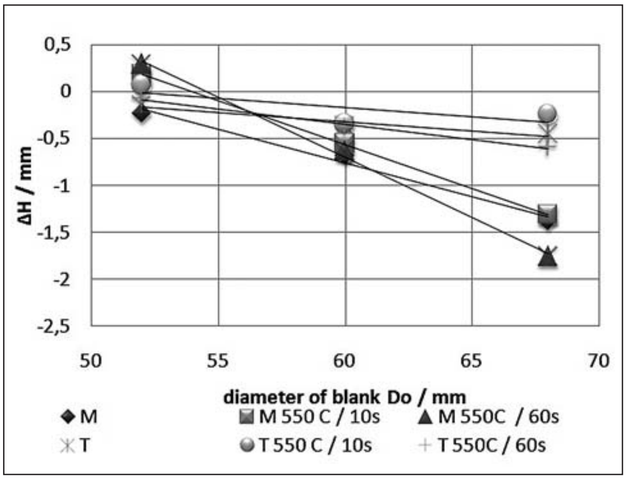

Figure 2 Dependence of earring degree on diameter of Blank

Earring test for cup of inner diameter 31 mm and the influence of annealing temepature on change of ears creation

The earring test has been carried out for cylindrical cups with flat bottom. Cups have been drawn from circular blanks of diameter 52, 60 and 68 mm. The test has been evaluated from three tested samples of every kind of experimental steel and of every blank diameter. Experimental work has been carried out on steels ”M” steel and ”T” steel.

An experimental drawing tool used for this test had following parameters:

- punch diameter d_{te} = 33 mm,
- die diameter d_{tk} = 31 mm,
- die clearance t_m = 1 mm,
- punch radius r_{te} = 4,5 mm,
- die radius r_{tk} = 6,0 mm.

The earring test has been realized for limit contact friction conditions – drawing with lubricant. Cups of inner diameter 31 mm in base state (unaffected by heat treating) have been compared with cups after annealing of Fe-Zn coating. Samples were cut from galvanized sheets and additionally heat treated in Nabertherm laboratory furnace with protective nitrogen atmosphere at temperature 550 °C for 10 and 60 seconds holding times. The temperature of samples was verified by a contacted thermocouple, after annealing samples were air-cooled [7].

The heights of cups have been measured in base state and after annealing at temperature 550 °C for 10 and 60 s holding times for both tested materials.

The measuring data have been statistically processing as well as cups of inner diameter 69,15 mm. Dependence of earring degree on diameter of blank for cups of inner diameter 31 mm is shown in Figure 2.

RESULTS AND DISCUSSION

The cups **of inner diameter 69,15 mm** made of steels DC06 Y and DC06 Z shown ears in directions 0° and 90° in relation to the direction of rolling. This fact is in agreement with calculated positive values of normal anisotropy coefficient Δr = 0,288 (Table 1) and Δr = 0,576 (Table 2). The cups made of M steel shown ears in direction 45° in relation to the direction of rolling, what is in agreement with calculated negative value of normal anisotropy coefficient Δr = - 0,285 (Table 3). The cups made of T steel shown ears in direction 45° in relation to the direction of rolling. Mentioned knowledge is in agreement with calculated negative value of normal anisotropy coefficient Δr = - 0,108 (Table 4).

From Figure 1 follows that value of earring degree ΔH increased with increasing blank diameter D_0 of steels DC06 Y and DC06 Z and decreased with increasing blank diameter D_0 of M steel and T steel.

The cups **of inner diameter 31 mm** made of M steel shown ears in direction 45° in relation to the direction of rolling, what is in agreement with calculated negative value of normal anisotropy coefficient Δr = - 0,285. After annealing there have been achieved higher absolute values of earring degree ΔH compared with the basic state. This fact we can consider to be unfavorable effect.

The cups made of *T* steel shown ears as well in direction 45° in relation to the direction of rolling, what is in agreement with calculated negative value of normal anisotropy coefficient Δr = - 0,108. After annealing at temperature T = 550 °C for 10 seconds holding time the absolute value of earring degree ΔH decreased but tendency of increase of height ears with increasing blank diameter D_0 stays. At temperature T = 550 °C for 60 seconds holding time (the absolute value of earring degree ΔH increased) and with increasing blank diameter D_0 there have been achieved higher values of earring degree ΔH compared with the basic state.

CONCLUSIONS

From measured and calculated values the following can be state **- the cups of inner diameter 69,15 mm:**

- Degree of earring ΔH calculated from (3) is in agreement with calculated number sign of normal anisotropy coefficient Δr. The values of earring degree ΔH of deep-drawing steels DC06 Y and DC06 Z are positive and of micro-alloyed steel *M* and transformation-induced plasticity steel *T* are negative.

- Calculated values of earring degree ΔH of deep-drawing steels DC06 Y and DC06 Z by drawing with using lubricant have been higher as by drawing without using lubricant. This fact we can consider to be unfavorable effect (higher ears). Calculated values of earring degree ΔH of micro-alloyed steel *M* and transformation-induced plasticity steel *T* by drawing with using lubricant have been lower as by drawing without using lubricant.

The cups of inner diameter 31 mm:

- Degree of earring ΔH calculated from (3) is in agreement with calculated number sign of normal anisotropy coefficient Δr. The values of earring degree ΔH of micro-alloyed steel M and transformation-induced plasticity steel T are negative. After annealing at temperature $T = 550°$ C for 10 seconds holding time the absolute value of earring degree ΔH decreased in comparison with the basic state. And after annealing at temperature $T = 550°$ C for 60 seconds holding time the absolute value of earring degree ΔH increased in comparison with the basic state. In the mentioned case the heat treatment of steel has a positive effect.
- From Figure 2 follows that value of earring degree ΔH decreased with increasing blank diameter D_0 of micro-alloyed steel *M* and transformation-induced plasticity steel *T*.

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