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The Comparison of Properties of Tinplates during Uniaxial and Biaxial Stress

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--**ABSTRACT**--
The majority of thin steel sheets is used to make of food covers, cans, capsules and other products, which are produced by metal forming. Concerning considerable changes in production of tinplates and still higher requests on their properties there is requirement to use such methods on their evaluation, which are able to determine especially mechanical and plastic properties of sheets quickly and with the low costs. Following of present know-how there were developed new testing methods, which correspond more to steel sheets stress during technological treatment (concerning their stress-strain state). In the contribution we deal with the comparison of properties of tinplates during uniaxial tensile test and biaxial tensile test.
Keywords: *Tinplates, uniaxial tensile test, biaxial tensile test*

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I. INTRODUCTION

Thin steel sheets with different surface treatments are finding in industry wider application for their properties compared with black steel sheets. It is necessary to develop new methods and methodic for evaluation of tinplates properties due to considerable changes in production of tinplates. From everyday problems which build up between customers and producers of these sheets we can affirm that none of use test methods and methodic are suitable for evaluation of all kinds and qualities at currently produced tinplates. At currently produced sheets are characterized by a large range of mechanical properties, plastic properties and thicknesses. We can affirm that methods and methodic which are used for evaluation of sheets of thicknesses above 0.25 mm cannot be identical with methods and methodic for evaluation of tinplates thicknesses 0.14 – 0.18 mm, which are produced by process of double rolling. Therefore we try to develop an optimum methods for evaluation of tinplates for different qualities and thicknesses and at different stress-strain states. The results of these methods should lead to the establishment of relations between results from different tests.

II. EXPERIMENTAL MATERIAL AND METHODS

Thin tinned sheets produced by simple rolling (TS 275 BA, TS 260 BA and TS 480 BA) batch annealing and double reduced (TH 550 CA and TH 620 CA) continual annealing and batch annealing (DR 550 BA) have been used for experimental research. Material, thicknesses and number of samples are shown in Table 1.

Table 1: Experimental material

Material	Thickness of sample [mm]	Number of sample
TS 275 BA	0.28	32
TS 260 BA	0.17	86
	0.18	25
TS 480 BA	0.157	73
	0.157	74
TH 550 CA	0.155	46
	0.155	47
	0.155	4
TH 620 CA	0.152	72
	0.152	90
DR 550 BA	0.14	12

In the Fig. 1 is shown sample of DR tinplate in unetched state. In the center of the sample is rolled visible impurities.These impurities greatly influence the mechanical properties. From the results of the uniaxial tensile test the elongation considerably decreasing. Typical structures of materials of double reduced tinplates continual annealing (Fig. 2) and batch annealing (Fig. 3) are shown in the Fig. 2 and 3.

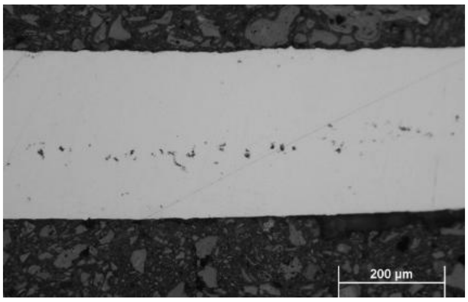


Figure 1: The sample with inside impurities

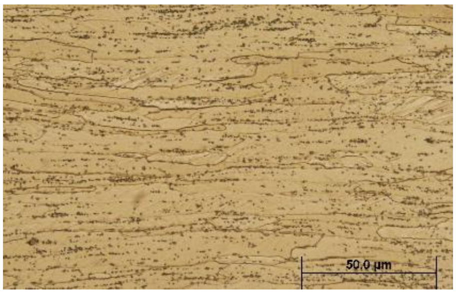


Figure 2: The microstructure of DR CA sheet

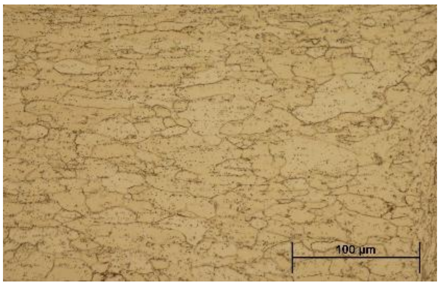
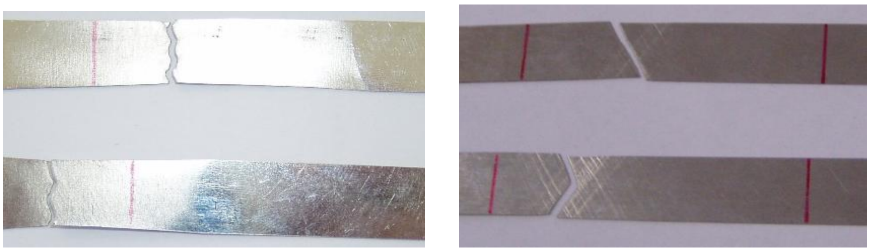


Figure 3: Defective annealed structure of DR BA sheet

III. UNIAXIAL TENSILE TEST

The low carbon steels suitable for forming are generally judged by the behaviour in uniaxial stress state, i. e. by the results from the uniaxial tensile test. The objective of the test is to obtain values of basic mechanical characteristics of yield strength, of ultimate tensile strength and elongation. The conditions and the shape of the test sample indicate standards STN EN 10002-1+ AC1 and STN 42 0321.The samples in rolling direction 0° and perpendicular direction 90° in respect of rolling direction have been taken for the uniaxial tensile test to determine of anisotropic properties of tested material. Examples of breaking of samples are shown in the Fig. 4a), b). From the figure is clear that during uniaxial tensile test is tends to increase inhomogeneity of plastic deformation. Plastic deformation does not pass in whole measured area of tested sample. Considerable part of measured area is non-deformed. Breaking of double reduced tinplates during the uniaxial tensile test is significantly different from breaking of simple rolled sheets. Breaking is carried out in two ways; either it spreads perpendicularly to the axis of sample (Fig. 4a) or it spreads at an angle of 45° (Fig. 4b).



a) b)

Figure 4: Samples after uniaxial tension test

a) sample is breaking perpendicularly to the axis of sample

b) sample is breaking at angle of 45°

In the Fig. 5 and 6 is shown characteristic manner of plastic deformation in the samples taken perpendicular to the rolling direction (Fig. 5) and in the rolling direction (Fig. 6). The deformation propagates at an angle of 45° in samples taken in the direction of rolling. In samples taken in a direction perpendicular to the rolling direction are boundaries between deformed and non-deformed area of the test sample very significant. Breaking of the sample is due to microcracs, arising from the edge of the test sample.

Figure 5: Inhomogeneity of plastic deformation

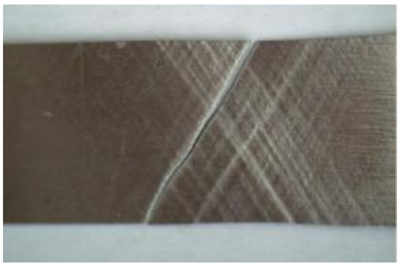


Figure 6: Slip bands

IV. BIAXIAL TENSILE TEST

Biaxial tension is to the most unfavorable schema of stress by plastic deformation of material. It is preferred, therefore, to use this method of sheet stress when considering plastic properties of sheets. Biaxial tensile stress of the material very well simulated the hydraulic test of biaxial tensile test, also called a bulge test (next the biaxial tensile test).In the biaxial tensile test have been used the same materials as in the uniaxial tensile test.The principle of the test consists in bulging sample tested sheet (130x130mm) delivered by a hydraulic fluid under pressure. The tested sheet is firmly tightened between the lower plate and the draw die with a diameter of 80 mm. The force of blankholder can be regulated using a valve. The flange prevents the draw-in of the sample material by means of the stopping rib disposed in the draw die, which consists of a jut on the blankholder and a corresponding groove on the other side. The lancing pressurized fluid bulging tested sheet until breaking (Fig. 7). The criterion of the plastic properties of the tested sheet is the height of spherical cap in breaking of sheet, the form of crack after breaking and surface of a spherical cap. From the test have been evaluated: yield of strength, ultimate tensile strength (after breaking of sample), height of bulging and total deformation by breaking of sample. Plastic properties of tested sheet have been expressed by the so-called “Elongation” by biaxial tensile test.

$$"Elongation" = \frac{l - l_0}{l_0} * 100 \quad (1).$$

The measured signals are through of technological card and own software program worked into the graphic relation “stress-strain”. From the diagram it is possible to read the size of stress and strain at any point in the diagram. In the Fig. 8a), b) show the relations between the stress and strain of sheets quality TS 275 BA and DR 550 BA.

Figure 7: Samples after bulge test

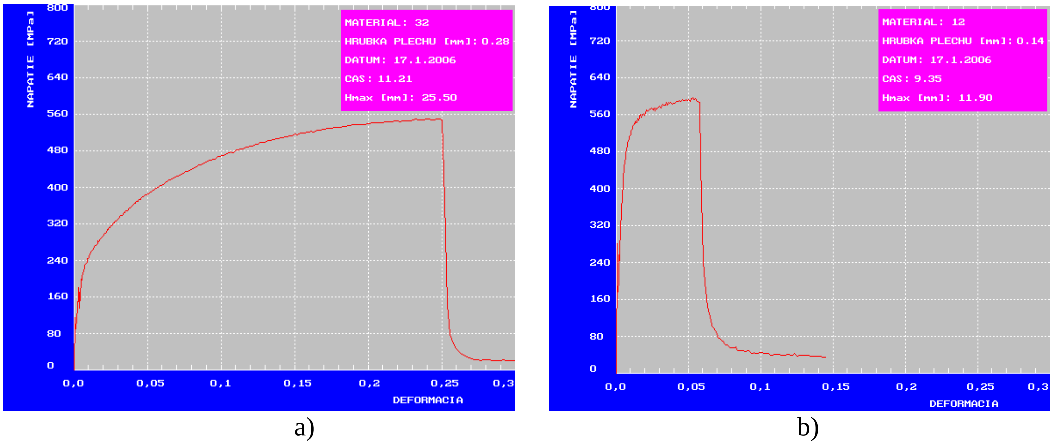


Figure 8: The relation between the stress and strain
a) of material TS 275 BA, thickness 0.28 mm
b) of material DR 550 BA, thickness 0.14 mm

In the Fig. 9 is show the microstructure of DR tinplates before plastic deformation and after biaxial tensile test.

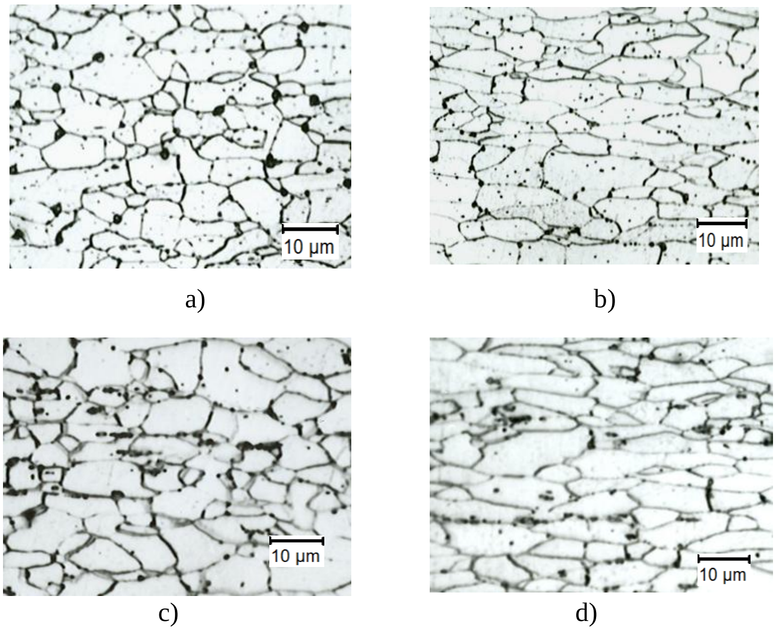


Figure 9: Microstructures of DR tinplates
a) microstructure of DR CA tinplate before plastic deformation
b) microstructure of DR CA tinplate after biaxial tensile test
c) microstructure of DR BA tinplate before plastic deformation
d) microstructure of DR BA tinplate after biaxial tensile test

V. RESULTS AND DISCUSSION

The measured results of the mechanical properties of the uniaxial and biaxial tensile test are shown and compared in the Fig. 10 to 12. From the above figures can be affirmed that materials TS 275 BA and TS 260 BA significantly in properties differed from the other four investigated qualities. The measured values of yield strength of materials TS 275 BA and TS 260 BA obtained from uniaxial tensile test are significantly lower as values obtained from biaxial tensile test. In most of other studied materials opposite is true.The values of tensile strength of materials TS 275 BA and TS 260 BA from the uniaxial tensile test are also lower in comparison with result from biaxial tensile test. In most of other studied materials opposite is true. From the measured results of elongation we can affirmed that for materials TS 275 BA and TS 260 BA was obtained very high value of elongation (about 35%) from the uniaxial tensile test and significantly lower value of elongation (over 20%) from biaxial tensile test. In another tested materials the values of elongation were significantly higher from biaxial test than from uniaxial tensile test, with the exception of sample no. 73. It is not possible to compare results obtained from uniaxial and biaxial test.

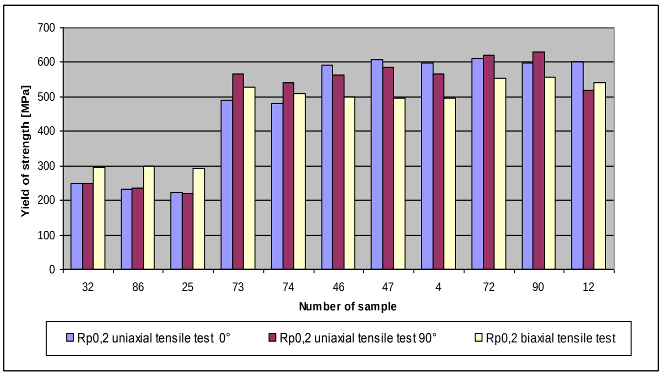


Figure 10: Comparison of yield strength by uniaxial tensile test in direction 0° and in direction 90° and yield of strength by biaxial tensile test

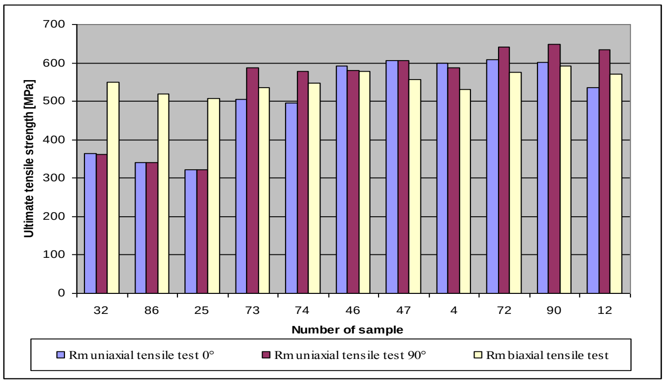


Figure 11: Comparison of ultimate tensile strength by uniaxial tensile test in direction 0° and in direction 90° and ultimate tensile strength by biaxial tensile test

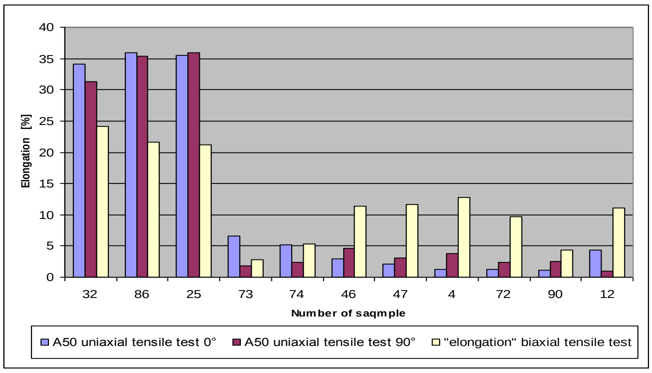


Figure 12: Comparison of elongation A_{50} by uniaxial tensile test in direction 0° and in direction 90° and „elongation" by biaxial tensile test

VI. CONCLUSION

In the contribution have been compared the mechanical properties of tinplates during uniaxial and biaxial stress. From the results of this the most commonly used tests, it can be clearly concluded that it cannot be compared single test results, which have been chosen with different stress-strain states.The measured plastic properties from biaxial tensile test are lower compared with results from uniaxial tensile test at materials with very good values of elongation of 30% (TS 275 BA and TS 260 BA). At another tested materials the values of elongation at biaxial tensile test were higher as values from uniaxial tensile test. This fact can be explained by the fact that the result of the measured elongation from uniaxial tensile test is considerable influenced by production of tested sample (geometry and microgeometry). In many of these materials the plastic deformation has been not developed on the whole measured length even at very low strain rates. The measured values of yield strength, tensile strength and elongation have a very large variance during uniaxial tensile test. For these reasons we do not recommended the uniaxial tensile test use for determination of the mechanical and plastic properties of double reduced tinplates.

VII. ACKNOWLEDGEMENTS

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VIII. BIOGRAPHIES AND PHOTOGRAPHS

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