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TIN COATING ON A STEEL SHEET AND ITS INFLUENCE ON BASIC MECHANICAL PROPERTIES REGARDLESS OF SAMPLE ORIENTATION

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ABSTRACT

This contribution deals with influence of tin coating on steel sheet mechanical properties. A sheet 0.16 mm thick provided with electrolytically applied tin coating of 2.0/2.0 gm^{-2} surface weight was used for experiments. This sheet was manufactured by U.S. STEEL in Košice and marked as DR 580 with the stone finish surface. Mechanical properties of coated and uncoated sheets were examined. Attention was paid to tensile strength, yield point and deep-drawing quality.

1. INTRODUCTION

Development of progressive technologies is directed by utilisation of new materials taking into account their surface finish. Very thin tin-coated sheets belong to these new materials. Tin, under certain circumstances, is exceptionally able to create insoluble layers of stannic oxide SnO_2 and stannous oxide SnO on its surface. That is why it is resistant to atmosphere and water impacts. Stannic oxide SnO_2 crystallises in the tetragonal system and is very brittle. If the applied tin coating is homogenous and non-porous, it can provide anodic protection by so called self-dissolution. Considering tin compatibility with health, goodsolderability and chemical resistance, very thin tinned steel sheets can be used on a large scale especially in foodstuffs industry [1, 2, 3, 4]. Research of selected type of the very thin 0.16mm tinned sheet, manufactured by double reduction on a rolling stand, requires to monitor, under determined conditions of a tensile test, effect of electrolytically applied tin coating on mechanical properties of examined tinned and non-tinned steel sheets.

2. MATERIAL TESTED

The 0.16 mm thick sheet with double-sided electrolytically applied tin coating of surface weight 2.0/2.0 gm^{-2} was used for experiments.
The sheet marked DR 580, CA, STONE FINISH was supplied by U.S. STEEL spol. s r.o. Košice.

To find out influence of tin coating on mechanical properties of the selected thin steel sheet, set of samples nos. 1 to 12 was prepared. Samples nos. 1 to 6 were chemically deprived of tin coating using solution of hydrochloric acid and antimony oxide in ratio: HCL – 500 ml and Sb_2O_3 – 10g. The tested sample was dipped in prepared solution until end of gas bubbles liberation. The test was performed in compliance with ČSN 160201. After dissolution of the tin coat, the sample was removed from the bath, rinsed with water and dried out.
Tin coats for samples nos. 7 to 12 were preserved in original supplied condition.

Experiment Course and Results

Mechanical properties of the selected sheet sample of nominal 0.16 mm thickness, provided with tin coating of 2.0/2.0 $g.m^{-2}$ surface weight, were determined by the tensile test performed on the TIRA TEST 2300 testing machine [5].

Tensile test conditions:
Crosspiece movement speed was 5 mm/min, width of the flat testing bar was 20 ± 0.1mm and other test parameters were consistent with ČSN EN 10002-1. Temperature in laboratory was 20 °C.

Results of tensile tests for flat bars 20 ± 0.1mm wide and 0.16mm thick are summarised in Table 1.
Table 1 - Results of tensile tests for samples nos. 1 to 12.

a) Samples nos. 1 to 6 after tin coating removal

Sample no.	$R_{p0.2}$ [MPa]	Rm [MPa]	A_{80} [%]
1	556	587	3.30
2	547	581	3.35
3	553	582	3.75
4	556	586	3.52
5	554	582	3.56
6	551	587	4.38

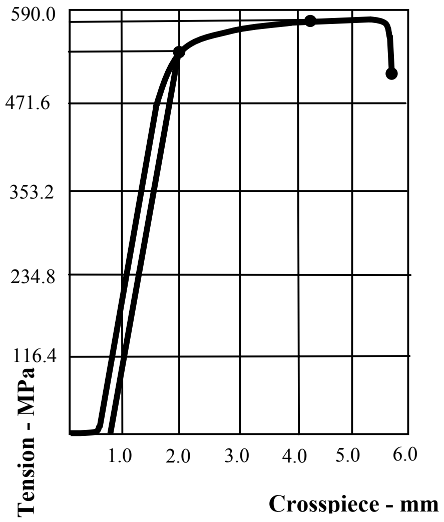
Tensile strength mean value for examined set of samples Rm = 584.17 MPa and standard deviation σ_{Rm} = 2.54 MPa.
Contractual yield point mean value $Rp_{0,2}$ =552.83 MPa and $\sigma_{Rp0.2}$ = 3.13 MPa.
Deep-drawing quality mean value A_{80} = 3.64 % and σ_{A80} = 0.36%.

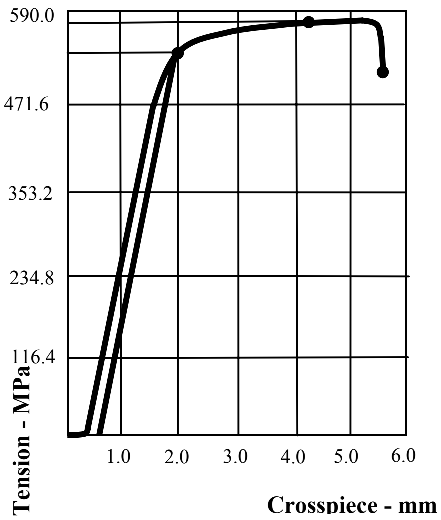
b) Samples nos. 7 to 12 tin-coated

Sample no.	$R_{p0.2}$ [MPa]	Rm [MPa]	A_{80} [%]
7	560	588	3.87
8	557	587	4.00
9	558	589	3.63
10	555	586	3.25
11	558	587	3.52
12	555	585	3.51

Mean values of mechanical properties incl. standard deviations are as follows:
Rm = 587 MPa (σ_{Rm} = 1.29 MPa)
$Rp_{0,2}$ =557.17 MPa ($\sigma_{Rp0.2}$ = 1.77MPa)
A_{80} = 3.63 % (σ_{A80} = 0.25%)

Figures 1a and 1b show tensile test records for selected tinned and non-tinned steel samples.
*Note: The tensile test was performed immediately after sheet supply.





3. COAT SURFACE MORPHOLOGY

Morphology of tinned surfaces was evaluated by means of the TESCAN VEGA Plus TS 5135 MM electron microscope in BSE reflected electrons and RESOLUTION modes, at electron beam accelerating voltage of 30 kV and 250-fold magnification. Figure 2 illustrates morphology of the "freshly" tinned surface and Figure 3 shows morphology of the tinned surface exposed to impacts of air oxidation for one year. At first sigh both samples differ in size and rate of abundance of surface formations with average size in tens of microns for the sample in Figure 2 and up to hundreds of microns for the sample in Figure 3.

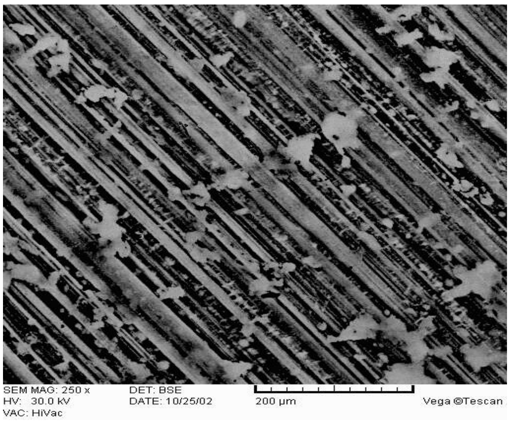


Fig 2 Morphology of the newly-prepared tin coat.

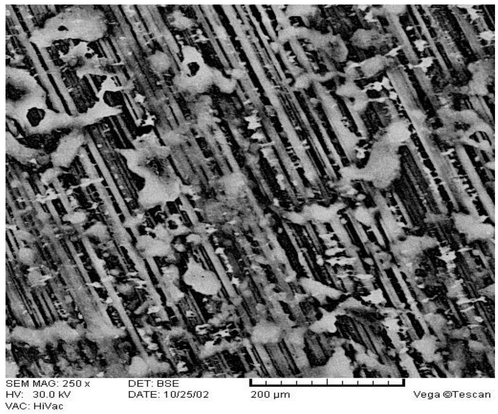


Fig 3 Morphology of the tinned surface exposed to impact of air oxidation for one year.

Results obtained from previous experiments proved that thickness of the tin-oxide layer on the tin-coat surface increases together with extending exposure time of atmospheric oxidation and morphology of the coat surface changes simultaneously [6]. These coats, provided with the surface layer of oxides, can be used to increase adhesion when applying varnishes, mastics, bonding cements and the like.

In addition, the Erichsen recess value technology test was performed and a through crack appeared in depth of IE = 4.32 ± 0.38 mm across the spherical cap recess in non-tinned samples.

Depth of IE = 4.77 ± 0.42 was detected in tinned sample set. The used drawbar was ended with a sphere 20 mm in diameter in compliance with ČSN EN ISO 20 482, edited by ČNI in 2004. The Erichsen recess index was determined by the HEIDENHAIM VRZ 102.002 measuring panel that is the complementary item to the ERICHSEN F-4 testing device. Measuring panel differentiability was 0.001 mm. Figure 4 shows the selected sample with a crack.

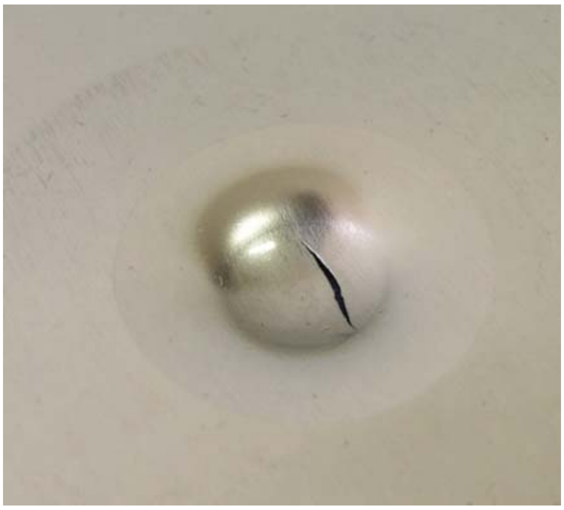


Fig 4 Crack shape

4. CONCLUSION

Within the experiment, the selected very thin sheet, thickness 0.16 mm, provided with both-sided tin coat of minimum surface weight 2.0/2.0 gm^{-2}, was examined using the tensile test. Further, the same samples were tensile-tested after removal of the tin coat from the steel sheet. Experiment results confirmed the fact that presence of the electrolytically applied tin coat on the steel sheet in practice does not improve basic mechanical properties, such as tensile strength, yield point and deep-drawing quality. As for tinned samples, the mean value Rm was higher by 2.83 MPa and there was contractual yield point difference $Rp_{0,2}$ = 4.34 MPa for the benefit of the tinned sheet, which is increase by 0.74 %, i.e. less than 1 %. The situation is nearly the same in case of the contractual yield point difference – increase amounts to 4.34 MPa, which is 0.785 %, i.e. less than 1 %.

The similar value differences were discovered for deep-drawing quality in case of tinned and non-tinned steel sheets. Available specialised literature does not include research on influence of tin coat on thin steel sheet mechanical properties and experiment results confirmed negligible effect of the electrolytically applied tin coat on final values of tensile strength, yield point and deep-drawing quality.

Deep-drawing quality of tinned sheets was examined using the Erichsen technology test and the difference between tined and non-tinned sample sheets was 0.45 mm, which is insignificant difference taking into account value dispersion when measuring deep-drawing quality of sheets. Further it was discovered that the tensile curve course for tinned sheets is similar to that for uncoated sheets and that both curves do not differ in shape.

5. REFERENCES

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***Note*: This contribution comprises partial results of the MSM 262100003 research intention "Development of Progressive and Very Precise Engineering Technologies" solved by FSI VUT in Brno.**

OSLOJAVANJE ČELIČNOG LIMA I NJEGOV UTICAJ NA OSNOVNE MEHANIČKE OSOBINE LIMA, BEZ OBZIRA NA ORIJENTACIJU

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REZIME

Rad se bavi istraživanjem uticaja nanesenog tankog sloja na mehaničke osobine čeličnog lima. U eksperimentalnom delu istraživanja korišćen je čelični lim debljine 0,16mm na koji je elektrolitičkim putem na obe strane nanese sloj (2./2.0 gm^{-2}). Materijal: DR580, CS, Stone Finish (U.S. Steel-Košice). ukupan broj uzoraka: 12.
Mehaničke osobine navedenog lima bile su određene pomoću test mašine TIRA TEST 2300. Eksperimenti su sprovedeni na sobnoj temperaturi. Rezultati koji su dobijeni prikazani su u donjoj tabeli:

Uzorak br.	$R_{p0.2}$ *[MPa]*	*Rm [MPa]*	A_{80} *[%]*
1	*556*	*587*	*3.30*
2	*547*	*581*	*3.35*
3	*553*	*582*	*3.75*
4	*556*	*586*	*3.52*
5	*554*	*582*	*3.56*
6	*551*	*587*	*4.38*
7	*560*	*588*	*3.87*
8	*557*	*587*	*4.00*
9	*558*	*589*	*3.63*
10	*555*	*586*	*3.25*
11	*558*	*587*	*3.52*
12	*555*	*585*	*3.51*

Osnovni rezultat rada je taj da je uticaj nanešenog sloja na čelični lim nesignifikantan tj. da se može zanemariti. Isti zaključak se može izvesti i kada je u pitanju duboko izvlačenje.