E. SPIŠÁK, J. SLOTA, T. KVAČKAJ, A. BOBENIČ

ISSN 0543-5846
METABK 45 (1) 45-49 (2006)
UDC - UDK 669-413:621.771.23=111

THE INFLUENCE OF TANDEM MILL REDUCTION ON DOUBLE REDUCED (DR) TINPLATES ANISOTROPY

Received - Primljeno: 2004-12-29
Accepted - Prihvaćeno: 2005-04-05
Preliminary Note - Prethodno priopćenje

In this paper, influence of tandem mill reduction on double reduced tinplates anisotropy is presented. In order to achieve favourable anisotropy properties (deformation texture) of tinplates for deep drawing operations, optimal percentage reduction on tandem mill is important. The experiment was carried out in laboratory conditions and three sorts of materials (T 57, T 61 and T 65) were used. The anisotropy was classified by earing test determining the ear height of tinplate after deep drawing by measuring the height of any ear. Percentage reduction on tandem mill and final earing relationships of tinplates are researched.

Key words: *earing, double reduced tinplate, anisotropy, thickness reduction*

Utjecaj redukcije u tandem stanu na anizotropiju bijelog lima pri dvostrukoj redukciji. U ovom radu je prikazan utjecaj redukcije tandem stana na anizotropiju bijelog lima pri dvostrukoj redukciji. Da se dobiju povoljna anizotropska svojstva (deformacija teksture) bijelog lima za dvostruko izvlačenje važan je optimalan postotak redukcije u tandem stanu. Pokus je izveden u laboratorijskim uvjetima s tri vrste materijala (T 57, T 61 i T 65). Anizotropija se slagala ispitivanjem uški tako da im je određena visina na limu nakon dubokog izvlačenja i postotak redukcije na tandem valjcima i izmjerom visine svakog uha. Istražen je postotak redukcije na tandem valjaonici i završnog odnosa izvlačenja.

Ključne riječi: *izvlačenje, dvostruko reducirani bijeli lim, anizotropija, redukcija debljine*

INTRODUCTION

Tinplates are used for food packaging, cans, crown caps and other packaging products and still appertain to required materials. They have a low weight, good mechanical properties - strength, stiffness, good weld-ability, required formability, good anticorrosion properties, etc. Regarding to tinplates production and technology, there are several technologies for various tempers. Good tinplate properties depend not only on continual casting, which provides steel with homogenous chemical composition and structure. The continual annealing including ageing unit at about 450 °C temperature, which enables to produce almost ageless material suitable for deep drawing operations with wall ironing (DWI = drawn and wall - ironed) for cans production. The materials with double reduction (DR = double reduction) are much inquired and very favourable in last years. Application of DR tinplates relates to thickness reduction and increasing strength properties [1 - 6].

E. Spišák, J. Slota, Faculty of Mechanical Engineering Technical University of Košice, Košice, Slovakia, T. Kvačkaj, Faculty of Metallurgy Technical University of Košice, Košice, Slovakia , A. Bobenič, US Steel Košice, Slovakia

Table 1. **Chemical composition of materials T 57, T 61 and T 65**
Tablica 1. **Kemijski sastav materijala T 57, T 61 i T 65**

Temper	C / %	Mn	Si max	P max	S max
T 57	0,06 – 0,08	0,35 – 0,45	0,02	0,015	0,015
T 61	0,03 – 0,05	0,12 – 0,19	0,02	0,015	0,012
T 65	0,06 – 0,08	0,20 – 0,37	0,03	0,02	0,018

Temper	Al	N max	Cu max	Ni max	Cr max	As max
T 57	0,025 – 0,055	0,006	0,06	0,03	0,045	0,010
T 61	0,030 – 0,060	0,006	0,06	0,03	0,045	0,010
T 65	0,030 – 0,060	0,007	0,06	0,03	0,045	0,010

For achieving favourable deformation texture in deep drawing operations, the optimal percentage reduction on tandem mill and initial steel sheet thickness before second reduction, is important. These parameters are especially important because they influence final cups earing, therefore, this paper is primarily oriented on the effects mentioned above [7 - 11].

EXPERIMENTAL WORK

The materials used in the present investigation are listed in Table 1. In this work, tinplates of tempers T 57 (T3), T 61 (T4) and T 65 (T5) were used. These tempers were made from low-carbon steel. The chemical composition is given in Table 1. and mechanical properties are presented in Tables 2., 3. and 4. DR tinplates of all tempers from above mentioned steel sheets are produced on tandem mill.

Table 2. **Mechanical properties and thicknesses of tinplates T 65 CA**
Tablica 2. **Mehanička svojstva i debljine bijelih limova T 65 CA**

Sample	Temper	t_0 / mm	t_1 / mm	ε_{SVa} / %	$R_{p0,2}$ / MPa	R_m / MPa	A_{50} / %
A	T - 65	0,280	0,280	0,0	383	410	27,7
A1	T - 65	0,280	0,265	5,4	445	456	2,1
A2	T - 65	0,280	0,250	10,7	503	511	6,3
A3	T - 65	0,280	0,240	14,3	529	533	4,1
A4	T - 65	0,280	0,220	21,4	571	587	2,1
A5	T - 65	0,280	0,210	25,0	594	598	1,5

Mechanical properties (Tables 2., 3., 4.) of used materials were determined by means of the conventional tensile test. Standardised mechanical properties of tinplates are

Table 3. **Mechanical properties for tinplates T 61 CA**
Tablica 3. **Mehanička svojstva bijelih limova T 61 CA**

Sample	Temper	t_0 / mm	t_1 / mm	ε_{SVa} / %	$R_{p0,2}$ / MPa	R_m / MPa	A_{50} / %
B	T - 61	0,230	0,230	0,0	405	419	15,0
B1	T - 61	0,230	0,220	4,3	463	478	3,9
B2	T - 61	0,230	0,200	13,0	-	566	0,0
B3	T - 61	0,230	0,195	15,2	544	547	2,6
B4	T - 61	0,230	0,185	19,6	556	565	2,2
B5	T - 61	0,230	0,173	24,8	-	620	0,1

Table 4. **Mechanical properties for tinplates T 57 BA**
Tablica 4. **Mehanička svojstva bijelih limova T 57 BA**

Sample	Temper	t_0 / mm	t_1 / mm	ε_{SVa} / %	$R_{p0,2}$ / MPa	R_m / MPa	A_{50} / %
F	T - 57 BA	0,220	0,220	0,0	257	379	32,2
F1	T - 57 BA	0,220	0,174	20,5	487	493	2,5
F2	T - 57 BA	0,220	0,164	29,5	509	517	3,1
F3	T - 57 BA	0,220	0,138	40,0	553	568	3,2
F4	T - 57 BA	0,220	0,115	50,0	576	597	1,7

defined in EN 10 202/2001. These tinplates were processed via continual and batch annealing. All of the steels were produced industrially.

Thickness reductions were realised by tandem mill DUO 210 under laboratory conditions. The samples were deformed with various percentage reductions (see Tables 2., 3., 4.). All experiments were performed at room temperature.

THE EARING TEST

The earing test is a method for determining the ear height of metal sheet and strip of nominal thickness from 0,1 mm to 3 mm after deep drawing by measuring the height of any ear. This test characterizes tensile-pressure stresses. The results of the test are significant mainly for cylindrical axial -symmetric cups [2, 3].

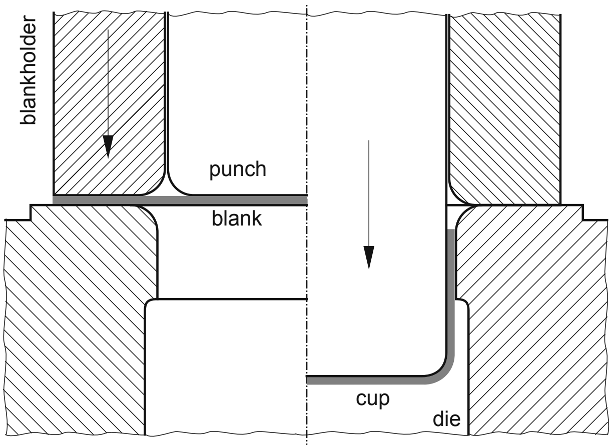

Figure 1. **Principle of the earing test**
Slika 1. **Princip pokusa izvlačenja**

The test principle is visible on Figure 1. The experiments determining anisotropy for all the tempers studied

Figure 2. **Drawn cups of tinplate for determining the ear height**
Slika 2. **Izvučene probe od bijelog lima za određivanje visine izvlačenja**

were carried out on experimental tool for earing test in The universal material-testing machine ZD-40 with specimens

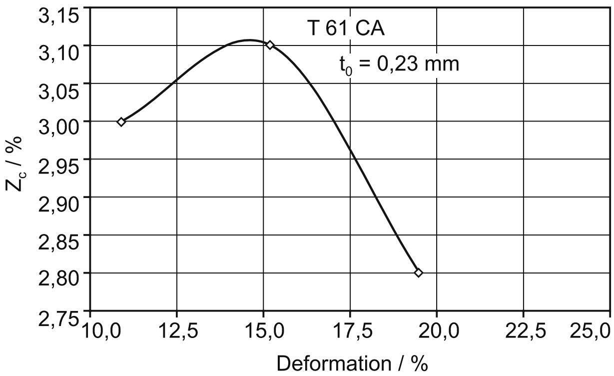

Figure 3. **Influence of tandem mill reduction on earing coefficient Z_c of the T61 temper with initial thickness t_0 = 0,23 mm**
Slika 3. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja Z_c materijala T 61 s početnom debljinom t_0 = 0,23 mm**

of circular shape. Specimens were deformed by a rigid punch with cylindrical shape. The punch diameter was 33 mm and the punch speed was 0,8 mm·s^{-1}. For each temper,

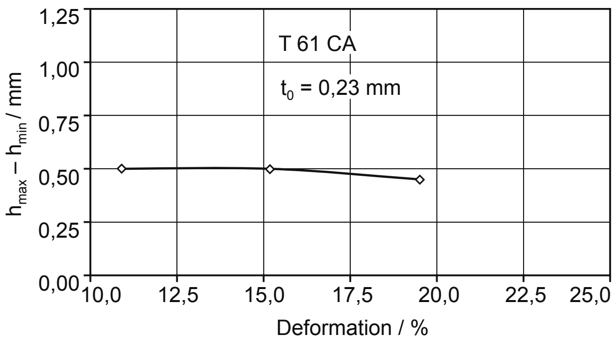

Figure 4. **Influence of tandem mill reduction on the value $h_{max} - h_{min}$ of the T61 temper with initial thickness t_0 = 0,23 mm**
Slika 4. **Utjecaj redukcije u tandem valjaonici na koeficijent izvlačenja $h_{max} - h_{min}$ materijala T 61 s početnom debljinom t_0 = 0,23 mm**

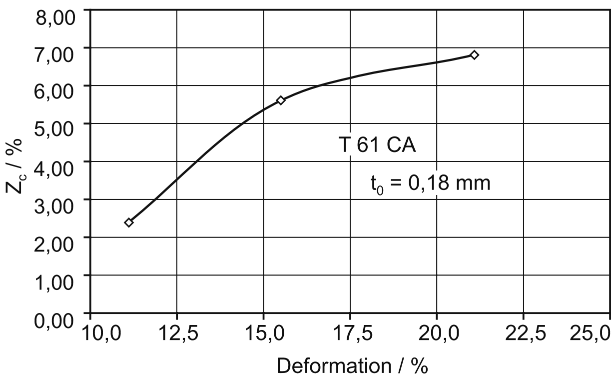

Figure 5. **Influence of tandem mill reduction on earing coefficient Z_c of the T61 temper with initial thickness t_0 = 0,18 mm**
Slika 5. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja Z_c materijala T 61 s početnom debljinom t_0 = 0,18 mm**

minimum 5 cups were drawn at each reduction and then mean value was calculated and putting into graph. This test enables to recognize the tendency to earing and slip line occurring.

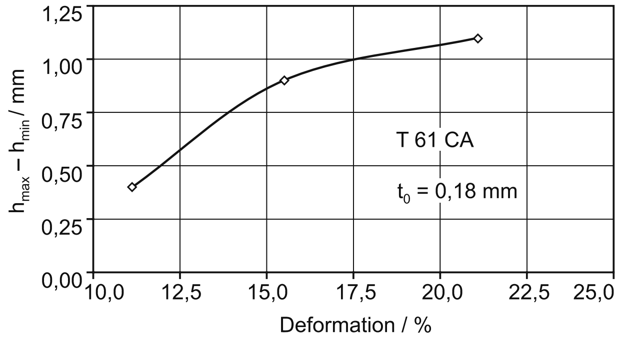

Figure 6. **Influence of tandem mill reduction on the value $h_{max} - h_{min}$ of the T61 temper with initial thickness t_0 = 0,18 mm**
Slika 6. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja $h_{max} - h_{min}$ materijala T 61 s početnom debljinom t_0 = 0,18 mm**

The formulae for calculating the cup earing can be given in the form:

$$\Delta h_{max} = h_{max} - h_{min} \quad (1)$$

$$Z_c = \frac{h_{max} - h_{min}}{h_{min}} \times 100 \ /\% \quad (2)$$

Maximum and minimum cup's height have been measured by digital micrometer with 0,01 mm accuracy. The results of earing test are documented on Figure 3. till Figure 10.

RESULTS AND DISCUSSION

Evaluation of tandem mill reduction on tinplates anisotropy (earing)

T 61 CA

The higher deformation the higher earing coefficient. For lower initial sheet thickness before DR, the earing is higher. The influence of tandem mill reduction on DR tinplates anisotropy (earing): The higher intensity of deformation the higher absolute values of maximum and minimum difference $h_{max} - h_{min}$ [mm] are. For initial thickness t_0 = 0,230mm the values $h_{max} - h_{min}$ for all deformation grades are convenient.

T 65 CA

The influence of tandem mill reduction on earing coefficient Z_c is following: The higher intensity of deformation the higher earing coefficient Z_c is, independently on initial thickness. As Figures 7. and 8. shows the earing is suitable at deformation about 12 %.

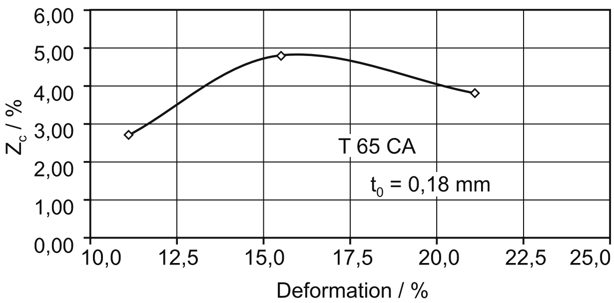

Figure 7. **Influence of tandem mill reduction on earing coefficient Z_c of the T65 temper with initial thickness t_0 = 0,18 mm**
Slika 7. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja Z_c materijala T 65 s početnom debljinom t_0 = 0,18 mm**

T 57 BA

Results indicate that the earing coefficient Z_c is comparable with continual annealing tinplates also in double higher reductions. Figures 9. and 10. shows that maximum and minimum difference $h_{max} - h_{min}$ of cup ears is suitable at

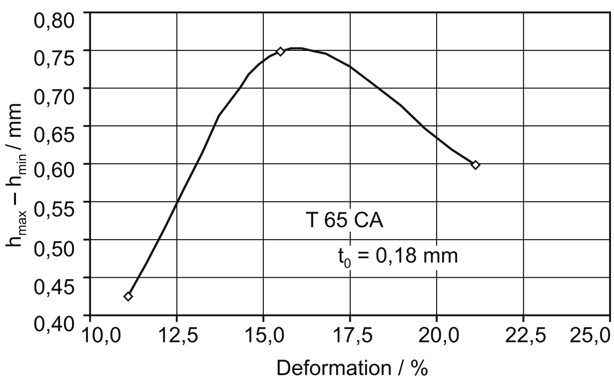

Figure 8. **Influence of tandem mill reduction on the value $h_{max} - h_{min}$ of the T65 temper with initial thickness t_0 = 0,18 mm**
Slika 8. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja $h_{max} - h_{min}$ materijala T 65 s početnom debljinom t_0 = 0,18 mm**

deformation up to 25 % for soft tempers (batch annealing). With reduction about 40%, drawing cups fail for higher initial thickness. It is assumed that the second reduction decrease tinplates formability.

Evaluation of the influence of tandem mill reduction on mechanical properties of tinplates

T 61 CA

To achieve the standardised mechanical properties of DR tinplates- temper T61 CA, the percentage reductions from 12 to 24 % for all investigated initial tinplates thicknesses are required.

T 65 CA

As resulting from Figures 7. and 8., to achieve the standardised mechanical properties of DR tinplates - temper T65 CA, the percentage reductions from 11 to 23 % for all investigated initial tinplates thicknesses are required.

T 57 BA

As resulting from Figures 9. and 10., to achieve the standardised mechanical properties of DR tinplates - temper

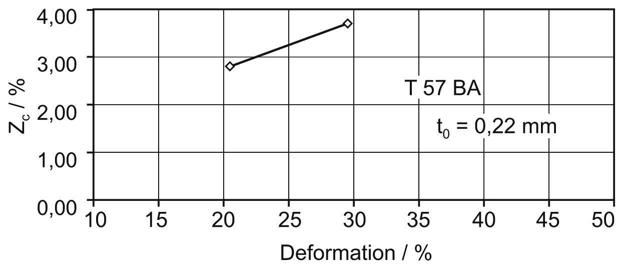

Figure 9. **Influence of tandem mill reduction on earing coefficient Z_c of the T57 temper with initial thickness t_0 = 0,22 mm**
Slika 9. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja Z_c materijala T 57 s početnom debljinom t_0 = 0,22 mm**

T57 BA, the percentage reductions from 35 to 40 % for all investigation initial tinplates thicknesses are required.

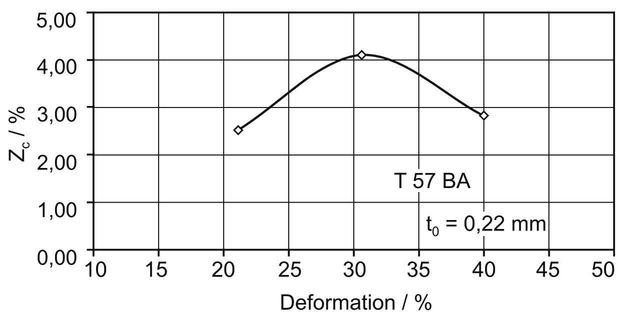

Figure 10. **Influence of tandem mill reduction on the value $h_{max} - h_{min}$ of the T57 temper with initial thickness t_0 = 0,22 mm**
Slika 10. **Utjecaj redukcije u tandem stanu na koeficijent izvlačenja $h_{max} - h_{min}$ materijala T 57 s početnom debljinom t_0 = 0,22 mm**

Some mechanical properties such as R_m as well as A_{50} are not strictly defined, they are only recommended, but experiments show certain correlation between R_{p02} and R_m.

To achieve suitable mechanical properties R_{p02}, R_m after second reduction on tandem mill, following percentage reductions should be kept:

- T 61 CA for DR520 12 % deformation is required,
  for DR550 15 % deformation is required,
  for DR580 19 % deformation is required,
  for DR620 24 % deformation is required,
- T 65 CA for DR520 11 % deformation is required,
  for DR550 15 % deformation is required,

for DR580 18 % deformation is required,
for DR620 23 % deformation is required,
- T 57BA for DR520 and DR550, 35 % deformation is required.

CONCLUSIONS

In this paper, the influence of tandem mill reduction on DR tinplates anisotropy (earing) is determined. Results indicate that the final anisotropy properties of double reduced tinplates significantly depend on the percentage reduction of tandem mill.

Experimental results and their analysis show:

1. The influence of tandem mill reduction on DR tinplates anisotropy (earing): The higher intensity of deformation, the higher absolute values of maximum and minimum difference $h_{max} - h_{min}$ [mm] and the higher earing coefficient Z_c [%].
2. For respectable earing, the percentage reduction of tandem mill is required:
   - max. 25 % for tinplates DR – BA,
   - max.15 % for tinplates DR – CA.

   If deformation is higher than 15% for DR – CA and 25% for DR– BA tinplates, then material hardened so much that it is not suitable for deep drawing operations.
3. The lower initial tinplates thickness, the higher earing is, consequently non-homogeneity of mechanical properties increases.
4. As resulting from microstructures of double reduced tinplates, strong deformation texture occurs (grains are

REFERENCES

[1] V. Kohúteková: Tinplates properties with very thin coatings (dissertation thesis), Košice, 1999.
[2] A. Bobenič, E. Spišák, J. Slota: Evaluation of tinplates formability, Acta Mechanica Slovaca, Košice, 3 (1999), 29 - 34.
[3] A. Bobenič: Evaluation of tinplates formability (dissertation thesis), Košice, 2000.
[4] V. Kohúteková, A. Bobenič: Actual trends in production and evaluation tinplates, Hutnické listy, 11 (1999), 16 - 22.
[5] F. Bugnard, P. Seurin, M. Entringer, J. Calas: Variations in tinplate anisotropy and their influence on drawing operations. In: Third International Tinplate Conference, London, 1986.
[6] J. F. Renard, J. Gelez: Tinplate specification trend for new applications. In: Fifth International Tinplate Conference, London, 1992.
[7] E. Spišák, F. Greškovič, J. Slota: Evaluation of plastic properties of tinned steel sheets, Rudy Metale 42 (1997) 11, 510 - 512.
[8] E. Spišák, J. Slota, J. Mihok: Analýza základných modelov plasticity pre veľmi tenké oceľové plechy, Acta Metalurgica Slovaca 8 (2002) 1, 23 - 28.
[9] E. Spišák, J. Slota: Hodnotenie cípocvitosti DR obalových plechov a medzných pretvorení tenkých plechov. Záverečná správa ZOD 16/2002, TU Košice, september 2002.
[10] EN 10 202/2001.
[11] EN 10 002-1 +AC1.

Notation

t_0 /mm - initial tinplate thickness
t_1 /mm - tinplate thickness after deformation
ε_{SVa} /% - percentual tinplate reduction
R_{p02} /MPa - yield stress
R_m /MPa - tensile strength
A_{50} /% - drawability (according to EN 10 002-1 +AC1)
h_{max} - maximum cup height
h_{min} - minimum cup height
Z_c - earing coefficient