

## The Microgeometry Parameters of Uncoated and Zinc-Coated Cold Rolled Steel Strips

Jana BIDULSKÁ<sup>1</sup>, Tibor KVAČKAJ<sup>1</sup>, Vladimír BODÁK<sup>2</sup> and Róbert BIDULSKÝ<sup>3\*</sup>

<sup>1</sup>Department of Metal Forming, Faculty of Metallurgy, Technical University Košice, Letná 9, 042 00 Košice, Slovakia

<sup>2</sup>Research and Testing Institute, U. S. Steel Košice, s.r.o., Košice, Slovakia

<sup>3</sup>Institute of Materials Research, SAS Košice, Watsonova 47, 043 53 Košice, Slovakia

### Abstract

Received Jul. 24, 2007

Accepted Sept. 3, 2007

The microgeometry of surface is arithmetically expressed by the arithmetical mean deviation of the profile, Ra and peak count, Pc. Roughening of working rolls was achieved by using the technology EDT (Electric Discharge Texturing) and SBT (Shot Blast Texturing). The paper shows the relationship between the basic microgeometry parameters and the adjustment technology of working rolls. Zinc-coated cold rolled steel strips, uncoated cold rolled steel strips and the Ra, Pc parameters were measured using the tangent profilometer "Hommel Tester T1000". Measurements of Ra and Pc showed the scatter for SBT and EDT rolls, respectively. EDT can provide a considerably greater degree of control of surface texture than SBT together with an accurate selection of surface roughness, Ra, and peak count, Pc. The peak count obtained can be appreciably higher than that obtained with shot blasting. In comparison with SBT, it is considered that the operating costs associated with EDT are lower.

**Keywords :** cold working, microgeometry parameters, texturing, surface roughness, peak count

### Introduction

The ideal surface texture is one that has suitable surface topographical characteristics, i.e., an appropriate average roughness and peak count that provides good formability and also a good appearance after painting.<sup>(1,2)</sup>

The basic property of surface is its unevenness. Profile unevenness is described by the arithmetical mean deviation of the profile - **Ra** (surface roughness). The arithmetical mean deviation of the profile - **Ra** is the average arithmetical deflection from all unevenness  $y$  from the central line in the measured length.<sup>(3-5)</sup>

Peak count - Pc is the amount of profile peak in 1 cm crossing limit lines c1 and c2. Limit lines are parallel and symmetric with the central line.<sup>(3-5)</sup>

The Ra is an amplitude parameter because it is measured the vertical characteristics of the surface deviations, whereas the Pc is an example of spacing parameter because it measures horizontal

characteristics of the surface deviations.<sup>(6)</sup> El-Menshawy and Snaith.<sup>(1)</sup> suggested that limitations of both parameters in providing a true representation over an area of surface are recognized and can be overcome.

Steel sheets are manufactured in a rolling process where the rolls are used to reduce the sheet thickness and to achieve desired surface characteristics. There are two important processes that follow the pickling of the strip. The first one is cold rolling at the 4-stand Rolling Train (4ST). Where the textured chrome plated working rolls are housed in the four stands. The second important process is rolling at the skin-pass work rolls or at the smoothing mill the work rolls (HK). At the skin-pass or at the HK process, the microgeometry is finally created on the strip surface.

Shot Blast Texturing (SBT) is the most frequently used method to texture cold mill working rolls. The surface texture is created with shot blast to the working roll surface.<sup>(3)</sup> In the shot blast texturing method, the change in surface

structure is attributable to plastic deformation of the working roll surface brought about by the projection of fine-grained shots. The roll surface quality is depends on<sup>(7)</sup> : shot shape and bulk, kinetic energy of blast shots, and surface quality before texturing. However, the stochastic surface structure can be produced by this technology only.

The process of electric discharge texturing (EDT) consists of the formation of minute surface craters through the discharge of electrical energy between two metal electrodes which are separated by a dielectric fluid.<sup>(1)</sup> Optimisation of roll texture based on the depth of distribution of the small craters, produced by the individual discharges, is possible though the selection of appropriate electrical and mechanical operating parameters.<sup>(8)</sup> Similarly, the opportunity exists to preserve the metallurgy and surface integrity of the roll through regulation of the amount peak current, pulse on/off time, capacitance, polarity, tool electrode material, etc.<sup>(9)</sup>

The major disadvantages of the SBT are bad texture uniformity and poor repeatability.<sup>(9)</sup> In addition, the texture produced and final roll performance is strongly dependent on relative hardness of shot and roll.<sup>(10)</sup> EDT processed strip is therefore claimed to be more suitable for exposed auto body parts than SBT processed strip.<sup>(7)</sup> A major feature of the technology over

better reproducibility than SBT and can be accurately controlled to achieve Ra values between 0,5 and 10  $\mu\text{m}$  with a variety of Pc. The Pc in a given area can be in the order of 40 to 60% higher than that achieved by the SBT.<sup>(1)</sup> The main difference between the two surface types was that the EDT surfaces generally had higher values of roughness in the centre of the sheet width.<sup>(11)</sup>

The aim of this work was to investigate the influence of the adjustment technology of working rolls on the basic microgeometry parameters.

### Experimental Materials and Methods

The measurement of microgeometry parameters of the uncoated cold rolled steel strips and the zinc-coated cold rolled steel strips were used. Microgeometry parameters Ra and Pc were measured using a tangent profilometer "Hommel Tester T1000".

Using the technology EDT and SBT resulted in roughening of working rolls. The uncoated cold rolled steel strips were only textured using adjusted rolls by EDT technology.

Before the cold rolling at the HK the coils were rolled at the 4ST and they also were annealed in the batch furnace. The chemical composition is shown in Table 1. The specification of the steel coils is shown in Table 2.

**Table 1.** The chemical composition

Grade	C	Si	Mn	P	S	Al	Cr	Ni	Mo	Cu	Ti	V	Nb	N
C	0,027	0,007	0,153	0,011	0,005	0,04	0,022	0,028	0,004	0,026	0,003	0,001	0,002	0,0032
B	0,0028	0,004	0,132	0,009	0,003	0,04	0,014	0,025	0,002	0,013	0,073	0,001	0,001	0,0026
A	0,030	0,006	0,164	0,009	0,004	0,053	0,045	0,026	0,003	0,016	-	-	-	0,0028

SBT is its ability to produce a roll surface with a higher density of peaks for the given value of roughness in the case of chromium-plated rolls.<sup>(1, 9)</sup> EDT provides the randomness of the SBT, yet roll texture is significantly more uniform and controllable. With SBT, a consistent, well-defined surface is extremely difficult to achieve and Ra, Pc can vary, not only between rolls textured under apparently similar conditions, but also at different locations on the same roll. Accordingly, cold rolled strip can show relatively large variations in measured surface finish. EDT gives considerably

The uncoated cold rolled steel strips were textured by the EDT technology on 35 coils. The values were obtained by measuring surfaces of both sides of strip on sickle shapes after smoothing. The location, from which the sickle was taken, was always situated at the end of the coil. Pressures, speeds and tensions could influence the final microgeometry parameters. As the surface area of the sickle was small (ca. 0,15  $\text{m}^2$ ), and as it is measured at the coil edge, the experimental microgeometry parameters could differ from the real ones.

*The Microgeometry Parameters of Uncoated and Zinc-Coated Cold Rolled Steel Strips*

**Table 2.** The specification of material

Material	Number of coils	Sizes: h x b [mm]	Rolling weight [t]	Rolling length [km]
C (EDT rolls)	20	0,7 x 1246 0,7 x 1256	541,08	786,05
	15	0,7 x 1246	435,98	635,96
B (SBT rolls)	32	1,5 x 1325 1 x 905 1 x 855 0,8 x 875 0,8 x 855	428,26	565,58
	5	0,8 x 1044 1 x 1131	78,92	87,25
B (EDT rolls)	15	1,5 x 1325 0,8 x 1155	337,67	292,77
A (SBT rolls)	15	1 x 1131 1 x 1004	392,95	366,31

The reverse direction of strip winding in HK in comparison with strip unwinding caused the up side of the strip to be formed by means of transfer of the bottom working roll and vice versa. In the following flow of the material there is no further change of the strip sides.

The device measuring error could distort the measured data. The producer sets the value of error  $\pm 5\%$ .

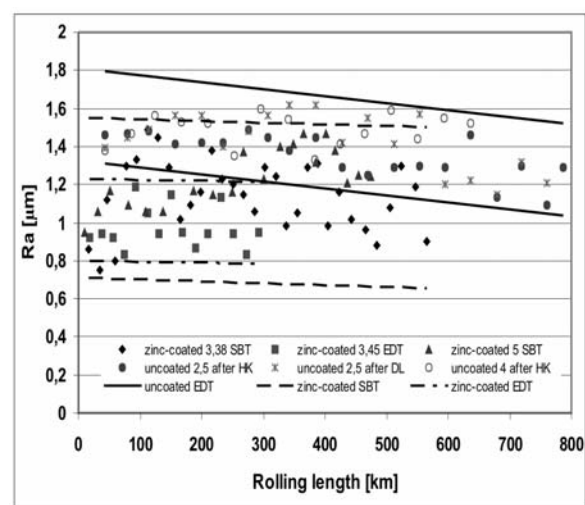
The zinc-coated cold rolled steel strips were textured by the SBT technology on 52 coils and by the EDT technology on 15 coils, respectively. From each coil one piece of sheet was taken for measuring the Ra and Pc microgeometry parameters.

## Results

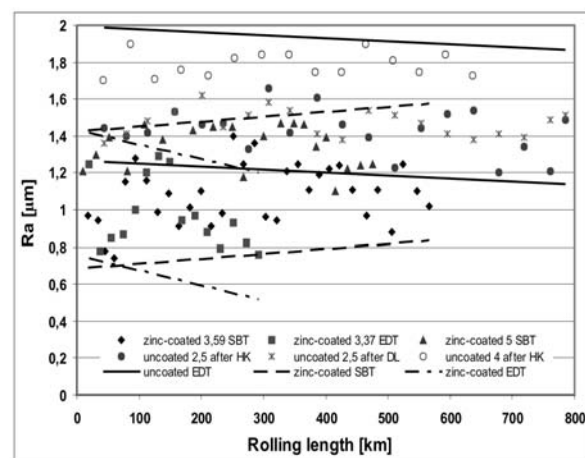
The relationship of parameters Ra and Pc for rolled length of uncoated strips after HK and after cutting machine (DL), as well as for zinc-coated strips after skin-pass, are graphically illustrated in Figure 1-4. Surface parameters of working rolls are separately shown at the caption in Figure 1-4.

As seen from the relationship in Figure 1-4 the scatter of Ra values with rolls adjusted by SBT technology is higher than with EDT technology. That is caused by the spraying equipment, which cannot ensure value uniformity on the whole roll surface. The values of roughness

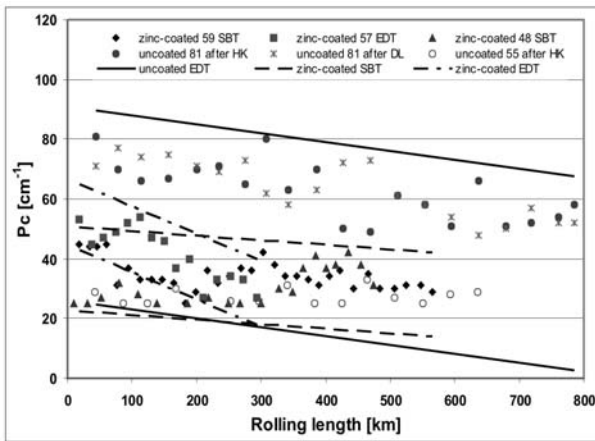
parameters for uncoated cold rolled steel strips vary within 1,09 - 1,9 [ $\mu\text{m}$ ] for EDT rolls and for zinc-coated cold rolled steel strips they vary within 0,76 - 1,29 [ $\mu\text{m}$ ] for EDT rolls and within 0,74 - 1,49 [ $\mu\text{m}$ ] for SBT rolls. The strips rolled with the rolls adjusted by EDT technology show higher Pc values in comparison with the strips rolled with the rolls adjusted by SBT technology. For both ways of texturing peak count achieves the required values,  $P_c \geq 25 [\text{cm}^{-1}]$ . Comparison of rolls preparation technologies (SBT, EDT) and comparison of Ra, Pc values of customer demands and experimentally obtained data are given in Table 3.



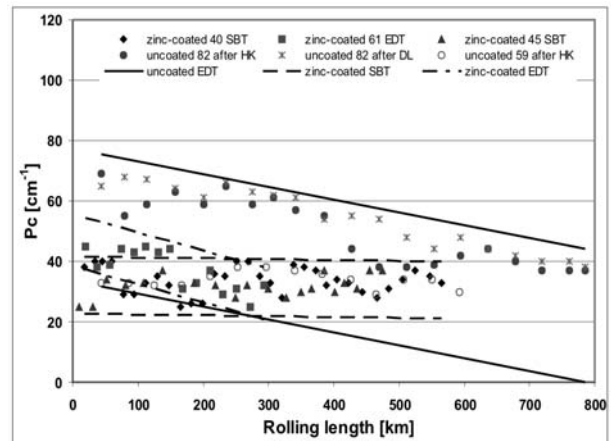
**Figure 1.** Comparison of Ra for working rolls adjusted by means of SBT and EDT technologies-upside of strip



**Figure 2.** Comparison of Ra for working rolls adjusted by means of SBT and EDT technologies-downside of strip

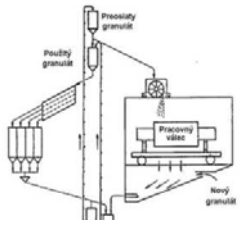
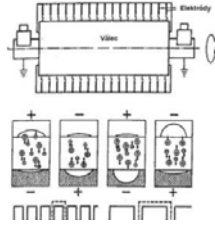
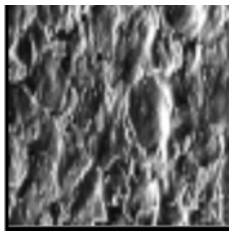
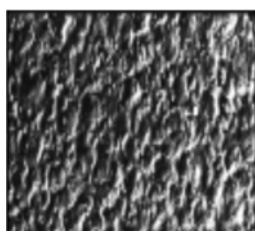


**Figure 3.** Comparison of Pc for working rolls adjusted by means of SBT and EDT technologies-upside of strip



**Figure 4.** Comparison of Pc for working rolls adjusted by means of SBT and EDT technologies-downside of strip

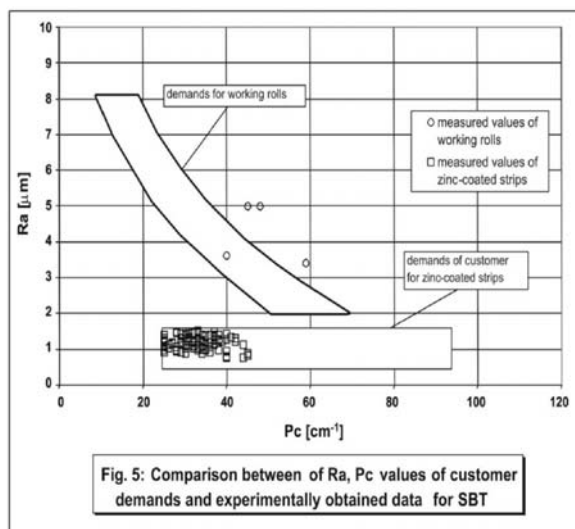
**Table 3.** Comparison of rolls preparation technologies (SBT, EDT) and comparison of Ra, Pc values of customer demands and experimentally obtained data

Technology			SBT	EDT
Principle of rolls preparation				
Roll surface after application of technology				
Strip surface			stochastic	stochastic
The uncoated cold rolled steel strips	customer demand	Ra [ $\mu\text{m}$ ]	1 – 1,9	1 – 1,9
		Pc [ $\text{cm}^{-1}$ ]	$\geq 25$	$\geq 25$
	experimental data	Ra [ $\mu\text{m}$ ]	-	1,09 – 1,9
		Pc [ $\text{cm}^{-1}$ ]	-	25 - 81
The zinc-coated cold rolled steel strips	customer demand	Ra [ $\mu\text{m}$ ]	0,5 – 1,5	0,5 – 1,5
		Pc [ $\text{cm}^{-1}$ ]	$\geq 25$	$\geq 25$
	experimental data	Ra [ $\mu\text{m}$ ]	0,74 – 1,49	0,76 – 1,29
		Pc [ $\text{cm}^{-1}$ ]	25 - 45	25 - 54
Preparation time per one roll			Ca. 20 min. (1 roll)	25 – 60 min. (1 roll)

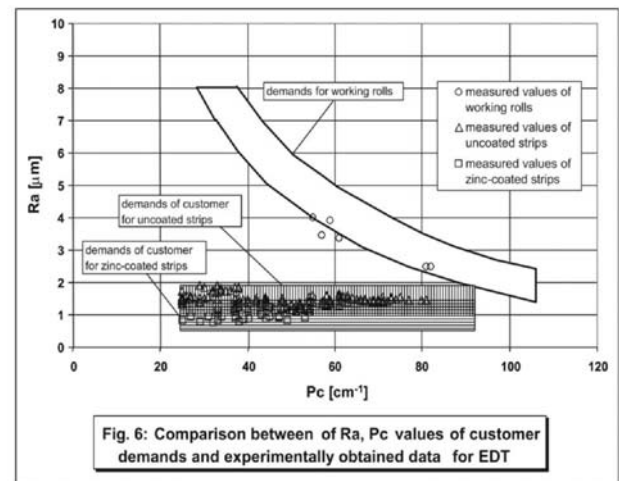
## The Microgeometry Parameters of Uncoated and Zinc-Coated Cold Rolled Steel Strips

Typical relationships between of Ra and Pc values of customer demands and experimentally obtained data for the working rolls adjusted by means of SBT technology and the zinc-coated cold rolled steel strips are shown in Figure 5. The correlation between of Ra and Pc values of customer demands and experimentally obtained data for the working rolls adjusted by means EDT technology as well as the uncoated cold rolled steel strips and the zinc-coated cold rolled steel strips are illustrated in Figure 6.

As seen from the relationship in Figure 5 the parameter Ra values for the SBT rolls vary within 2 - 8 [ $\mu\text{m}$ ] with a variety of peak counts Pc ranging from approximately 10 to 70 peaks/cm. Also in Figure 6, the parameter Ra values for the EDT rolls vary within 1,5-8 [ $\mu\text{m}$ ] with a variety of peak counts Pc ranging from approximately 30 to 105 peaks/cm. Surface topographies obtained throughout the tests for the uncoated cold rolled steel strips can be accurately controlled to achieve Ra values between 1-1,9 [ $\mu\text{m}$ ] with a variety of peak counts,  $Pc \geq 25$  [ $\text{cm}^{-1}$ ]. For the zinc-coated cold rolled steel strips the values of Ra can be in the range 0,5-1,5 [ $\mu\text{m}$ ] with a variety of peak counts,  $Pc \geq 25$  [ $\text{cm}^{-1}$ ] (Figure 5 and 6). The relationship between the basic microgeometry parameters of Ra and Pc is not random process, but the obtained values are move in relatively narrow areas.



**Figure 5.** Comparison of Ra and Pc values of customer demands and experimentally obtained data for SBT



**Figure 6.** Comparison of Ra and Pc values of customer demands and experimentally obtained data for EDT

### Discussion

Bastawros<sup>(12)</sup> demonstrated that EDT rolls showed a distinctly higher degree of decay than SBT rolls ones when used in similar rolling campaigns with the same material properties. Opposed to this finding, El-Menshawy and Snaith<sup>(1)</sup> presented that the peak count is maintained for EDT rolls whereas the peak count for the SBT rolls drastically decreased. Johansson<sup>(11)</sup> did not record any surface decay. The probable reason for these contradictory results is unsatisfactory measurements. The numbers of factors in both texturing the rolls and the cold rolling process can explain the difference in results.

The relationship and character of microgeometry parameters (Ra and Pc) decrease on the rolled length allows us to say that the working rolls could be under operation for much longer time without considerable change of their parameters. Similar results obtained by El-Menshawy and Snaith<sup>(1)</sup> revealed that a prolongation of the campaign by 40% is common practise.

The measured Ra and Pc values show scatter for SBT and EDT rolls. Vermeulen<sup>(13)</sup> suggested that the variation in Ra and Pc is typically up to 25 and 50%, respectively, of which approximately 4 to 6% can be associated with the measuring device. EDT can provide a considerably

greater degree of control of surface texture than SBT together with an accurate selection of surface roughness, Ra, and peak count, Pc. Kuwamoto<sup>(14)</sup> stated that surface roughness was reduced more with SBT rolls. The peak count obtained can be appreciably higher than that obtained with shot blasting. For the same rolls higher roughness parameters are achieved for grade A than that for grade B. For grade A first of all peak count, Pc increases with rolling thickness.

Skin-pass SBT technology is much more frequently used for adjustment of working rolls. It is possible to predict that working rolls adjusted by means of EDT technology will gradually push off the working rolls adjusted by means of SBT technology. In comparison with SBT, it is considered, that the operating costs associated with EDT are lower, the process requires a smaller operating area and the loading/preparation times are shorter. The economics of the process<sup>(15)</sup> are such that up to 25% more sheet steel can be rolled using EDT work rolls compared with SBT rolls, prior to retexturing.

## Conclusions

On the basis of theoretical analysis and experimentally achieved results it is possible to state the following conclusions: The measured Ra and Pc values show scatter for SBT and EDT rolls. EDT can provide a considerably greater degree of control of surface texture than SBT together with an accurate selection of roughness, Ra, and peak count, Pc. The peak count obtained can be appreciably higher than that obtained with shot blasting. Finally, for the same rolls higher roughness parameters are achieved for grade A than for grade B. In comparison with SBT, it is considered, that the operating costs associated with EDT are lower.

## References

1. El-Menshawey, M.F. and Snaith, B. 1991. Advances in electro-discharge texturing (EDT) for cold mill work rolls. *Iron Steel Eng.* **68** : 57 – 59.
2. Aspinwall, D.K., Zhao, F. L. and El-Menshawey, M. F. 1989. Electrodischarge texturing of steel rolls. *Surf. Topography.* **2** : 123-141.
3. Bidulska, J., Kvackaj, T., Bodak, V. and Bidulsky, R. 2002. Creation of microgeometry cold rolling strip of material ST 15. *Acta Metall. Slovaca.* **8** : 145-150
4. Pankert, R. 1990. Work roll roughening in cold mills. *Stahl und Eisen.* **110** : 55-60.
5. Thomas, T.R. 1999. *Rough surfaces.* 2<sup>nd</sup> ed. New York : Imperial College Press.
6. Larena, A., Millan, F., Verdu, M. and Pinto, G. 2001. Surface roughness characterisation of multilayer polymer films for graphic arts applications. *Appl. Surf. Sci.* **174** : 217-224.
7. Barica, S. and Bodák, V. 1998. Analysis of contemporaneous possibilities of work rolls surface preparation for sheets cold rolling. *Hutnícke Listy.* **53** : 22 - 26.
8. Simao, J., Aspinwall, D. K., Wise, M.L.H. and El-Menshawey, M. F. 1994. Mill roll texturing using EDT. *J. Mater. Process. Technol.* **45** : 207–214.
9. Simao, J. D., Aspinwall, K., Wise, M.L.H. and El-Menshawey, M. F. 1996. Electrical discharge texturing of cold mill work rolls using different tool electrode materials. *Iron Steel Eng.* **73** : 42 – 47.
10. Carless, P. 1985. Use of "high chrome" irons as roll materials for cold rolling applications. *Conference on Advanced in cold Rolling Technology.* London, 17-19. September, 1985 : 168 – 172.
11. Jonasson, M., Pulkkinen, T., Gunnarsson, L. and Schedin, E. 1997. Comparative study of shotblasted and electrical-discharge-textured rolls with regard to frictional behavior of the rolled steel sheet surfaces. *Wear.* **207** : 34–40.
12. Bastawros, A.F. and Speer, J.G. 1992. A procedure to determine surface waviness. In: *Proc. 34th Mechanical Working and Steel Processing Conference.* Montreal, Canada, 1992. **30** : 485-489.

*The Microgeometry Parameters of Uncoated and Zinc-Coated Cold Rolled Steel Strips*

13. Vermeulen, M. 1994. *Proc. of 6<sup>th</sup> International Conference on Metrology and Properties of Engineering Surfaces*. University of Birmingham, UK, April 6-8, 1994.
14. Kuwamoto, H., Kawano, M., Koga, Y., Kachi, Y. and Hiasa, M. 1985. Development of a new roll texturing system: electric discharge method. In: *Conference on Advanced in cold Rolling Technology*. London, 17-19. September 1985 : 108-114.
15. Kellock, B. 1988. Laser-EDM challenge to shot-blast texturing. *Mach. Product. Eng.* **146** : 26-27.

