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NEW APPROACH FOR EVALUATING THE SURFACE TOPOGRAPHY OF ROLLED SHEETS

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Abstract: *The paper deals with the evaluation and surface quality improvement of sheets produced by longitudinal cold rolling. In this paper we analyze relations between the arithmetic mean deviation of the assesed profile Ra and technological parameters of the laboratory rolling mill such as rolling force, rolling speed, rolling reduction etc.*

Keywords: ***Surface topography, cold rolling.***

1. Introduction

A knowledge of surface quality is very important both for manufacturers and customers. Having knowledge of the surface quality would help to affect the technological process of cold rolling in any manufacturing company. This goal can not be achieved without a high level of automatization, monitoring and controling throughout the whole manufacturing process with minimal manual intervention. Continuous cold rolling is an important process within the steel industry. Its performance directly affects the quality of the finished product. Any correctly designed system renovation can bring many financial gains for a company, mainly in performance and quality improvement as well as in overall business competitiveness (Alsman et al., 2004; Kenmochi et al., 1997; Mišičko et al., 2009; Othmani et al., 1998; Valíček et al., 2009; Valiev et al., 2006; Zrník et al., 2008).

2. Experimental set up

The experimental part is primarily focused on examining the relationship between the mean arithmetic deviation *Ra* and technological parameters of the rolling mill such as rolling force F_{roll} [kN], rolling reduction Δh [mm], rolling speed v_{roll} [m.s^{-1}] and revolutions of the rolls n_{roll} [s^{-1}], which affect the process of rolling.

An initial material was a low carbon structural sheet steel PN EN 10263-2:2004. The steel stripes with dimensions of 72 x 33 x 1.6 mm were cold rolled at the Technical University of Košice by the laboratory rolling mill DUO 210 Sva. The chemical compositions of the used sheet steel is given in Tab. 1.

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Tab. 1: Chemical composition of low carbon steel (%).

C	Mn	Si	P	S	Cr
0.0228	0.1928	0.0117	0.0081	0.0053	0.0209
V	Cu	Al	Co	B	As
0.0014	0.0275	0.0562	0.0075	0.0004	0.0047

Chemical analysis was performed by a glow discharge optical emission spectrometer LECO GDS 750.

This device allows to perform quantitative chemical analysis of metals and alloys, which is based on the measurement and subsequent evaluation of the intensities of selected spectral lines of the given elements. It is a device for the simultaneous determination of all elements. The device is equipped with channels for the determination of 28 elements. These are: Mg, Al, Cu, B, Mo, Cd, Ni, Fe, Mn, Na, C, S, P, As, Si, Zn, Ti, Co, Ta, V, Cr, Pb, Sb, Bi, Sn, Nb, Zr and W. The analysis by means of this device depends on calibration using reference materials with a known advanced content of elements. Through plastic deformation that occurs during cold rolling, there were made four rolled pieces with different rolling reductions which are listed in Tab. 2.

Tab. 2: Technological parameters of created steel strips.

Steel strips marking	**h_0 [mm]**	**h_1 [mm]**	**Δh [mm]**	*Picture*
a	1.6	1.6	-	
b	1.6	1.2	0.4	
c	1.6	1.1	0.5	
d	1.6	1.0	0.6	
e	1.6	0.8	0.8	

The steel strips *b, c, d, e* were several times rerolled at the rolling force F_{roll} from 65.55 to 90.07 kN and at the rolling speed of $v_{roll} = 0.7$ m.s^{-1}. The original sample *a* did not pass through the rolling mill by reason of a mutual comparison of surface roughness on the rolled pieces.

3. Results and discussion

The surface topography of the sheet steel strips was measured in three regions due to different deformation of material. The region I represents the entrance zone of the steel strip and its surface topography within this region. The region II represents the middle zone and the region III represents the bottom zone of the steel strip. The surface topography was measured by an optical profilometer MicroProf FRT. The steel strips were placed on the scanning table and these three regions with dimensions of 5 x 5 mm were scanned by a stationary sensor with a step of 3 µm and frequency of 1 kHz. In this manner, the surface topography data were obtained.

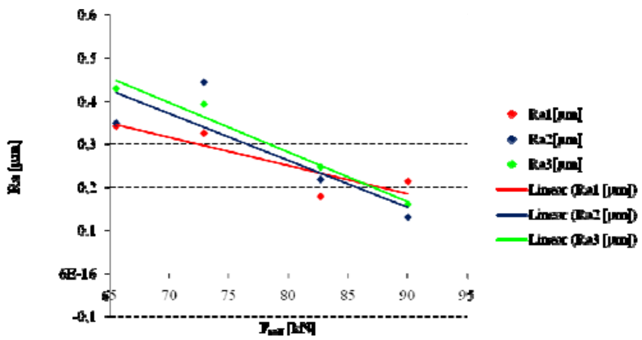
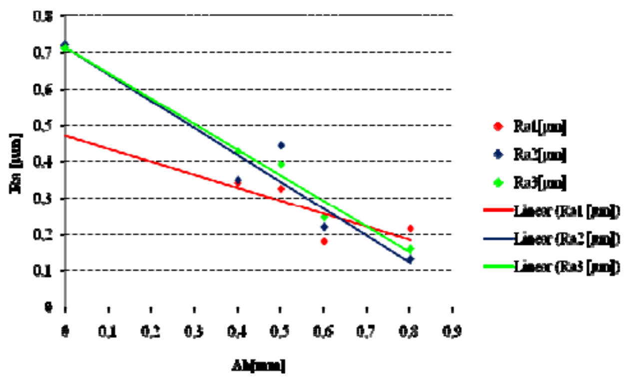
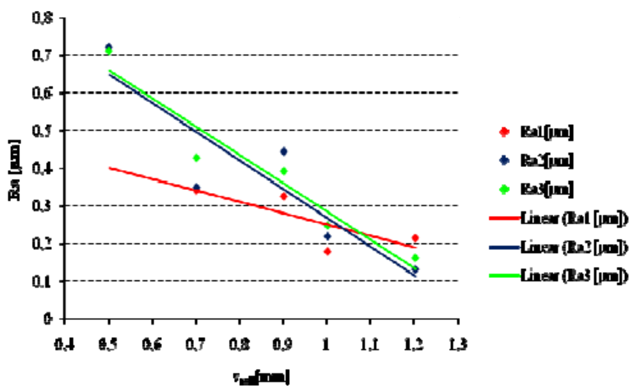
The collected data were analyzed using Gwyddion. The surface roughness data were obtained from all measured regions using this program. The surface roughness information in explicit form for each of the selected parameters (the rolling reduction Δh, the mean arithmetic deviation of the assessed surface profile *Ra,* the root mean square deviation from the assessed profile *Rq* and the maximum height of profile *Rz*) are given in Tab. 3.

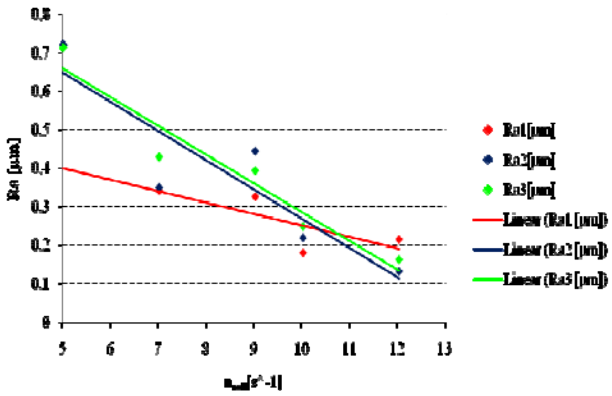
Tab. 3: Assessment parameters *of the* surface *roughness obtained from each sample and region.*

	Region I			***Region II***			***Region III***		
Steel strips marking	*Ra*[µm]	*Rq*[µm]	*Rz*[µm]	*Ra*[µm]	*Rq*[µm]	*Rz*[µm]	*Ra*[µm]	*Rq*[µm]	*Rz*[µm]
a	-	-	-	0.722	0.967	6.860	0.712	0.955	7.053
b	0.341	0.479	3.011	0.349	0.485	3.293	0.428	0.593	3.946
c	0.325	0.425	2.545	0,444	0.583	3.714	0.392	0.569	5.277
d	0.179	0.235	1.448	0.218	0.293	2.097	0.247	0.340	2.519
e	0.214	0.284	2.244	0.131	0.185	1.769	0.161	0.229	2.136

The surface roughness is expressed in implicit form as follows: Ra = f (F_{roll}, Δh, v_{roll}, n_{roll}). It is necessary to search for the relations between the technology, material and final surface quality. The charts (Tab. 4) were created on the basis of the obtained data.

Tab. 4: Dependence of the Ra on the technological parameters of rolling mill.

Regression equation	***Dependence of the Ra on the technological parameters***
Ra = f (F_{roll}) $Ra_1 = -0.0065F_{roll} + 0.7721$ $Ra_2 = -0.0108F_{roll} + 1.1291$ $Ra_3 = -0.0114F_{roll} + 1.1964$	
Ra = f (Δh) $Ra_1 = -0.3591\Delta h + 0.4713$ $Ra_2 = -0.7392\Delta h + 0.7129$ $Ra_3 = -0.7051\Delta h + 0.7124$	
Ra = f (v_{roll}) $Ra_1 = -0.3004v_{roll} + 0.5501$ $Ra_2 = -0.7633v_{roll} + 1.0293$ $Ra_3 = -0.7527v_{roll} + 1.0354$	

$Ra = f(n_{roll})$	
$Ra_1 = -0.03n_{roll} + 0.5501$ $Ra_2 = -0.0761n_{roll} + 1.0293$ $Ra_3 = -0.0751n_{roll} + 1.0354$	

The best correspondence between experimentally determined data and correlation equations is obtained in the third region, where the correlation coefficient ranges from 93 to 98.3%. It appears from this, that the analyzed region III the best corresponds to our assumption.

4. Conclusions

The paper describes the methodology of surface topography evaluation of sheet strips from low carbon structural steel PN 10263-2:2004, which is based on the comparison of the mean arithmetic deviation with the technological parameters of the rolling mill DUO 210 SVa. The benefit is the relation between the surface topography that is in our case represented by the mean arithmetic deviation *Ra* and technological parameters. The presented results from this rolling mill confirm the correctness of the assumption, that with an increase in rolling force F_{roll}, rolling reduction Δh, rolling speed v_{roll}, and revolutions of the rolls n_{roll}, the quality of the rolled surface can be improved. It is obvious that the surface quality is very important for manufacturing companies, because the requirements on the quality during cold rolling are steadily increasing.

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