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QUALITY CONTROL OF THE ELECTRO-DISCHARGE TEXTURING

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This paper deals with quality control of the electro-discharge texturing. Automobile manufacturers have strict requirements for micro-geometry parameters of rolled metal plates from contractors of body sheet metal. The micro-geometry of the roll surface has significant influence on the final quality of the rolled metal plate. In this paper electro-discharge texturing parameters are analyzed, for example, the texturing current, impulse time, technological pause, and their impact to roughness average and peak counts. Quality control is discussed based on mathematical model for estimating the texturing current, impulse time, and technological pause for roughness average or peak counts required value.

Key words: quality control, electro-discharge texturing, mathematical model

Kontrola kvalitete elektroerozijske teksture. Rad opisuje kontrolu kvalitete elektroerozijske teksture. Proizvođači automobila postavljaju prema dobavljačima lima za karoserije stroge zahtjeve za parametre mikrogeometrije valjanih limova. Mikrogeometrija valjane površine ima značajan utjecaj na završnu kvalitetu valjanih limova. U ovom su radu analizirani parametri elektrolizijske teksture, npr., jakost struje, trajanje impulsa, tehnološka pauza i utjecaj na prosječnu hrapavost i broj vrhova.
Kontrola kvalitete se razmatra na osnovu matematičkog modela za procjenu jakosti struje, trajanja impulsa i tehnološke pauze za zahtjevanu hrapavost i broj vrhova.

Ključne riječi: kontrola kvalitete, elektroerozijska tekstura, matematički model

INTRODUCTION

Automobile manufacturers specify in their requirements the characteristics of the microgeometry of metal plate quality. These quality criteria are a necessary condition for realization of supply of metal plates to the manufacturers. Each manufacturer has its own specifications. For example the Ford company requires that the roughness average on both sides of the metal plate be within the range 1,1 to 1,7 μm, while the peak count has to be more than 50 cm^{-1} [1].

These requirements are important mainly for good pressability and varnishability of the metal plates and also to achieve their long lifetime in the automobile industry.

The roughness of the surface is a part of geometric unevenness of the surface with relatively small distances of uneven parts. For the purpose of evaluation of the surface relief statistical parameters were chosen which we call microgeometric quantities. The microgeometry of the surface is given by the roughness average and the peak count.

Ra (roughness average) is a generally known and most widely used international roughness parameter. It is the mean arithmetic deviation of the roughness profile from the median line in the range of basic length [2]. Geometrically, this parameter is interpreted by the height of the rectangle constructed on the median line with the same area as the profile unevenness, enclosed by the profile from the median line. The values obtained show considerable accuracy in repeated measurement.

Pc (peak count) is the number of peaks that intersect the defined upper and then lower level of the section, measured in the range of the evaluated length, transformed to the length of 1 cm [2].

In addition to the above quantities the following characteristics are used:

- Rq – average quadratic deviation of the profile in the range of basic length, so called medium effective value
- Rv – depth of the largest dip of the roughness profile within a single measured path
- Rp – height of the tallest peak of the roughness profile within a single measured path
- Rz – sum of Rv and Rp is the total depth of the roughness profile of a single measured path
- Rmax – largest height of the profile (tallest peak to largest dip) measured in the range of entire length being evaluated

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Individual parameters of the metal plate are achieved by rolling the plate with textured (roughened) metal plate rolls. The quality of the roll surface can be influenced by several technological parameters which are given by individual technologies.

To date there are five known methods of texturing the surface of work rolls [3, 4] for rolling steel belts: blasting with steel grit, electro-discharge texturing, laser texturing, texturing with electron beam, and topochrom method. The roll surface can be achieved with these methods that are stochastic or fully deterministic.

ELECTRO-DISCHARGE TEXTURING

Electro-discharge texturing (EDT) is a technological process characterized by the fact that the melting down of the roll's material is caused by electric discharges that are temporally and spatially separated. The discharges occur in the work slot between the electrode and the roll. The electrodes are immersed in a dielectric fluid during the process of texturing [5, 6].

The result of the process is textured, stochastic surface, characterized by non-oriented, randomly located craters after individual discharges. The resulting values of the microgeometry after electro-discharge texturing are affected by several parameters having different weight of influence on the required characteristics. Among the most important are the following [7, 8] effect of the value of texturing current, of the impulse length, of the value of technological pause, and of the voltage. Among further important parameters of the EDT are: revolutions of the roll, velocity of the shift, shape and size of the area of the electrodes used, material of the electrodes being used, etc.

The evaluation of the microgeometry of the work rolls was performed according to the DIN methodology which represents a generally used standard [9]. Two basic characteristic of surface microgeometry were evaluated, namely Ra and Pc, measured in nine locations in four quadrants along the roll.

The results of individual measurements of the characteristics were recorded in tables. Subsequently, mean values were determined of Ra and Pc from each set of measurements and also the value of mean deviation. The measurements were taken by using the Hommel Tester T1000 device.

ANALYSIS OF THE EFFECT OF PARAMETERS

The data for analysis were provided by the company NEO Slovak Inc. realizing electro-discharge texturing of chrome rolls, which is more than 4500 measured data items. Processed rolls are grouped into individual programs characterized by required value Ra and Pc (Figure 1). Reaching the desired values is then dependent on the setting of main parameters of the process, i.e. by texturing current, impulse length, and the length of the technological pause.

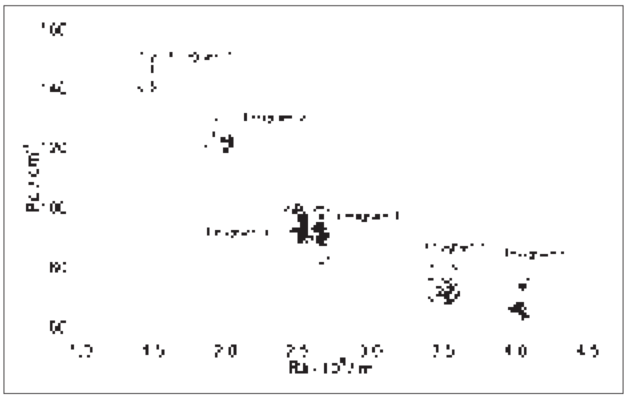

Figure 1. Considered programs of chromed rolls

Classical histograms and the Shewart regulation diagrams were used for the evaluation. For those sets of values with more than 20 measurements regulation diagrams for arithmetic mean value and standard deviation were used. For the sets with less than 20 measurements regulation diagrams for arithmetic mean value and variational range were used. After excluding the values outside of regulation boundaries, the parameters of dependence and correlation coefficients between the monitored parameters and Ra and Pc were calculated with the method of least squares.

Effect of texturing current

The value of the texturing current has fundamental effect on the roughness achieved. It is obvious from the measured values that roughness Ra increases with increasing texturing current (Figure 2). In the case of constant value of the impulse this increase is negligible after reaching specified value Ra. Based on this finding it can be stated that, if higher values of Ra are needed, from the viewpoint of efficiency of electro-discharge texturing and concurrently with increasing the value of texturing current, it is necessary to increase the value of the impulse length. The dependence of Ra on current determined with the least squares method is given by the formula

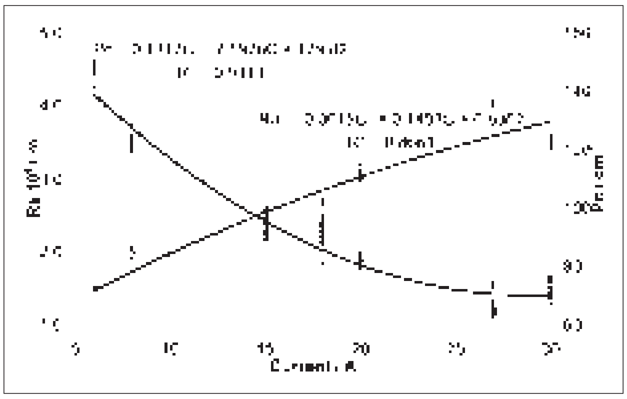

Figure 2. Dependence of Ra and Pc on the current

$$Ra = -0{,}0015I^2 + 0{,}1493I + 0{,}6362 \ / \mu\text{m} \quad (1)$$

where the correlation coefficient has value 0,8661 for current within 5 to 30 A (Figure 2).

The value of the texturing current for the value Pc has reverse character as with the value Ra. That means that with increasing value of the texturing current the peak count decreases because of increasing area of the melted-out crater. From certain value of the texturing current, with unchanged value of the impulse, this decrease stops

$$Pc = 0{,}1317I^2 - 7{,}5978I + 179{,}82 \ / \text{cm}^{-1} \quad (2)$$

while the correlation coefficient has value 0,9313 for current within 5 to 30 A (Figure 2).

Effect of impulse length

The length of impulse affects the roughness in a fundamental way. With increasing value of the impulse length (On) increases the value of Ra. However, at certain value of the impulse length at constant value of the texturing current a considerable slowdown in increasing the value of Ra occurs and subsequently it stops. This value is directly proportional to the value of texturing current I

$$Ra = -0{,}003On^2 + 0{,}2442On + 0{,}3802 \ / \mu\text{m} \quad (3)$$

while the correlation coefficient has value 0,9969 for On within 5 to 20 μs (Figure 3).

Based on the evaluated results there is an obvious decrease in the peak count Pc at increasing value of the impulse length (On). After certain value of Pc has been reached at unchanged value of texturing current, the process is stopped

$$Pc = 0{,}4084On^2 - 15{,}00On + 205{,}26 \ / \text{cm}^{-1} \quad (4)$$

while the correlation coefficient has the value 0,9521 for On between 5 and 20 μs (Figure 3).

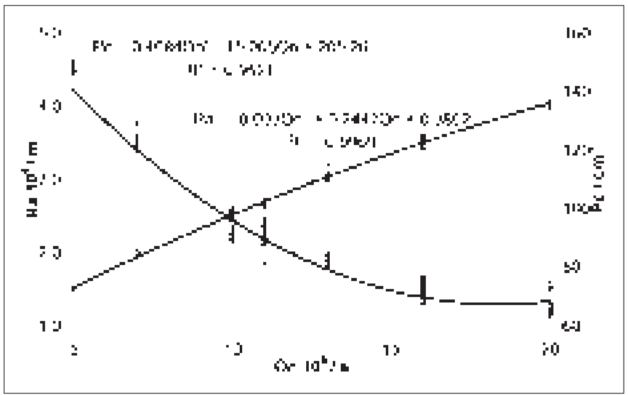

Figure 3. Dependence of Ra and Pc on the length of impulse

Effect of technological pause

The obtained data did not confirm substantial effect of the value of technological pause (Off) on the roughness [1]. There is a dependence of roughness Ra on technological pause, this, however, does not equal the dependencies Ra on the strength of current and impulse. However, it was shown that in the case of excessive shortening of the technological pause regeneration of the channel in the discharge gap does not occur and a phenomenon appears that is called roll burning. Roll burning is an unacceptable fault from the viewpoint of the quality of the surface. The optimum value of the duration of technological pause is related to the value of the texturing current and the duration of the impulse. In general, it can be stated that with increasing value of the texturing current it is necessary to increase the value of technological pause.

The measured data did not confirm direct influence of the duration of technological pause on the peak count.

Effect of other parameters

Other parameters, i.e. electrical voltage, method of electrode motion, revolutions of the roll, speed of electrode shift, shape and size of the area of the electrodes used, material of the electrodes do not have significant effect on the values of the characteristics Ra and Pc.

PREDICTION MODEL

In view of the requirements Ra and Pc in texturing new rolls, that have not yet been used, it is necessary to set the most accurate estimates possible for the current and length of impulse. Therefore a prediction model was designed for determination of the value of current and impulse for required value of Ra.

Prediction model for the current

The prediction model for determination of the current was created on the basis of measured data by using a nonlinear regression model. The obtained dependence is given by the formula

$$I = -2{,}7441Ra^2 + 26{,}545Ra - 33{,}31 / \text{A} \quad (5)$$

where the index of correlation has the value 0,8885 for Ra within 1,5 to 4,0 μm Figure 4.

Prediction model for impulse

Similarly, the prediction model for determination of the length of the impulse has been set (Figure 4)

$$On = 0{,}6698Ra^2 + 2{,}1215Ra + 0{,}3922 / \text{A} \quad (6)$$

where the correlation index is 0,9967 for Ra in the range 1,5 to 4,0 μm.

In the same way we could determine the prediction model also for Pc, however, based on analysis a strong dependence between Ra and Pc follows which is given by the following relation

$$Pc = 12{,}717Ra^2 - 101{,}26Ra + 269{,}66 / \text{cm}^{-1} \quad (7)$$

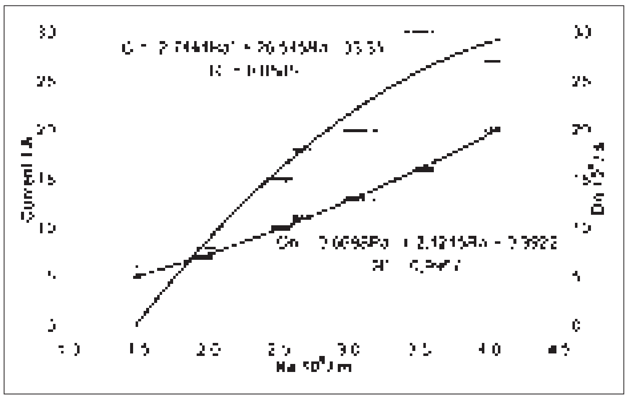

Figure 4. Prediction model for the current and the impulse

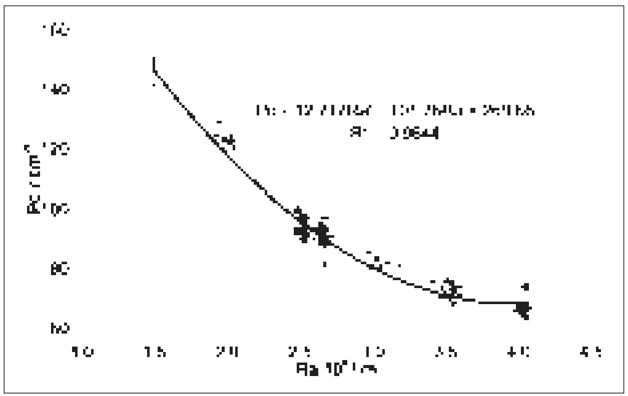

Figure 5. Dependence of Pc on Ra

while the correlation index has the value 0,9644 for Ra in the range 1,5 to 4,0 μm (Figure 5).

Verification of prediction models

For verification of prediction models (5) and (6) 12 measurements were used for texturing new rolls with required roughness Ra=3,0 μm and minimum number of peaks Pc=75 that did not appear before in the analyzed measurements. The recommended value of the current according to (5) is 21,63 A and the value of the length of the impulse according to (6) is 12,78 μs.

Operators decided on the value of the current 20 A, while the possibility of setting the current in the texturing device is with minimum step size 1 A. The value of the impulse and technological pause was set at the same value 13 μs. From the measured values resulted the average value Ra=3,04 μm and Pc=81,9. If we substituted the value Ra=3,04 μm as the desired value into the formula (5) then the predicted value of the current would be 22,03 A which in the case of possible settings of the device corresponds to the value 22 A. The difference between the predicted and real value is 2 A which corresponds to relative error 10 %.

Multiple linear model

Because of quite large relative error, a multiple linear model was subsequently designed and realized:

$$I = a_0 + a_1 On + a_2 Off + a_3 Ra / \text{A} \qquad (8)$$

where a_0 = –21,287; a_1 = –2,5878; a_2 = 0,5595; a_3 = 22,6574.

The value of the predicted current according to the above model for the values of the impulse 13 μs, technological pause 13 μs, and required roughness 3 μm is 20,317 A. In view of the possibilities of the device this corresponds to setting the value of the current to 20 A.

CONCLUSION

By analyzing the effects of individual parameters of the EDT process on the microgeometry of the surface of work rolls used for cold-rolling metal sheets it was found that the most important parameters are the intensity of the texturing current and the length of its impulse. These parameters have the largest effect on the values of Ra and Pc, while the parameters are mutually independent. From the above results followed the need of creating a prediction model for determination of the texturing current. Based on verification of predicted and measured values we can conclude that the designed models can be used in the system of quality control of the process with the parameters set for new, not yet used, texturing of rolls.

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Note: The responsible translator for English language is Ladislav Pivka, Košice, Slovakia.