THICKNESS OF THE HEAT AFFECTED LAYER AT DEPOSITION AND SURFACE ALLOYING BY ELECTRICAL DISCHARGES

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ABSTRACT:. There are circumstances when a mechanical part must have a surface layer harder than the rest of the part. The hardening by electrical discharges is one of the technologies able to ensure the increase of the surface hardness, by developing phenomena of depositing, surface alloying and quenching. Experimental researches were designed and developed in order to study the influence exerted by some electrical parameters on the hardness of the surface layers for test pieces made of two categories of steels. On the basis of experimental results, empirical mathematical models were established and an image about conditions for reaching the best results was obtained

KEYWORDS: electrical discharges, deposition and surface alloying, heat affected layer, thickness

1. INTRODUCTION

There are practical situations when the surface layer must have a hardness higher than the hardness of the base material; for example, such a requirement could appear when a high wear resistance is desired, while the rest of part mass is not affected by significant stresses.

Of course, there are also situations when even if the workpiece material has a high hardness, an increased hardness is desired for the piece surface layer. Various technologies can be used to obtain an increase of the surface layer hardness; the most utilized group of operations able to ensure the increasing of the hardness includes the so called surface heat treatments, when the change of the metallic material structure is possible only in the surface layer.

Other group of technologies able to generate an increase of the surface layer hardness is based on the surface deposition and alloying; nowadays, there are techniques based on various phenomena and which can determine the deposition and eventually alloying phenomena on the workpiece surface layer.

Such techniques are the plasma beam deposition and alloying, laser beam deposition and alloying, electrochemical deposition etc. Among these techniques, the electrical discharge deposition and alloying could be included; this technique is based on the developing successive electrical discharges between an electrode made of the material to be used for deposition and alloying and the workpiece surface.

At the contact of the plasma column specific to the electrical discharge with the workpiece surface and the electrode, phenomena of melting are generated; if small drops of the electrode material arrive in contact with the workpiece material, either deposition or alloying processes develops.

Generally, in the electrical deposition and alloying, the electrical discharges are generated by the interrupting of the contact between the electrode and the workpiece, because the voltage is not high enough to ensure the development of the electrical discharge only at the decrease of the distance between electrode and the workpiece.

Along the time, the electrical discharge deposition and alloying was studied in various countries and research structures [1, 3-5].

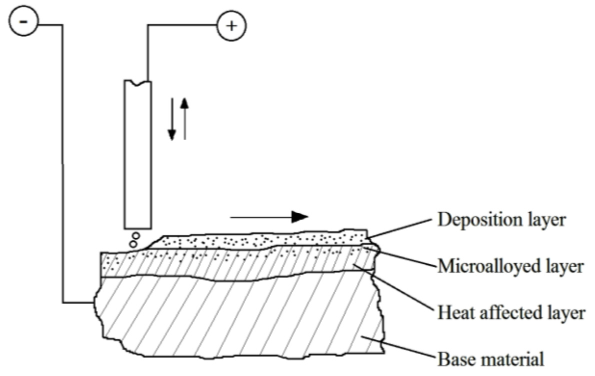

Fig. 1. Phenomena at electrical discharge depositon and superficial alloying

2. FACTORS ABLE TO AFFECT THE SURFACE LAYER

Essentially, during the deposition and surface alloying by means of the electrical discharges, the electrode achieves a vibratory motion, taking contact and interrupting the contact with the workpiece surface; because both the electrode and the workpiece are connected at the poles of a direct electric current source and a certain voltage is applied to the two components, between the electrode and workpiece electrical discharges appear (fig. 1).

If the electric current is high enough, at the contact with the electrode and the workpiece, the plasma column corresponding to the electrical discharge generates melting and vaporizing phenomena. If the electrode is placed over the workpiece surface, small quantities of melted material from the electrode are detached and fall on the workpiece surface; if here the workpiece material is melted too, a surface alloying phenomenon develops; in this way, a layer including both workpiece base material and electrode material is generated. Because usually the electrode material includes components having hardening effects, it is expected that the surface layer hardness becomes higher than the workpiece material hardness.

The base material from the surface layer could increase also as consequence of a quenching effect; as abovementioned, the value of temperature in the surface layer could increase up to melting and even boiling temperature; when the electrical discharges stop, the heat could be dissipated into the workpiece material with a high enough speed so that quenching structures could be generated in the surface layer. As one can see, these are a second category of phenomena which can contribute to the increase of the surface layer hardness.

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3. EXPERIMENTAL RESEARCH

Within the “Gheorghe Asachi” Technical University of Iaşi, an experimental research was developed in order to highlight several aspects concerning the electrical discharge deposition and surface alloying. A set of such experiments was directed in order to study the influence exerted by some factors on the values of the parameters of technological interest.

An equipment destined to the manual deposition and surface alloying was used; the equipment ensures the vibration of the electrode made of the material to be deposited; the chemical composition of this material was including 97 % tungsten and 3 % carbon.

Two test pieces of two different steels were fixed in a chuck and in a live center (fig. 2). One of the steels was the carbon steel 1C45 (containing 0.45 % carbon); this steel is largely used in the machine building and

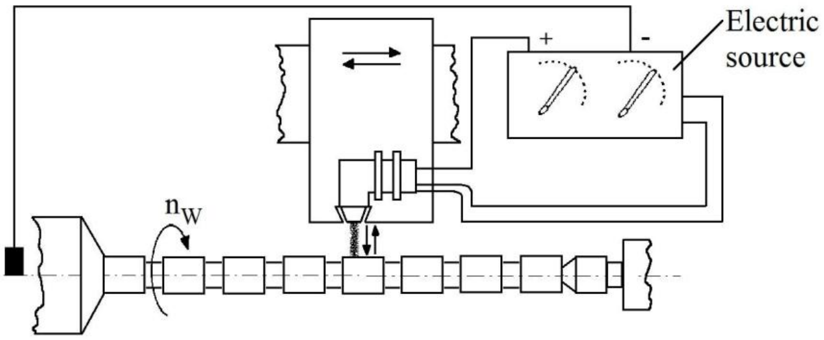

Fig. 2. Deposition and superficial alloying schema

sometimes it is used as an etalon material, when two or many materials must be compared from various points of view. The second steel was the steel 42CrMo4; it contains 0.41 % carbon, 0.22 % molybdenum and 0.90 % chromium; it is an alloyed steel, used when the mechanical parts are intensively solicited.

The manual device for deposition obliges the electrode to materialize a vibratory motion with a frequency of 50 Hz and an amplitude of some hundredths or tenths of millimeters. There is the possibility to change the voltage applied to the vibrator coil and the voltage applied to the electrode and test piece. The device was mounted on the vertical slide of a computer numerical controlled machine, in order to obtain a reciprocating rectilinear motion along the cylindrical surface of the test piece. As one can see in figure 2, the test piece had eight zones, for each zone being applied a certain set of the operating parameters (table 1).

In order to diminish the number of experiments, the rules specific to a complete factorial experiment were applied; the values of the input factors were included in the columns no. 3-10 of the table 1. In the columns no. 3, 4 and 5, the values of the discharge voltage U_d, the voltage U_v at the vibrator coil and the specific duration t_{sp} were mentioned. In the columns no. 6-10, there are 5 values of the distances from the free surface of the test piece where the Vickers microhardness was measured. The experiments proved that the microhardness is generally higher than the base material microhardness for a layer thickness of about 0.2 mm, so that in the table 1 only the values valid for this thickness were specified. The microhardness was evaluated by means of a microhardness tester type Affri DM2A.

The experimental results were mathematically processed by means of software based on the method of the least squares [2]; the software offers the possibility to select the most adequate empirical model, from 5 various models, on the basis of the so-called Gauss's criterion. In this way, for the steel 1C45, the following empirical model was determined:

$$H_{1C45} = 91.08 U_d^{0.02048} U_v^{0.09575} t_s^{0.03470} h^{-0.1331}. \quad (1)$$

In the case of test piece made of the steel 42CrMo4, the most adequate empirical model was the following:

$$H_{42CrMo4} = 250.378 + 0.4448 U_d + 0.7032 U_v + 0.6011 t_{sp} - 200.0019 h \quad (2)$$

Appreciating that a power type function

Table 1. Experimental results

Material	Exp. no.	Discharge voltage, U_d, V	Vibration voltage, U_v, V	Specific duration, t_{sp} s/mm^2	Distance h from free surface, mm				
					0.03	0.08	0.12	0.18	0.23
1	2	3	4	5	6	7	8	9	10
Carbon steel 1C45	1.1	56.90	11.25	2	189	183	155	153	147
	1.2	56.90	11.25	4	202	182	179	164	163
	1.3	56.90	18.65	2	220	189	184	175	167
	1.4	56.90	18.65	4	237	195	181	171	165
	1.5	78.50	11.25	2	220	186	177	173	155
	1.6	78.50	11.25	4	197	186	178	165	166
	1.7	78.50	18.65	2	223	178	169	165	162
	1.8	78.50	18.65	4	207	195	184	167	165
Alloyed steel 42CrMo4	2.1	56.90	11.25	2	276	258	251	231	223
	2.2	56.90	11.25	4	285	276	263	252	231
	2.3	56.90	18.65	2	283	279	266	258	252
	2.4	56.90	18.65	4	294	285	263	256	258
	2.5	78.50	11.25	2	297	283	281	279	258
	2.6	78.50	11.25	4	284	274	269	261	252
	2.7	78.50	18.65	2	285	278	270	265	251
	2.8	78.50	18.65	4	296	274	269	257	249

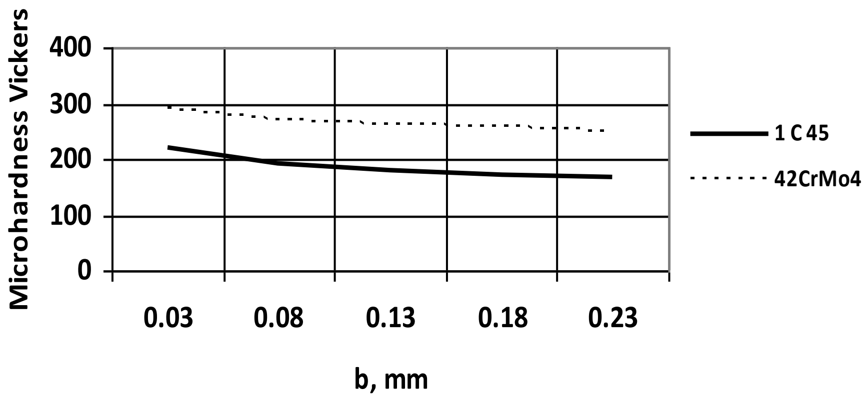

Fig. 3. Influence of the distance from the free surface on the microhardness of the surface layer affected by the deposition and alloying process

offers a more direct image about the intensity of the influence exerted by the input factors on the thickness of the layer affected by the process, such a function was also established:

$$H_{1C45} = 123.602 U_d^{0.1161} U_v^{0.04147} t_s^{0.007404} h^{-0.07128} \quad (3)$$

On the basis of the relations (1) and (3), the diagram from figure 3 was elaborated.

Analyzing the relations and the graphical representation from figure 3, some remarks could be formulated. Thus, one can notice that the influence exerted by the considered factors is low enough, because all the exponents attached to the factors U_d, U_v and t_{sp} have relatively small values (lower than 0.13). As expected, the hardness is higher in the superficial layer and it decrease when the distance from the free surface increases. The microhardness is higher in the case of the steel 42CrMo4, whose content in hardening elements is higher.

4. CONCLUSIONS

The electrical discharges could be used to develop a process of deposition and surface alloying, if the electrode is connected to the positive pole of the direct current source and the drops of electrode material arrive on the workpiece surface. There are various factors able to affect the output parameters of the deposition and surface alloying by means of the electrical discharges. Some experimental researches were designed and developed in order to highlight the influence exerted by the discharge voltage, the voltage at the vibrator coil and the specific duration of the process. Empirical models were determined by mathematical processing of the experimental results. The experiments proved the increase of the microhardness of the surface layer, in comparison with the microhardness of the base material. In the future, there is the intention to more detailed investigate the deposition and surface alloying process, by taking into consideration inclusively other materials for the electrodes and the test pieces.

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