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ELECTROSPARK DEPOSITION FOR DIE REPAIR

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The electrospark deposition is a process for surfacing of hard metal alloys, e.g. carbides and stellites, on the surfaces of new or old machine elements. In this process, a high current is conducted through an oscillating electrode and a substrate for a very short period of time. In the paper, the process is described and the thickness of deposited layer, chemical composition, dilution rate and the layer roughness are determined.

Key words: welding, electrospark deposition, repair of dies

Nanošenje električnom iskrom za popravak alata. Nanošenje električnom iskrom postupak je za navarivanje tvrdih metalnih slitina, npr. karbida i stelita, na površinu novih ili starih elemenata strojeva. U tom postupku visoka struja provodi se kroz oscilirajuću elektrodu i supstrat na vrlo kratko vrijeme. U članku opisan je postupak i određeni su debljina nanesenog sloja, kemijski sastav, stupanj miješanja i hrapavost sloja.

Ključne riječi: zavarivanje, nanošenje električnom iskrom, popravak alata

INTRODUCTION

In the everyday industrial manufacturing practice, there are many products for which it is essential that they show high abrasion, corrosion and/or thermal resistance. Such products are gas turbines, casting dies, cutting tools, pumps, compressors, and similar. In such equipment, usually only their individual parts or individual surfaces are exposed to strong dynamic, mechanical, thermal, abrasive, corrosion, and other similar loads. Consequently, it is very useful to protect such surfaces or parts with a suitable cladding.

Today a number of methods for the deposition of hard claddings on substrates are known. They can be classified with respect to different criteria, one of them being the aggregate state of the material deposited. Known processes are cladding (by rolling and by explosion), surfacing (gas, arc, plasma, laser surfacing), spraying (gas, plasma, laser spraying), and evaporating.

One of the numerous modes of depositing hard claddings on new, damaged, or worn-out products is the electrospark deposition. This process is characterised by the deposition of primarily carbides and other hard alloys on the substrate in very thin layers.

The paper aims to show some characteristics of electrospark deposition. The process has not been studied thoroughly yet, although it is used in practice. In the literature there are very few publications dealing with electrospark deposition from the scientific or engineering point of view [1–5].

The issues not studied yet are primarily the material transfer from the electrode to the workpiece, the influence of shielding gases on the process of material transfer and properties of the deposited layers, an analysis of the joint formed by the substrate and the deposit, the burn-off of elements, the efficiency of supplied energy, the influence of the amount of energy input, and so forth.

EXPERIMENTAL PROCEDURE

In the experimental work, a classical unit enabling manual electrospark deposition was used. The unit consisted of an electronically controlled source of electric pulses and an electrode holder with a vibrating mechanism. The source was of the capacitor type.

The parameters of electrospark deposition, i.e. the welding current, the type of filler material, and the type of shielding gas, were varied. The substrates used were a hot working tool steel, designated H13 in accordance with ASTM, and a high-alloy austenitic steel. Three different types of filler material were used (WC, TiC, stellite 6). The filler materials used were electrodes in the form of uncoated bars with a diameter of 2,4 mm and a length of 100 mm. The deposition process was carried out without a shielding gas, with pure argon (99,99 %), and with pure helium, respectively.

EKSPERIMENTAL RESULTS

In the study of compatibility of hard layers and tool steels and of a proper deposition technique, it was found

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that the basic requirement, i.e. suitable hardness, was comparatively easy to fulfil. It is more difficult, however, to ensure an appropriate surface homogeneity without cracks, and particularly adherence to the substrate taking into account high thermal and mechanical loads.

Droplet size

The surface roughness of the deposit and other mechanical properties of the surface are influenced by the number, shape and size of the droplets transferred. The approximate droplet size can be calculated from the known weight of the droplet transferred per unit time. Figure 1 shows the influence of electric energy in the electrospark deposition on the average number of droplets. The average droplet diameter is around 80 μm and their average mass is around 40 μg (WC). Tungsten carbide (WC) was used as filler material, austenitic stainless steel (SS) and tool steel (CS) as substrates, and Ar and He as shielding gases. The electric pulse energy has the most important influence on the droplet diameter.

Rate of dilution

The filler material transferred from the electrode to the small molten area at the workpiece is diluted by the substrate. This dilution decreases considerably with each new material transfer; therefore, the deposit thickness is limited to approximately 30 μm. One of very important findings is that the deposit thickness cannot be increased indefinitely. The most important is the first contact of the electrode with the substrate (first layer). Further contacts (other layer) with the electrode have a negligible influence on the dilution; the energy input in the first layer is therefore important.

Roughness of the deposited surface

Deposit roughness was evaluated as well. It was found that the surface roughness depended on the type of the substrate, the material deposited, and the deposition parameters. It was also found that roughness increased with an increase in energy input, i.e., higher pulse intensity. It was also found that in a substrate of austenitic stainless steel, the roughness was quite proportional to pulse intensity. In case of a substrate being a low-carbon steel plate, it was much more difficult to determine a correlation between pulse intensity and roughness. The dependence of roughness on the deposit material, the substrate, and the pulse energy is shown in Figure 2.

Addition of a shielding gas

In the investigation conducted, however, the entire process of the material transfer from the electrode to the work piece surface was shielded against the atmosphere by using two inert gases. The respective shielding gases used were He and Ar. The gas was supplied through a nozzle from one side. The flow rate of Ar was approximately 6 l/min and that of He 10 l/min. The deposit structures differed considerably. The deposits were free

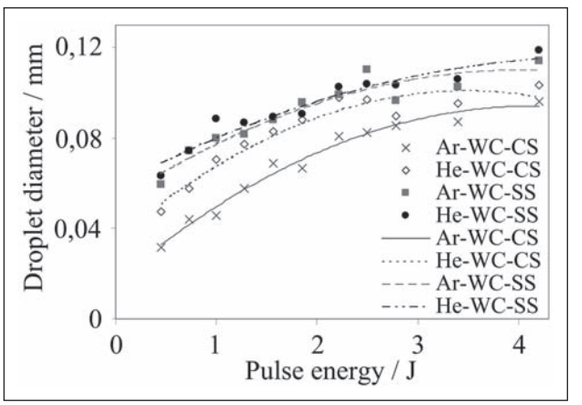

Figure 1 Average diameter of droplets as a function of electric pulse energy

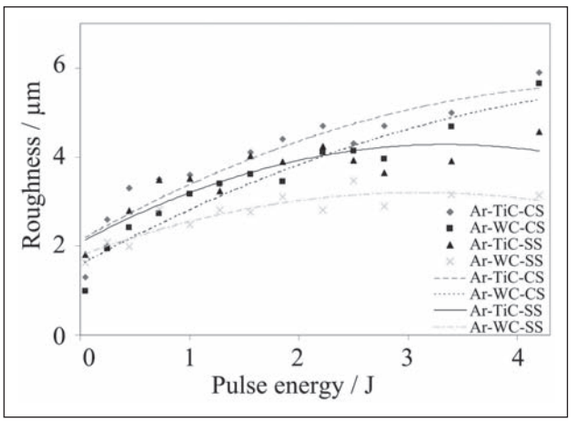

Figure 2 Surface roughness of the deposited layer as a function of electric pulse energy

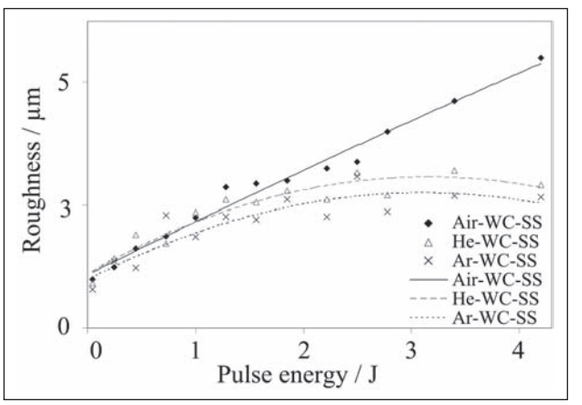

Figure 3 Influence of shield gas and electric pulse energy on surface roughness of deposited layer

of cracks. There was, however, some porosity, but less than in the case where no shielding gas was used.

Figure 3 shows the influence of the shielding gas and the pulse energy on the roughness of the deposited layer. When the two shielding gases used were compared, it was found that the pores in the deposit obtained with He showed a smaller diameter than those in the deposit obtained with Ar. There was less porosity if heat treatment, i.e., quenching and tempering, was applied after the deposition. This indicates that degasification occurred. The latter was stronger with He as the shield-

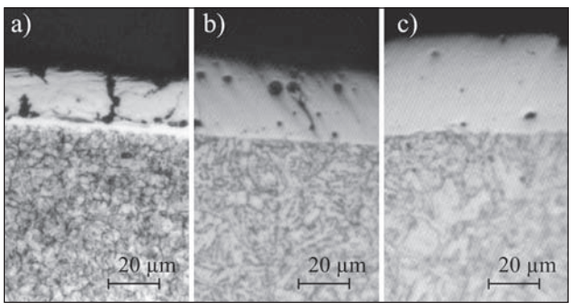

Figure 4 Macrographs of layers deposited: WC layer using no shield gas (a), WC layer using Ar (b), stellite layer using Ar (c)

ing gas. It is a fact that He is easier to degasify from the deposited layer than Ar. One of the basic findings is that the deposit made in the shielding atmosphere is much more homogeneous. The manufacturer of the device has not prescribed the use of a shielding gas, but the study showed that in such a case the resulting deposit was inhomogeneous. This is shown in Figure 4a.

Type of filler material

A comparison of the carbide deposits, i.e. of WC and the stellite 6 deposit, is interesting as well. With stellite 6 it was found that it was easier to deposit in Ar than in He. In this case it was found that the deposit showed almost no porosity, regardless of the fact that stellite 6 was deposited using Ar. The macro specimens of the WC deposit produced without shielding gas, of the WC obtained using He, and the stellite 6 deposit obtained using Ar are shown in Figure 4. The macrographs clearly show that the deposition should be carried out using a shielding gas and that stellite 6 is more suitable than tungsten carbide.

Thickness of deposited layer

The thickness of the WC and stellite 6 deposits ranged up to 30 μm whereas that of the TiC deposits ranged up to 20 μm. The deposit thicknesses obtained with He were greater than those obtained with Ar by approximately 15 to 20 %. The case was quite different, however, if the deposition was carried out without a shielding gas. In this case maximum thicknesses up to 12 μm were obtained regardless of the type of deposit.

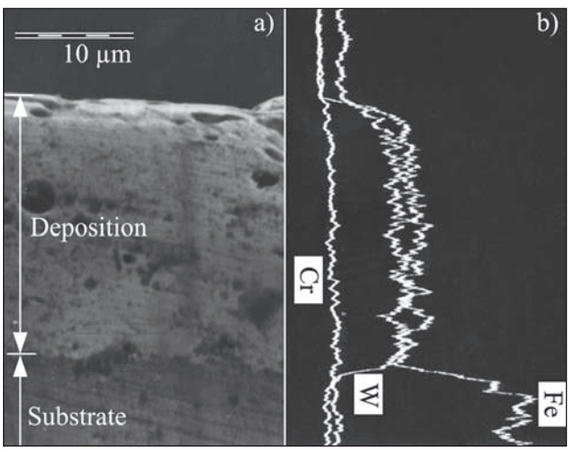

Figure 5 WC layer deposited using Ar (a) and line analysis of elements (b)

Deposit analysis

The only substrate used for the chemical analyses of the deposits made was the H13 tool steel. It was not heat-treated before deposition. For the analysis, TiC and WC layers were deposited on the substrate using Ar as the shielding gas. After deposition, the test pieces were heat-treated, i.e. quenched and tempered. They were additionally prepared before testing. For a through-thickness analysis of the deposited layer, however, the test pieces were cut. The cut surface was then ground, polished, and etched. The through-thickness composition of the deposit is shown in Table 1, not including carbon, whereas Figure 5 shows this for the WC deposit and Figure 6 for the TiC deposit, both obtained using Ar as shielding gas. Table 1 and Figures 5 and 6 indicate that the W and Ti contents decreased from the final layer of deposit to the substrate.

The same is true of the Co content in the deposit produced with stellite 6. As to the content of Fe, which is the main element of the substrate, the findings were quite the opposite. The results obtained are logical and were nothing to be surprised about. The thickness of the deposit obtained using Ar ranged between 22 and 30 μm, while that obtained using He ranged between 10 and 20 μm. There were pores in the layers, which were more numerous in the deposits obtained using Ar than in those obtained using He.

Table 1 **Chemical composition of the deposited layers obtained with different filler materials, different shielding gases, and at different locations**.

Deposit type	Shielding gas	Location of measurements	Chemical compositions / wt %							
			Cr	Fe	W	Ti	Co	Mo	Ni	Si
TiC	Ar	under surface	2,7	30,9	–	50,4	–	5,9	10,1	–
TiC	Ar	middle of layer	3,3	40,7	–	41,0	–	5,8	9,2	–
TiC	He	under surface	4,1	59,2	–	29,2	–	3,5	4,0	–
TiC	He	middle of layer	4,0	56,8	–	28,6	–	5,4	5,2	–
WC	He	under surface	2,7	40,7	54,0	2,6	–	–	–	–
WC	He	middle of layer	2,7	41,7	51,9	3,7	–	–	–	–
stellite 6	Ar	middle of layer	24,8	31,6	–	–	38,7	–	–	4,9
stellite 6	Ar	middle of layer	24,8	31,6	–	–	38,7	–	–	4,9

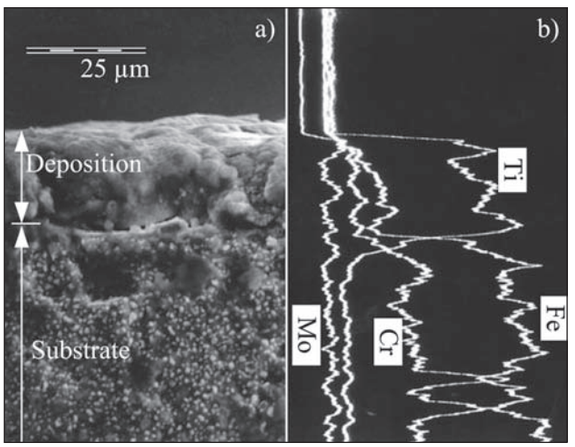

Figure 6 TiC layer deposited using Ar (a) and line analysis of elements (b)

In the TiC deposit produced using Ar, more Ti, i.e. around 40–50 % wt, was found than in the TiC deposit obtained using He (around 12–29 wt %). Similarly as with the WC deposit, in the layers of the TiC deposit, elements from the substrate, i.e. Fe and Cr, were found, which indicates interdiffusion between the elements of the deposit and those of the substrate. Ni (up to 10 wt %) and Mo (3–6 wt %) were found in the layers, too. They originated from the electrode material. The TiC layers deposited using Ar and He show approximately the same thickness around 10 to 20 μm.

In the stellite 6 deposit, Co, Cr, and Si were found. They were due to the elements from the deposit. Fe originated from the substrate. This indicated interdiffusion between the stellite 6 deposit and the substrate. The boundary between the layer and the substrate was represented by a line along which diffusion occurred. It was assessed that the zone next to the line was 1,5 to 4,0 μm wide. It was mainly in this zone that the elements from both the filler material and the substrate were found.

The chemical analysis of the deposits showed that the W content ranged between 4 and 18 wt %, while the Ti content ranged between 12 and 55 wt %. The W and Ti contents depended strongly on the deposition parameters, i.e. on the deposit thickness. A study of dilution in test pieces showed that the dilution was practically negligible. It was thus found that the type of shielding gas did not affect the rate of dilution. The differences occurred only in the deposit thickness, while the thickness of the layer in which dilution occurred was below 5 μm everywhere.

CONCLUSIONS

The electrospark process of depositing hard layers is one of the possibilities to improve the mechanical properties of surfaces, to re-establish worn-out surfaces, and thus to extend the life of tools or other machine elements. It is a rather simple process and permits repair of tools on site. The results obtained lead to the following conclusions:

1. In electrospark deposition, the use of inert shielding gases is a must. The inert shielding gas should protect the electrode tip and the molten surface on the workpiece.
2. The burn-off of Ti is the strongest of all the elements; therefore, Ti carbide should be deposited in vacuum or in an efficient shield of Ar or He.
3. WC, TiC, stellite 6, and other materials may be used as filler material. The highest-quality deposit (with respect to porosity) is obtained when using stellite 6 as the filler material.
4. An average droplet diameter when using WC as a filler material is around 80 μm and average droplet mass is around 40 μg.
5. On the average, around 100 droplets per second are transferred from the electrode to the workpiece.
6. Surface roughness of the deposit ranges between 0,8 and 5,5 μm.
7. The thickness of deposits ranges up to 50 μm and is strongly dependent on the welding current.
8. The width of the zone of dilution of the deposit with the substrate is around 4 μm.
9. On the macro level, the temperature of workpiece surface ranges below 100 °C.

It should be underlined that the process is highly useful in practice although it has not been scientifically studied much until now.

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Note: The responsible for English language is Marko Orešković, Ljubljana, Slovenia