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ESD (Electrospark Deposition) for surfacing of DMLS (Direct Metal Laser Sintering) tools

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The present paper focuses on the using of the electrospark deposition (ESD) for the surfacing of tools and tool inserts, which are made by direct laser sintering (DMLS) of steel powders and on this way to improve the characteristics of surfacing of tools. There is shown some characteristics of ESD. A relevant device and the process are schematically described and some makrosection of coatings is shown.

1. INTRODUCTION

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

Direct laser sintering of metal powder (DMLS) is nowadays certainly one of the most advantageous processes for Rapid prototyping (RT) and Rapid Tooling (RT) purposes. DMLS can be used for two main applications: direct laser sintering of tool inserts for injection moulding of plastics and casting of aluminium, and direct production of steel component as final products. Geometries that are difficult or even impossible to produce by conventional methods, such as complicated internal channels, can now be used for functional testing in, for example, the automotive, electronics and household appliances industry. Some recent research work on deposition of Ni, TiN, CrN or similar coatings is promising for the improvement of tool life and application of sintering parts for moulding of abrasive materials and materials with high loads. One of possibility is also using of ESD.

2. ESD – ELEKTROSPARK DEPOSITION

In the experimental work, a classical unit permitting 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. This means that the capacitors discharged at the moment at which the electrode came into contact with the surface. The parameters in the electrospark deposition, i.e., welding current, the type of filler material, and the type of shielding gas, were varied. Thus three different types of filler material were used. The deposition process was carried out without a shielding gas, with pure argon (Ar), and with pure helium (He) respectively.

Electrospark deposition is a specific process. Taking into account melting of the electrode and substrate, the material transfer, and other physical processes, this is a hybrid process. In the process two different kinds of energy are involved. The first is the energy of electric current i.e., Joule's heat and arc heat, and the second the mechanical energy, i.e., electrode vibration. The unit consists of a current supply and a welding head with the electrode. In the course of welding, the electrode will vibrate and melt whereas the electrode material will be transferred to the workpiece in the form of droplets. The electrode holder for electrospark deposition and its process is schematically shown in Fig. 1.

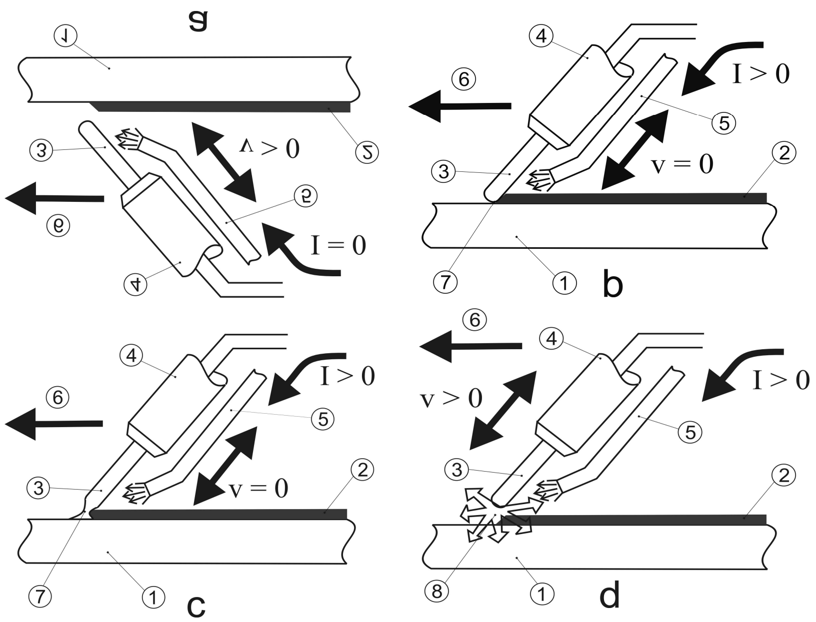

Figure 1. Schematic representation of the material transfer in electrospark deposition.
(I – electrical current, v – movement of the electrode (filler material), 1 – workpiece; 2 – deposited surface; 3 – electrode (filler material); 4 – welding head; 5 – shielding gas, 6 – welding direction; 7 – short circuit between electrode/workpiece; 8 – spark, i.e., welding arc. (a) Before electrospark deposition, (b) start of short circuit between electrode/workpiece, (c) before the interruption of short circuit, and (d) arc ignition between electrode and workpiece.

3. DMLS – DIRECT METAL LASER SINTERING OF TOOLS

In the process of sintering metal powders, called direct metal laser sintering (DMLS, see EOS www.eos-gmbh.de), a laser beam of higher intensity directly melts a metal powder (or one of its components) which is added as a thin layer (approximately 0.2 mm). After each pass over the surface layer the laser beam creates a two-dimensional shape of the desired product. With the movement of the powder container and additional supplement of the next layer of powder a three-dimensional form of the product can be produced (Fig. 2).

Some main characteristics of DMLS

Layered, material additive manufacturing
Laser sintering of cross sectional area
Net shape process, minimal shrinkage
Fully automatic, PC controlled process
Metal powder mix, no polymer binders
No high temperature post processing
Rapid and direct manufacturing of metal components and tool inserts from CAD data
Scanning optics and 240 CO_2 laser

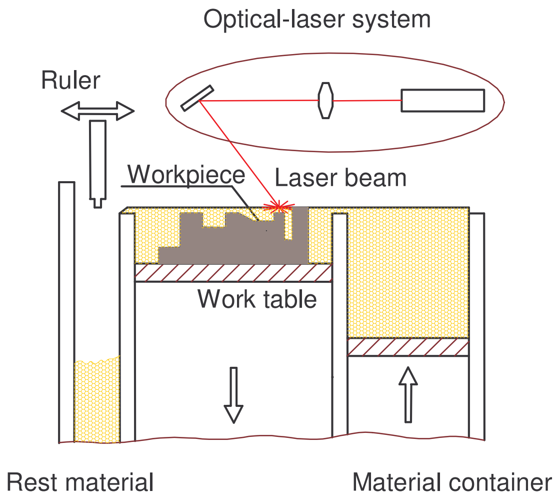

Figure 2. Principle of laser sintering of metal powder

For the DMLS applications two different materials are now available, the first one is one the basis of bronze (DirectMetal) and second one on the basis of steel (DirecSteel), both in granulation of 50 or 20 µm. Granulation and the composition of the material are related to sintering speed the applied and subsequent characteristics of the parts (some of the most important, obtained in using different powders, are presented in table 1 (Syrjala at [1]).

Table 1: Some of the characteristics of the DMLS parts

	DM 50	DM 20	DS 50	DS 20
Attainable accuracy of the part (µm)	± 80	± 50	± 100	± 50
Minimum thickness of the wall (mm)	0,7	0,6	0,9	0,7
Porosity of the part (min %)	20	8	5	2
Tensile strength (MPa)	200	400	500	600
Hardness (HB)	90	110	200	220
Surface roughness Ra (µm)	14	9	18	10
Roughness after shoot penning Ra (µm)	5	3	7	4
Roughness after polishing Rz (µm)	< 1 µm			
Coefficient of thermal extension (10^{-6}/K)	25	18	18	9
Thermal conductivity (W/mK 25 ^{0}C)	15	25	25	13
Maximal working temperature (^{0}C)	400	400	800	800

The life of laser sintering tool inserts can be already achieved for up 100 000 moulded parts, and for the casting of aluminium or similar metals the sintering tools are applicable only for testing purposes (below one thousand parts). The tool life of the laser sintering tool inserts can be significantly improved with the deposition of hard surface coatings (Dolinšek at [2]).

4. MAKROSECTION OF THE DEPOSITED LAYER

The filler material transferred from the electrode to the small molten area at the workpiece is diluted by the substrate. This dilution considerably decreases with every 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; therefore, it is important how high the energy input is in the first layer. The higher the energy input, the thicker the deposit achieved in the first material transfer and the higher is diluted between electrode material and substrate. Further material transfers to a certain area serve only to provide a uniform deposit and ensure that there are no spots without a deposit.
Nevertheless the deposit shape strongly depends on the deposition parameters, particularly its appearance. Fig. 3 presents two makrosection of the deposited layer. Left side (a) is a part of DMLS tool with deposited tungsten carbide (WC) using the ESD process, right side is DMLS tool with the melted up-skin layer.

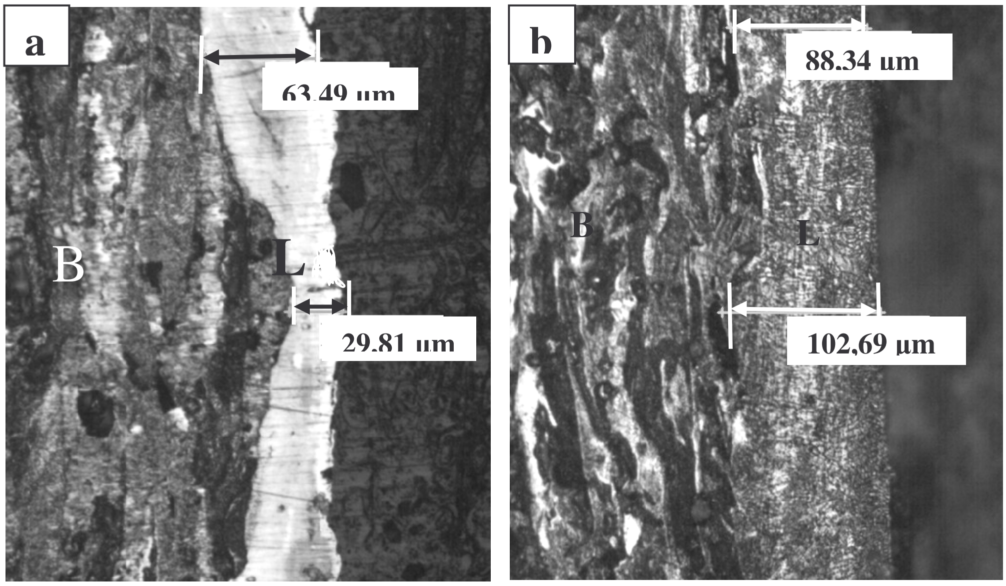

Figure 3. Macro section of two layers carried out by ESD process:
B – base metal (DMLS – tool), L – deposited layer: a – tungsten carbide, b- melted layer

With B is indicated base material; i.e. DMLS tool or inset for tools and with L layers. Magnification of this macrosection is so big, that is possible to see some layers in the base metal, which are made by laser sintering. In the layer of tungsten carbide (hardness 980 $HV_{0,1}$) are same porosity and some very small cracks, which are not very important. The melted up-skin layer (b) is much more homogeneous (hardness 250 $HV_{0,1}$).

5. CONCLUSION

The paper presents the electrospark process of depositing hard layers as a possibility for improving mechanical surface properties of the DMLS tool inserts and thus extend its life. It is a rather simple, on-site process for repairing tools without additional surface treatment.

6. REFERENCES

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2. S. Dolinšek, S. Ekinović, J. Kopač, M. Dolinšek: Introduction of DMLS rapid tooling technology into Slovenian industry, , CIM 2003, Lumbarda, Korčula, 2003.