Effect of Freezing Point and Surface Roughness on Coating by Electro-spark Deposition

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Abstract—WC-8Co and Nak80 is deposited on the surface of 45 steel by DZ-4000(Ⅲ) multifunctional surface hardening machine what use argon as shielding gas. By means of changing the order of WC-8Co and Nak80 electrodes' deposition and different of roughness of Nak80 coating's surface, thesis analyzes the effects what the freezing point and roughness have on composite coating thickness and topography as well as morphology of cross-section. The result shows that: only when WC-8Co electrode deposits (the WC-8Co's freezing point is higher than Nak80's) on surface of Nak80 coating which roughness is prodigious, the matrix cannot fasten the prill of WC-8Co what concretionary first and the splashing prill also takes Nak80 away what leads to bring the composite coating thickness down.

Key words-freezing point; electro-spark deposition; roughness.

I. INTRODUCTION

With the development of society, the utilization facto of metalwork has been greatly increased in the production life while more attention is paid to the antiseptic and rigidity of metalwork's surface. In this case, the electro-spark deposition has been thoroughly concerned as emerging process means in the 20th century.

There are few classifications of electro-spark deposition which generally have electrical discharge and deposition for two mainly parts by the effect.

The electrical discharge is mainly divided into three parts — approach、electron bombardment and transfer of the materials.

1) Approach: reduce the distance between the electrode and matrix to meet the requirement of on-load voltage breakdown. The breakdown distance mainly depends on the magnitude of on-load voltage as well as the medium between the electrode and matrix and so on.

2) Electron bombardment: there is electrical discharge between the electrode (anode) and matrix (cathode), the electron on the cathode bombards to the anode which makes the electrode material gasify or liquefy meanwhile forms the ionization.

3) Transfer of the materials: the liquid electrode material which is affected by the electric field migrates to the matrix through the ionization. The amount of the liquid electrode material rests with the output voltage and output capacitance as well as the texture of itself.

The deposition part is divided into the combination and metallurgy in general.

1) Combination: the liquid electrode material bombards to the matrix and combines with the liquid matrix material. More difference between the freezing point of the electrode and matrix and more rough the surface of matrix is, the less deposition there is on the matrix.

2) Metallurgy: there is metallurgy phenomenon while the electrode material deposits on the matrix, with the sharply reduce of the temperature, the deposition emerges quenching effect and obtains better hardness and abrasive resistance. The factors like materials' density and specific heat as well as viscidity and fluidity of the materials when it comes to liquid state impact the depth and fuse of interinfiltration between the two materials.

Thesis investigates the WC-8Co and Nak80 electrode deposition on the surface of 45 steel, and analyzes the effect which the different freezing point and roughness have on the composite coating.

II. EXPERIMENT METHOD

TABLE 1 PROCESS PARAMETERS

Voltage (V)	Frequency (Hz)	Capacitance (μF)	Protect gas (L/min)
80	2500	180	6

TABLE 2 EXPERIMENTAL SCHEME

Number	1	2	3	4	5
Deposition order	1	2	1+2	2+1	2+1
Time（min）	4	4	4+4	4+4	4+4

Note: in the deposition order, 1 means WC-8Co electrode, 2 means Nak80.4+4means to deposit 4 minutes first, then 4 minutes after polishing with 600# abrasive paper.

In this study, wire-electrode cutting device is used to complete the experiment. The deposition test is accomplished with DZ-4000(Ⅲ) multifunctional surface hardening machine which is manufactured by surface engineering research laboratory of China Agricultural Machinery Institute, measures the matrix and deposition's thickness with digital micrometer and observes the topography as well as morphology of cross-section of deposition with Olympus metalloscope.

The matrix is a formwork of 45 steel mould abandoned by a mold factory in Dalian. Incision the whole formwork into 6*10*15mm (deposit on 10*15mm) then wipe oil stain off the test specimen, polish the surface of matrix with 200# and 400# abrasive paper to strip the rust away, at last, clean the surface with acetone before the experiment. The electrode basset 8-10mm and uses argon as shielding gas when deposition. The process parameter refers to Table 1 and the experiment scheme refers to Table 2. The electrode material is WC-8Co and Nak80, all the diameter are Φ 5mm, the freezing point of WC is 2775℃ and Co is 1495℃ meanwhile Nak80 is 1350℃.

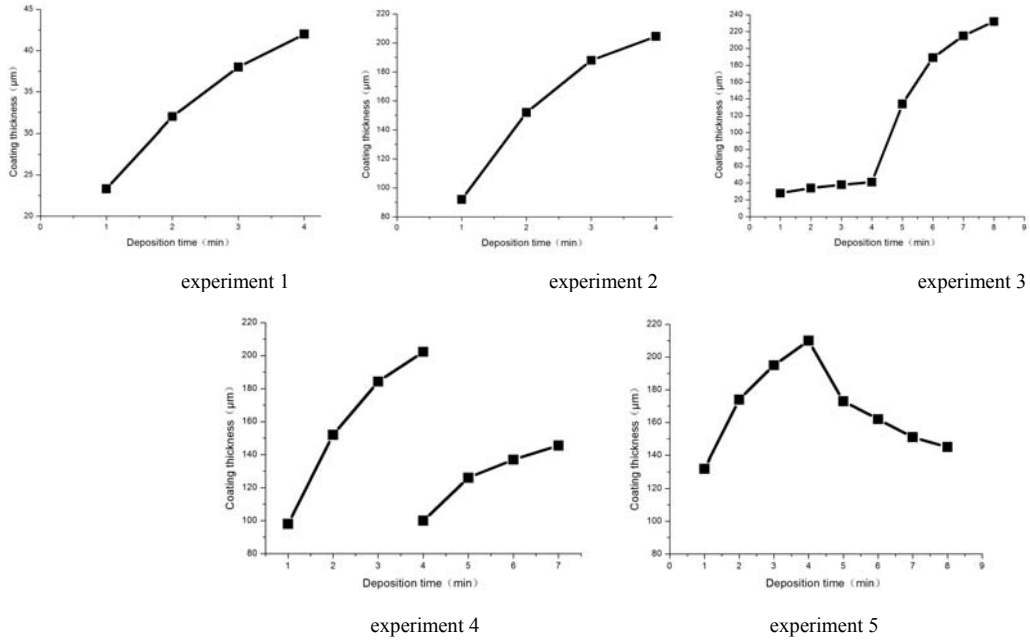


Fig.1 Coating Thickness

III. EXPERIMENTAL RESULTS AND ANALYSIS

A. *Coating thickness*

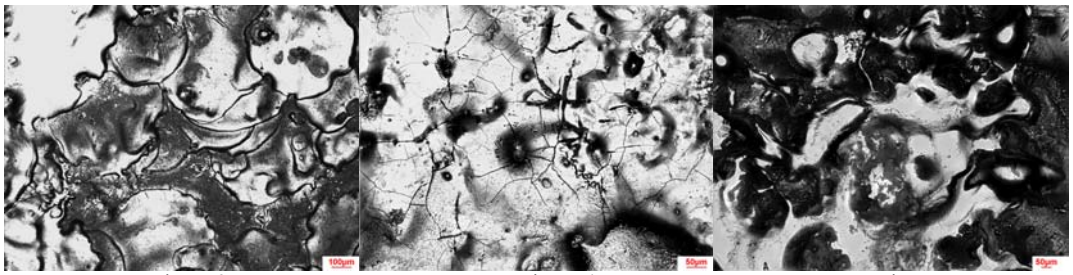
In Experiment 1-5, to measure the thickness each one minute when deposition with digital micrometer, and obtain the test data curve referring to Fig.1.

Experiments 1 and 2 of Fig.1 are the growth curve of deposition thickness when use WC-8Co or Nak80 as single electrode, the single electrode with WC-8Co as well as Nak80 can combine with 45 steel preferably on the surface when after polishing. Within 4 minutes, the increment speed of both kinds of coating thickness is favorable. The thickness of WC-8Co is 42μm and Nak80 is 204 μm

In Fig.1, compared with experiment 5, the deposition order of WC-8Co and Nak80 electrode is opposite in experiment 3. In experiment 3, when Nak80 electrode deposit on WC-8Co coating, the thickness increases rapidly, and approximately equals the sum of thickness of WC-8Co and Nak80. In experiment 5, when WC-8Co electrode deposit on Nak80 coating, the thickness reduces rapidly as a result of that WC-8Co freezing before Nak80 because of higher freezing point, Nak80 can't fasten WC-8Co electrode fine, and take few WC-8Co away when splashing.

In Fig.1, compared with experiment 5, the electrode has the same deposition order in experiment 4 but less rough than experiment 5 because of polishing before deposition. In experiment 4, Nak80 coating is polished with 600# abrasive paper until the surface is smooth (the thickness reduce to 103μm from 201μm because of polishing) before deposition. The deposition thickness growth curve of WC-8Co electrode deposition in composite coating is similar to single WC-8Co electrode's, the thickness is 142μm. WC-8Co can deposit on surface of Nak80 coating preferably. In experiment 5, without polishing, the thickness of composite coating reduces, the outsize roughness of Nak80 coating and crack as well as too much blowhole make liquid WC-8Co to splash result in

reduced thickness.



experiment 3 experiment 4 experiment 5

Fig.2 Surface Topography

B. Surface topography

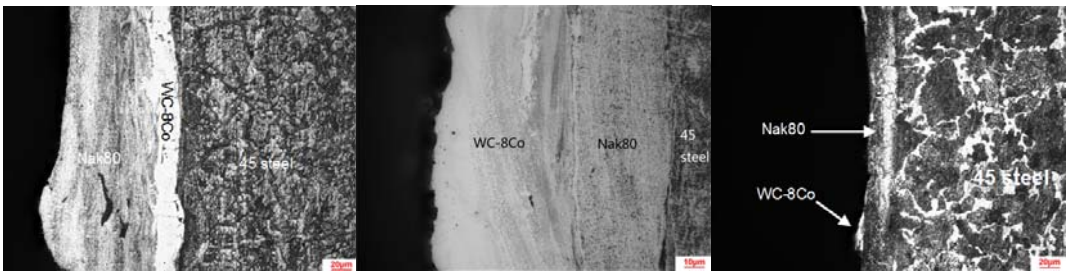
Fig.2 shows the topography of experiment 3 to 5. There is the same electrode (WC-8Co and Nak80) and matrix (45 steel) in the three experiments but the much difference among the topography.

Fig.2 Experiment 3 shows a plate-like and terrace-like topography. Nak80 electrode deposits on surface of WC-8Co coating and obtain a favorable combining although without polishing smooth, and the WC-8Co has been completely covered with Nak80 electrode material

Fig.2 Experiment 4 shows the surface has been covered with WC-8Co. Because WC-8Co has a higher hardness and can't bear bigger inner-stress, the surface is filled with crack. WC-8Co electrode can combine with Nak80 coating preferably when deposits on the coating with polishing smooth.

Fig.2 Experiment 5 shows the topography formed by the solidification after the WC-8Co electrode single-point discharge is similar to the splash shape. There is a serious spatter and dull black oxidation (black section) during deposition because of argon failing to play a protective role. WC-8Co electrode can't combine with Nak80 coating or cover the whole Nak80 coating without polishing.

In conclusion of experiment 3 to 5, the electrode used second time can preferably cover the whole surface of primary coating in experiment 3 and 4, yet liquidity of WC-8Co is better than Nak80 when they are liquid, the edge of coating formed by WC-8Co electrode single-point discharge is zigzag while the Nak80 is discoid. In experiment 5, the surface is covered with only a little WC-8Co, and has a serious oxidation phenomenon. WC-8Co is difficult to deposit on surface when the Nak80 coating is relatively rough.



experiment 3 experiment 4 experiment 5

Fig.3 Cross-section Morphology

C. Cross-section morphology

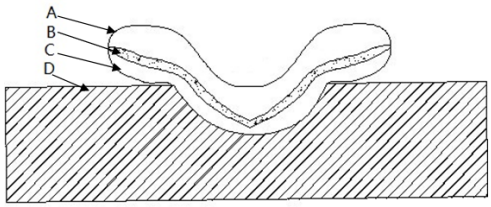
Fig.3 Experiment 3 and 4, there is obvious three stories among 45 steel、WC-8Co and Nak80 when the test specimen section is corroded by 4% nitric acid alcohol. 45 steel has the most serious dull black and corrosion, the second is Nak80, and WC-8Co has the best corrosion resistance (white light layer). In experiment 3, Nak80 can preferably combined with WC-8Co coating without the best process parameter, and there are defects such as pore and micro crack what affect coating quality in Nak80 coating. In experiment 4, the boundary line between WC-8Co and Nak80 is straight because of polishing the surface of Nak80 coating before deposition, and WC-8Co electrode has a favorable combining with Nak80 after deposition.

In Fig.3 Experiment 5, the Nak80 layer is clear, while WC-8Co is little. WC-8Co electrode reduce the thickness of Nak80 coating and has a effect of repeatedly quenching with argon failing to protect, there simultaneously is a various of phenomenon such as the thinner thickness of Nak80 settled layer、micro crack on section、micro pore along with more metal fragmentation.

D. Theory of materials combining

Deposition discharge theory diagram refers to Fig.4, A is liquid WC-8Co, B is mixture of liquid WC-8Co and liquid Nak80, C is liquid Nak80 while D is solid Nak80. When WC-8Co electrode bombards to Nak80 coating and splashes as spray, the temperature drops hastily (it is considered that the temperature of sector A、B and C drop at the same time),

sector A curdle first, and B is the second, C is the last. WC-8Co can't adhere B and C well after freezing because of lubrication action of liquid Band C. WC-8Co can't splash far due to gravity and most of them will combine with matrix on a smooth surface. If the surface is rough, sector A will splash into air while taking the material of sector B and C along, then curdle into solid prill without combining which cause the reducing of matrix thickness. Otherwise, A is liquid Nak80, B is mixture of liquid WC-8Co and liquid Nak80, C is liquid WC-8Co and D is solid WC-8Co, the effect of roughness is less than freezing point when Nak80 electrode deposit on WC-8Co coating, the coating thickness will increase.



(A: liquid electrode material; B: liquid electrode and the matrix material; C: liquid matrix material;D: solid matrix)

Fig.4 Deposition Theory

IV. CONCLUSIONS

1) The maximum composite coating thickness when WC-8Co and Nak80 electrode deposit on surface of 45 steel is 223.5 μ m.

2) When surface of Nak80's roughness is high, WC-8Co will curdle first and splash while taking materials of Nak80 coating result in reducing of composite coating thickness when deposit on surface of Nak80 coating because of higher freezing point.

3) When surface of Nak80's roughness is low, there is a excellent combining and stable composite coating when WC-8Co electrode deposit on surface of Nak80.

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