# Repair heavy-duty generator rotor shaft by electro spark deposition process†

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**KEY WORDS**: (Electro spark deposition) (Generator rotor shaft) (Repair)

## 1. Introduction

As the basic industry of national economy, power industry has been the focus of national development. Recent two decades, it is the fastest development period and gains the most achievements [1] [2].

If the generator rotor shaft wear or damage occurs, rotor running at high speed is hindered and generator output power decreased, which may result in the units failure [3]. This paper discusses that the repair of worn parts for generator rotor shaft at site using DZ 1400 Electro Spark Deposit (ESD) system manufactured by Surface Engineering Technology Institute of CAAMS with satisfactory results and successful experiences.

## 2. Electric Spark Deposition (ESD)

### *Electric Spark Deposition Principle*

Electric Spark Deposition (ESD) process is to instantly release in high frequency high-energy from the power supply between electrode and substrate, then produce air ionic passage, inducing micro-zone of high temperature, high-pressure physic-chemical metallurgical process between high alloy electrode and substrate surface.

ESD process combines the characteristics of welding, spraying and other processes with low heat input, good metallurgical bonding between weld pass and substrate.

### *ESD Equipment*

Power output of ESD (DZ-1400) is 1400W，using argon for welding, self-consumable anode moves at 4700rps at the worn place of the work piece, induce HF spark discharge, and form dense and homogeneous overlay coating with a thickness up to 2mm or more. Substrate temperature remains around 60℃during repair, and the substrate does not distort and undercut. **Table 1** is ESD parameters.

## 3. Experiment and Analyses

### *Sample preparation*

According to the common material of rotor shaft, 35CrMoA is selected as the sample substrate material with the size of 25mm×10mm×50mm.Nickel-based high alloy rod is chosen as electrode material with a specification of ϕ3.2mm×6.0mm, the chemical composition is listed in **Table 2**. After pretreatment, connect tightly substrate with ground line of ESD, and repair welding on the sample surface with a thickness of 1mm. After overlaying by ESD, obtain cross-section of the coating by line cutting method and prepare metallographic sample.

**Table 1** ESD Parameters

| Model | Input | Output | Size | Weight | Capacity | Discharge Frequency |
|---|---|---|---|---|---|---|
| DZ-1400 | AC 220 50 HZ | 1.4 KVA | 40× 60× 80 | 40 Kg | 420 F | 50-1200 HZ |

**Table 2** Chemical composition of the electrodes for sample

| Ni | Cr | Fe | Mo | Mn | Si | Other |
|---|---|---|---|---|---|---|
| **70** | **14** | **4.5** | **---** | **7.8** | **0.5** | **Bar** |

### *Test Analysis*

**Figure 1** is the cross-section micrograph (×3000) of the coating. It's known that:

1) There isn't welding defect such as pore, oxide slag inclusion, crack, etc. in overlay.
2) Crystallite of overlay and substrate transition layer is fine, no growing tendency.
3) The coating structure is very fine small columnar crystal, which shows good corrosion and abrasion resistance.

**Figure 2** is the energy spectrum analysis of Ni, Cr elements in the coating. The thickness of heat-affected zone of ESD is 10 $\mu$ m. It demonstrates that a good metallurgical bonding can be obtained by ESD, also shows that deposit heat-affected zone is small and welding residual stress can be ignored. The average hardness of coating and heat-affected zone is very close to the matrix hardness HV220.

### *Result*

The result of experiments show the metallurgical bond between coating and substrate has not welding defect by depositing inconel alloy on substrate 35CrMoA using ESD process. After welding, heat-affected zone is very narrow

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(thickness of coating reaches 1mm, but heat-affected zone is only 0.01mm), hardness of coating conform to that of substrate. The above results meet the requirement of rotor shaft repair in power plant.

**Fig. 1** Cross-section micrograph of the coating（×3000）

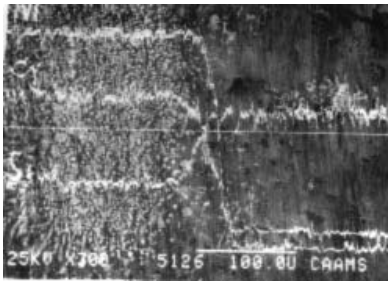

**Fig. 2** Heat-affected zone testing

## 4. Field Repair

***Pretreatment***

First, the worn section of shaft is filed. Then oxide and fatigue layer of the surface to repair is cleaned using sandpaper or flat file. After the iron cutting is cleaned using brass wire brush or compressed air, the oil stains of shaft surface are cleaned using acetone solution.

***ESD Equipment Preparation***

The removal & mounting and transport of generator rotor are difficult for its large size and weight of tens of tons, and repair has to be on the site. DZ-1400 ESD system is installed near the location of shaft to repair. AC220V power supply and industrial pure argon gas source are properly connected with quick connector. The argon gas flow rate is set at 7L/ min, the electrode should be controlled out of 2-3mm to ensure protective effect of argon gas during welding.

***Overlay deposition***

Refer to the processes provided by the equipment manual, welding at the worn part of generator rotor shaft to obtain silver homogeneous coating, which is the desired effect.

Visual check overlay after each layer (about 50μm thickness) to see if has welding defects such as oxide, if has, use needle file to remove and use brass wire brush to clean, then overlay the next layer. When overlay is close to the desired size, use toolmaker's straight edge to align, the overlay should be more than the final repaired size 50-70μm. After the completion of overlay, if there is weld spot or side missed during inspection can make up welding.

***Post-treatment***

After the completion of ESD, the bench worker will work on the dimensional recovery and finishing polish of the repaired surface of the shaft. The repair standard refers to the technical specifications of shafts. **Fig. 3** is seal section shaft of generator rotor after repair and finishing, respectively.

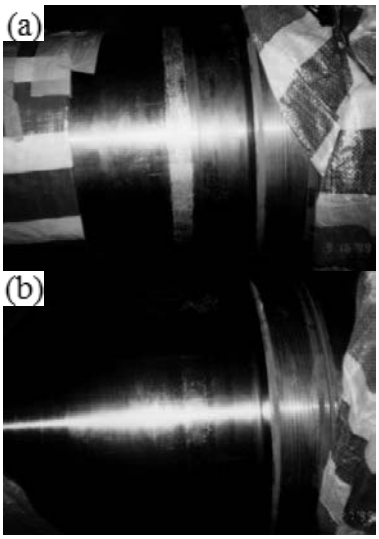


**Fig. 3** Seal section shaft after repairing and finishing, (a) repairing; (b) finishing.

## 5. Conclusion

(1) Between ESD overlay and substrate is metallurgical bond, heat-affected zone is very narrow, and residual stress can be ignored.

(2) Rotor seal section shaft of power plants can be repaired by ESD on the site, and the process is simple. There is a little post processing after patching to reduce downtime.

(3) We have collaborated with several power plants by ESD repaired seal section shaft of generator rotor with success and gained great economic and social benefits.

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