A Review on Electrical Discharge Coating (EDC) and its Multi-Optimization Techniques

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Abstract. This paper, primarily, enlightens the properties of the Electrical Discharge Coatings in the view of hardness. Coatings that withstand extremely high temperature, chemical corrosion, stress and other hostile environments are required in industries as functional surfaces. This type of coatings has already applied for purposes such as biomedical, aerospace, automobile etc. Then, secondarily, brings out the different types of optimization techniques and machine learning models used in the field of electrical discharge machining/coating.

Keywords: Coatings; CVD; EDC; Electro-Plating, Optimization Techniques; PVD.

1. Introduction
Improvisation and modification of material surface or workpieces with respect to mechanical, physical and biochemical properties could be carried out by hard coatings [1]–[4]. Surface modification with hard coatings have enhanced the resistance to corrosion, erosion and abrasive wear. In the field of biomedical, enhancement of biomechanical and morphological compatibilities between the already available and new receiving body tissues for promoting osteointegration, surface modification plays a vital role [2], [5]. Hard coatings have strong applications in dental and orthopaedics and previously, this was carried by carburising, electroplating and plasma spraying. Figure 1 explains the different types of coating procedure viz., PVD, CVD, electroplating, thermal spraying and EDC.

Recently, Electro-Discharge Coatings (EDC) have led to renewed interest which modifies the surfaces by electrical discharge energy. In EDC, an extremely high temperature of around 10000 degrees is used to melt the electrode material and deposit it on the surface of workpiece. This process will also be carried out on the Electrical Discharge Machine (EDM) as shown in Figure 2. In the Figure 2, three types of EDM’s, normal EDM, powder mixed in dielectric medium EDM and powder metallurgy electrode EDM are shown.

Like EDM, is used for brittle conductive and hard materials since it can melt any conductive materials regardless of its hardness without being in contact, EDC can also coat on the workpiece. Within a constant spark in minute gap between tool electrode and workpiece material, in a short span of time, a series of electrical sparks or discharges occur [27]. In this paper, EDM to EDC, Types of Electrical Discharge Machines used for EDC and techniques involved in achieving the higher thickness and list of optimization techniques are covered.
2. Review of EDC

Figure 3 shows the processes involved in ED Machining and ED Coating. In the same, material removal and material deposition can be carried out by fixing the suitable parameters. For EDC, Reverse polarity (electrode positive terminal) is more suitable than straight polarity (electrode negative terminal). Surface roughness, layer thickness and Material Deposition Rate can be controlled by peak current and pulse-on time [28], [29].

Different Types of Electrical discharge machine (EDM) for Electrical discharge coating (EDC). Figure 4 shows the different types of EDM machines, necessary process parameters and performance parameters.

But very few are only used for coating which are explained in Figure 5.

3. Case Studies

In the first case, Titanium alloy (Ti6Al4V) is being used a workpiece and brass as electrode. In the dielectric medium of de-ionised water, molybdenum disulphide (MoS2) powder of micron level is mixed and coated with micro-EDC[30], [31]. SEM and EDS image are shown in Figure 6. Dielectric fluid mixed powder can enhance the coating quality and reduce defect such as micro-holes. Significant effect can be observed by increase in concentration and particle size of the powder used and it can reduce environmental pollution problems by reducing dielectric fluid.

In the second case, Ti6Al4V workpiece is being used to test the micro-electro discharge coating using WS2 and Brass PM electrode. Figure 7 shows the SEM and EDS of the coating obtained. Layer thickness of the coating and tool wear rate depends upon the compact load applied while manufacturing PM electrode.
Figure 2. Different Types of EDM, (i) EDM, (ii) powder mixed EDC and, (iii) powder metallurgy electrode EDC [10, 11, 19, 20, 21, 22, 23, 24, 26].

Figure 3. EDM process Vs EDC process.
Figure 4. Procedure and process parameters involved in EDMs.

Figure 5. Types of EDC being in use.
Figure 6. SEM and EDX of Ti6Al4V workpiece in powder mixed dielectric medium [30].

Figure 7. SEM and XRD of Ti6Al4V with PM electrode [32].

4. Optimization Techniques

Techniques used by the researchers in this field for optimizing the parameters of Electrical Discharge Machines is been explained below. Techniques summarized could be useful for the researchers working in this field of EDC.

T1. Taguchi Experimental Optimization [33,34,35,36]
T2. Response Surface Methodology [30,37,38]
T3. Grey Relational Analysis [38,39]
T4. TOPSIS [38,40]
T5. Neural Network [38,41]
T6. Genetic Algorithm [42,43]
T7. Artificial Bee Colony Optimization [44]
T8. Finite Element Method [47,48]
T9. Simulated Annealing [45,46]
T10. Ant Colony Optimization Algorithm [49,50]
T11. Particle Swarm Optimization [50,51]
T12. Fuzzy-Optimization [51,52]
T13. Sheep Flock Heridity Algorithm [42,45,53]

Former 1 to 4 technics are most often used by the researchers because of its simplicity so are
they not considered here for explanation. Among the remaining techniques, procedures of few are explained in the figure as flowcharts. For in-depth knowledge about the above-mentioned techniques, refer to the citations.

4.1. Neural Network (NN)
NN works by learning the relation between input and output parameters. It has two types of propagations: feed forward and backward propagation methods in artificial neural networks. But only disadvantage of using neural network is it completely depends upon the amount of data. In order to have better accuracy, large amount of data is required. In the field of EDM, around 100 experiments were performed to apply neural networks.

4.2. Genetic Algorithm (GA)
GA developed on the foundation of probability that searches in a parallel and random way via operations of crossover, mutation and reproduction. ‘Survival of the fittest’ method is being used to preserve and control a population of solutions and implement them later for answers. It has the ability to solve both linear and non-linear problems and basically it was inspired by the Darwin’s concept of evolution.

4.3. ABC Optimization
ABC optimization is encouraged by the forage behaviour of honey bees. It works by two groups: un-looker bees and employed bees. In which, skilled bees will have an idea about the food source (nectar position) and food standards (nectar quantity). When unemployed bees receive information about food source, they turn into employed by luring the food from employed. So, always, unemployed bees are proportional to the employed bees. This concept is being used to solve continuous optimization problems.

4.4. Finite Element Method (FEM)
FEM is one of the most used techniques in the field of mechanical design to solve engineering problems. In this area of EDM/C, it could be used to solve structural issues occurring the process of material removal or deposition. ANSYS is the most used software for FEM and the accuracy of the solution depends upon the mesh shape and size. Meshing tactics are important to obtain high accuracy.

4.5. Simulated Annealing (SA)
As the name suggests, it works based on the cooling phenomenon of molten metal and it has evolutionary algorithms for searching the global optimum.

4.6. Fuzzy Logic (FL)
Any reasoning method of human within the linguistic terms helps to enable any user to model any reasoning method. Within the fuzzy set, the fuzzy values are set by the elementary functions that outline the degrees of elements of a selected object. Collection of the semantic statements characterizes the fuzzy model made with fuzzy rules to build up the link between inputs and outputs. Specific fuzzy system contains different number of fuzzy standards and fuzzy rules involved with every input variable. IF-THEN rules are accustomed for making the fuzzy logic. Single scalar terms, de-fuzzification method converts scalar quantity from the fuzzy quantity for output process [24].
4.7. *Sheep Flock Heridity Algorithm (SFHA)*

As the name suggests, sheep live within their own flock under the manage of shepherds. Hence, the inheritance of genetics develops within the flock only. Certain characteristics will grow only within the flock by heredity and the sheep with large fitness characteristics to their surroundings will breed in the flock. Sheep in neighbouring flock can be inherited to the sheep in additional flock by mixing of flocks. After the mixing of flocks, the one with superior characteristics to the field surroundings, breeds most. In contrast with this process is natural evolution which correspondence to genetic operations. This again has two types: (i) sub-chromosome level genetic operation and (ii) chromosome (global) level genetic operation.

5. **Conclusions**

Electrical Discharge Coating (EDC) is the recent development on the Electric Discharge machine for surface modification. In this paper, evolution of EDC from the EDM is explained along with the different types of ED machines available. Methodologies, parameters and characteristics of various EDC processes were discussed. Explanation of EDC in comparison with other available hard coating procedures is given. Various types of optimization techniques used in the field of EDM for optimizing input parameters w.r.t to required output performance parameters are listed and discussed.

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