MATERIAL DEPOSITION ON ALUMINUM BY ELECTRICAL DISCHARGE COATING (EDC) WITH TUNGSTEN POWDER SUSPENSION

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This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering

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Author's Name: **Yap Ching Yee**

Date: 31 **May 2018**

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka (UTeM) as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.).

The members of the supervisory committee are as follow:

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ABSTRACT

Among the metals, aluminum has a huge application and requirement for the industrial sector. However, the aluminum mold and die corrodes and wear after a duration of service life. Therefore, the material deposition on aluminum mold and die material was carried out in this research by using Electrical Discharge Coating (EDC) with tungsten powder suspension. The objective of this research is to investigate the effect of EDC parameters (peak current (Ip), pulse on time (Ton) and discharge voltage (V)) on weight percentage of deposited elements and micro-hardness of the deposited surface by using EDC process with tungsten powder suspension. The Sodick AQ35L die-sinker EDM machine will be used to run the experiment. After the experiment, the weight percentage of the deposited elements and surface topography of the deposited surface will be investigated by using a Energy Dispersive X-ray (EDX) and Scanning electron microscopy (SEM) respectively. While the micro-hardness of the deposited surface will be determined by a Micro Hardness Testing Machines. The expected result of this research are the tungsten powder will be deposited on the aluminum surface, the parameters used will have a significant result toward the weighted percentage of deposited elements and surface topography and also the micro-hardness of the deposited surface will be improved compared to the hardness of original workpiece.

ABSTRAK

Antara logam, aluminium mempunyai aplikasi dan keperluan besar untuk sektor perindustrian. Bagaimanapun, acuan aluminium dan dai akan mengakis dan memakai selepas tempoh hayat perkhidmatan. Oleh itu, pemendapan bahan pada acuan aluminium dan bahan dai akan dilakukan dalam kajian ini dengan menggunakan Lapisan Pelepasan Elektrik (EDC) dengan penggantungan serbuk tungsten. Objektif penyelidikan ini adalah untuk mengkaji kesan parameter EDC (puncak semasa (Ip), denyutan pada masa (Ton) dan voltan pembuangan (V)) pada peratusan berat unsur salutan dan kekerasan mikro permukaan yang didepositkan dengan menggunakan EDC proses dengan suspensi serbuk tungsten. Mesin EDM die-sinker Sodick AQ35L akan digunakan untuk menjalankan eksperimen. Selepas eksperimen, peratusan berat elemen salutan dan topografi permukaan permukaan yang didepositkan akan disiasat dengan menggunakan mikroskop elektron (SEM) dan X-ray Dispersive Energy (EDX). Walaupun kekerasan mikro permukaan yang didepositkan akan ditentukan oleh Mesin Ujian Kekerasan Mikro. Hasil yang dijangkakan dalam kajian ini adalah serbuk tungsten yang akan didepositkan pada permukaan aluminium, parameter yang digunakan akan mempunyai hasil yang signifikan ke arah peratusan tertumpu unsur deposit dan topografi permukaan dan juga kekerasan mikro permukaan yang dideposit akan ditingkatkan berbanding kepada kekerasan bahan kerja asal.

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CHAPTER 1
INTRODUCTION

Chapter 1 provides the background of this study, which focuses on the material deposition on aluminum by using Electrical Discharge Coating (EDC) with tungsten powder suspension. The research background, problem statement, research objectives, scope of research and thesis organization are clearly described in this chapter.

1.1 Research Background

Material deposition is an activity for transforming surface properties of material in term of physical, chemical and biological from the initial properties. The material deposition by using vary of methods able to transmute the surface properties, for example the corrosion resistance (Prakash and Uddin, 2017), surface roughness (Mussada and Patowari, 2017) and average of layer thickness (Ahmed, 2016).

The surface properties of material are also an important criteria to determine the performance in manufacturing process. Nowadays, there are a lot of methods used to enhance or treat the surface of material such as mechanical plating and cladding, thermal spraying, vapor deposition, diffusion coating, laser treatment, electroplating, conversion coating, surface texturing and painting (Kalpakjian & Schmid, 2014). The EDM manufacturing process has unlock another field in surface modification. Material deposition on the surface of workpiece by using Electrical Discharge Coating (EDC) process able to develop a thin or thick coating layer with a different parameters (Mussada & Patowari, 2015).

Electrical Discharge Machining (EDM) (which also known as electrodischarge or spark-erosion machining) is a very common technology that use the electrode spark or discharge for eroding the material. The arc was presented when the electrode approach with the material and both carry with current. The gap distance between material and electrode

used are very close and a small crater will form after spark or discharge (Kalpakjian and Schmid, 2014).

According to Koshal (1993), EDM can be used to produce a high quality surface by a low material removal rate (MRR) setup. EDM able to machine various of metal irrespective with the hardness and toughness, which also have more accurate and precise result than others manufacturing process such as drilling and turning.

Moreover, Gill and Kumar (2015) had explored that the phenomenon of surface alloying by using EDM with powder metallurgy electrode. The result of the research shows the alloying element (tungsten and carbon) has been transferred and coated on the surface of the machined surface. According to Marashi et al. (2016), EDC is a process that still in a research stage which used to enhance the surface characteristic of workpiece by coat a layer of material on it such as tungsten, aluminum, titanium and steel.

Among these metal, aluminum has a wide application and demand across the world. The word aluminum come from 'alumine' which discover by a scientist Louis Guyton de Morveau (1736-1816) from a sulphate contained in aluminum (Vargel, 2004). According to Vargel (2004), the essential of aluminum and its alloy has increasing compare to others metal due to its properties especially in engineering field, construction, conveyance. According to Kalpakjian and Schmid (2014), there are huge benefits to use aluminum such as heat and thermal conductive material, resist to corrode and environmental friendly due to it able to be recycled. However, aluminum panel and frame are difficult to repair when a force applied on it such as in collision.

Therefore, in this research, material deposition on aluminium using EDC with tungsten powder suspension will be carried out. The surface topography of deposited surface and the EDC parameter influence on it will be discuss in the following chapter.

1.2 Problem Statement

Today, the growth of industrial is increasing rapidly. Metals play a very important role in this case as huge requirement of manufacturing equipment production such as a cutting tool, die tool, machine surface and molds. This leads to the problem of wear and corrosion of metal after some duration of time. For the trend of industry which required to run a large production in a short period, a lot of companies decided to replace a new die or mold instead of repair or make a way to increase the lifespan of the metal equipment.

According to Kalpakjian and Schmid (2014), aluminum of 6000 series is widely used for the manufacturing process as the mold and dies material. Aluminum of 6000 series provides a high hardness, tensile and yield strength to the mold and dies. However, aluminum will corrode and wear in the certain case. There are few types of the common corrosion of aluminum such as filiform erosion and water line.

Filiform erosion occurs when the aluminum base metal endures an exceptionally shallow assault which not exceed a depth of a couple of several microns. Filiform erosion always begins at coating defect include scratches, and powerless focuses (beards, cut edges or holes). It can be seen after a few years of use. The water line occurs due to the scattered and part of the mold which contacts to water. This can be observed on the uncoated aluminum structure of scows (Vargel, 2004).

The wear and corrosion on the surface of aluminum die and mold may cause defect and decrease the service life due to the reduction in thickness and hardness as some of the material has lost (Vargel, 2004). Therefore, this research is focusing on material deposition on the aluminum workpiece based on hardness and investigate effect of EDC parameter to the deposited surface by EDC process and tungsten powder suspension.

1.3 Research Objectives

The aim of this research are as following

1. To investigate the effect of EDC parameters (peak current (I_P), pulse on time (T_{ON}) and discharge voltage (V)) on weight percentage of deposited elements by using EDC process with tungsten powder suspension.
2. To determine the micro-hardness and surface topography of deposited surface after the EDC experiment.

1.4 Scope of Research

The target of this research was to modify the surface of aluminum by EDC with tungsten powder suspension. The Sodick AQ35L EDM machine was used in this research. The materials prepared for this research included tungsten powder, aluminum workpiece, a 6 mm of the copper electrode and kerosene oil. The effect of EDC parameters (peak current (Ip), pulse on time (T_{ON}) and discharge voltage (V)) toward the aluminum were recorded. The weight percentage of the deposited elements, microhardness of the deposited surface and surface topography were determined after the experiment.

1.5 Thesis Organization

The organization of this thesis is divided into five chapters. Chapter 1 is about the introduction. The background of the research is clarified in this chapter. The problem statement in this chapter describes the current situation or problem of the aluminum die or mold in the industry and the type of defect about the aluminum. Moreover, the objective and scope present the aim and target of this research. The literature review is presented in chapter 2. The related journals and books will be clearly summarized in this chapter. In addition, the chapter 3, the methodology will clearly define the procedure, apparatus, and material using in the experiment. All the data collected and the explanation of result will be presented in chapter 4 which is result analysis and discussion. Lastly, the summaries of the analysis of data, result and the achievement of the objective will be discussed in the chapter 5 conclusions.

CHAPTER 2
LITERATURE REVIEW

This chapter gives a brief review of previous research which comprises of EDM machining process, the significant parameter and machining characteristic of EDC process and aluminum properties. At the end of this chapter, the summary of main findings from the past research was provided.

2.1 Electrical Discharge Machine (EDM)

Electrical Discharge Machine (EDM) was invented in the 1940s after a series of experiment and investigation of the material erosive technic and the method used to control the erosive by Boris and Natalie I. Lazarenko (Kumar et al. , 2010). EDM was designed and created to cut the complex 3-dimensional shape and hard material which unable or difficult to machine by using conventional manufacturing process such as sawing and milling (Jameson, 1983). The basic component of Electrical Discharge Machine (EDM) is shown in Figure 2.1 and Figure 2.2 shows the discharge or spark takes place at the closest points between the electrode and workpiece.

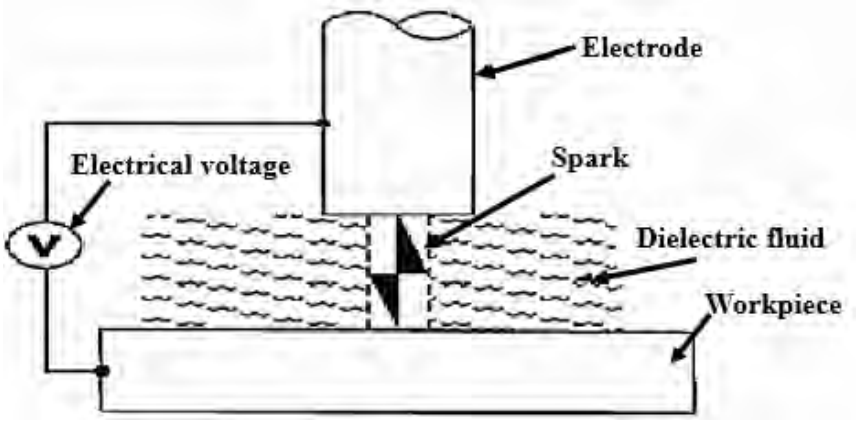

Figure 2.1: The basic components of Electrical Discharge Machine (EDM) (Jameson, 1983)

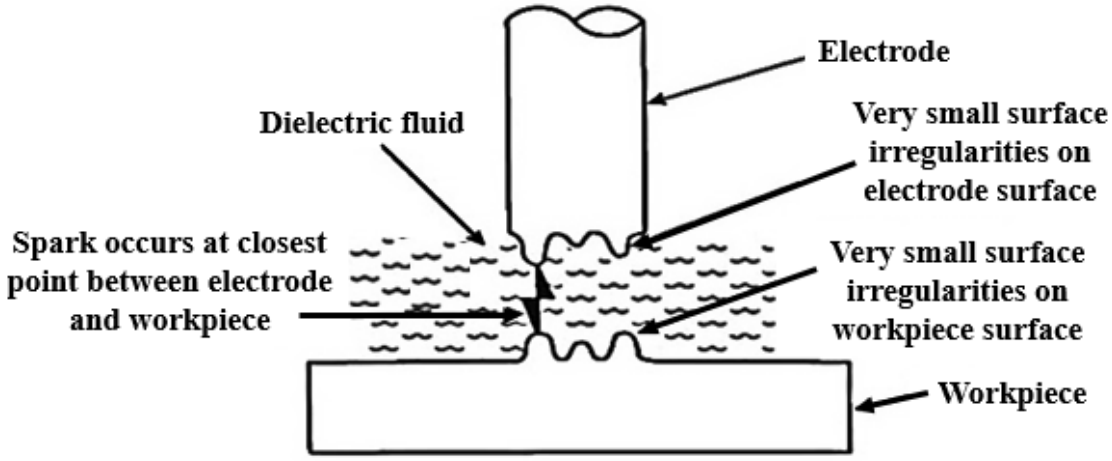

Figure 2.2: The discharge or spark takes place at the closest points between the electrode and workpiece (Jameson, 1983)

EDM is a common machine which used to remove the material from the surface of workpieces or to cut a workpiece by the electrical discharge. As the improvement and development of technology, EDM now became a very advanced machine with the function of automation machining. The user just needs to insert a related software which includes the design and parameter of the machining system then EDM will analyze the data and manufacture automatically (Kalpakjian and Schmid, 2014). This technology may help to produce the workpiece with a more accurate and precise dimension as the original design and to reduce the cycle time for mass production of the manufacturing process (Kalpakjian and Schmid, 2014).

According to Kalpakjian and Schmid (2014), there are two main types of EDM machine that commonly used in the industries today which are Wire Cut EDM and Die Sinker EDM. Die Sinker EDM are commonly used for removing the material and drilling on the surface of workpieces by an electrode. During the process, an electrical spark will be seen between the electrode and workpieces while the electrode does not have a direct contact with the workpieces. Figure 2.3 clearly shows the basic set up of a Die Sinker Electrical Discharge Machining process.

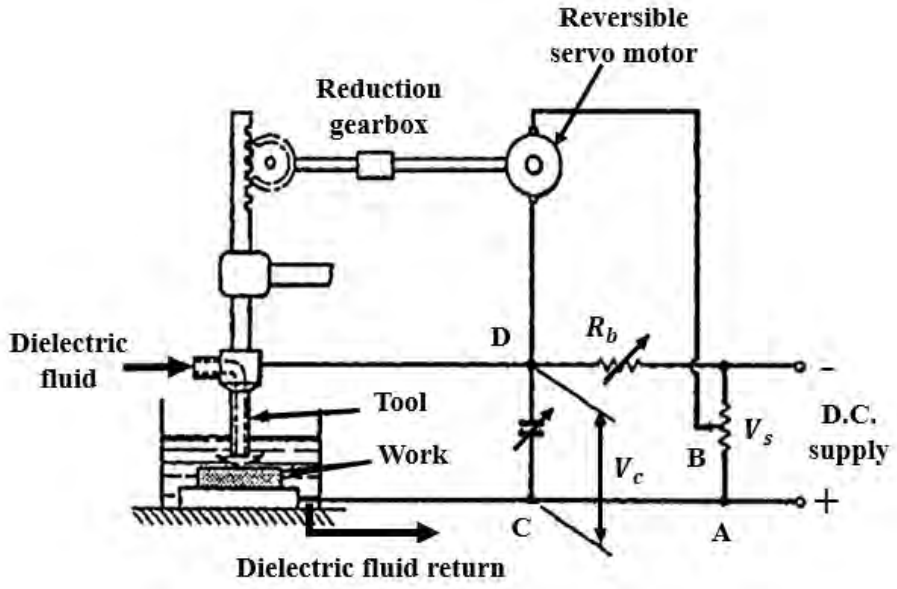

Figure 2.3: The Die Sinker EDM setup (Koshal, 1993)

For the Wire Cut EDM which usually uses a single-strand metal wire fed through the workpieces to cut the desired shape. Both processes are controlled by computer numerical machine (CNC) by given the related design programming and the movement setting of the tool then the process will be run automatically. In addition, a dielectric fluid acts as a very important role in the EDM machine process (Kalpakjian and Schmid, 2014). A dielectric fluid such as urea (Ndaliman et al., 2013), kerosene and deionized water used as a coolant and to flush away the debris from the surface of workpiece when machining (Kalpakjian and Schmid, 2014). Figure 2.4 shows the Wire Cut EDM process set up.

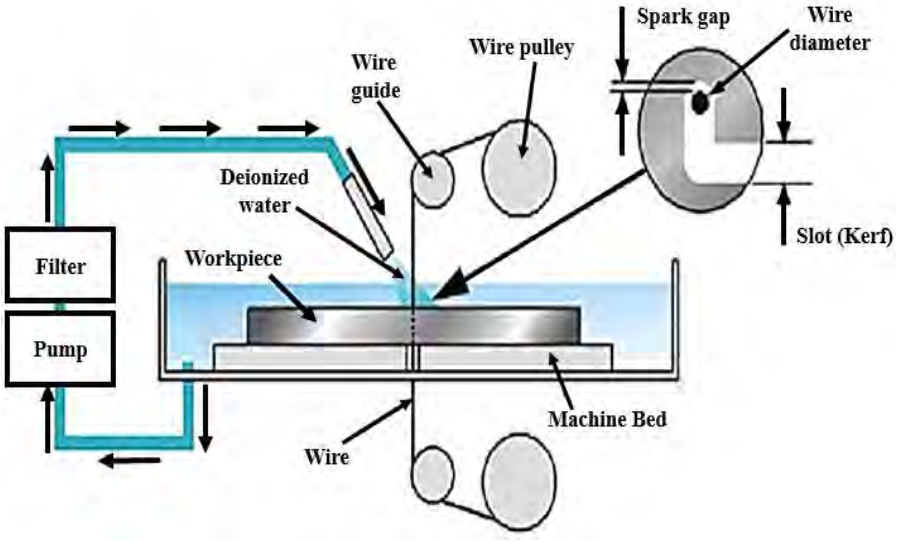

Figure 2.4: Wire Cut EDM process set up (Gupta and Jain, 2013)

2.2 Electrical Discharge Coating (EDC)

2.2.1 Material deposition by EDC

Electrical Discharge Coating (EDC) as known as Electrical Discharge Alloying (EDA). It is the new trend of technology which used the Electrical Discharge Machine Die Sinker to deposit a layer of coating on the workpiece surface (Funatani et al. , 2004). Based on the previous study, this technology still in a research stage and not yet being widely used in industry. EDC or EDA is a new process that can deposit the material on the surface of workpiece in a short period with a high current electrical pulse and the present of dielectric fluid (Funatani et al. , 2004). Figure 2.5 shows the basic schematic diagram of an electrical discharge coating process.

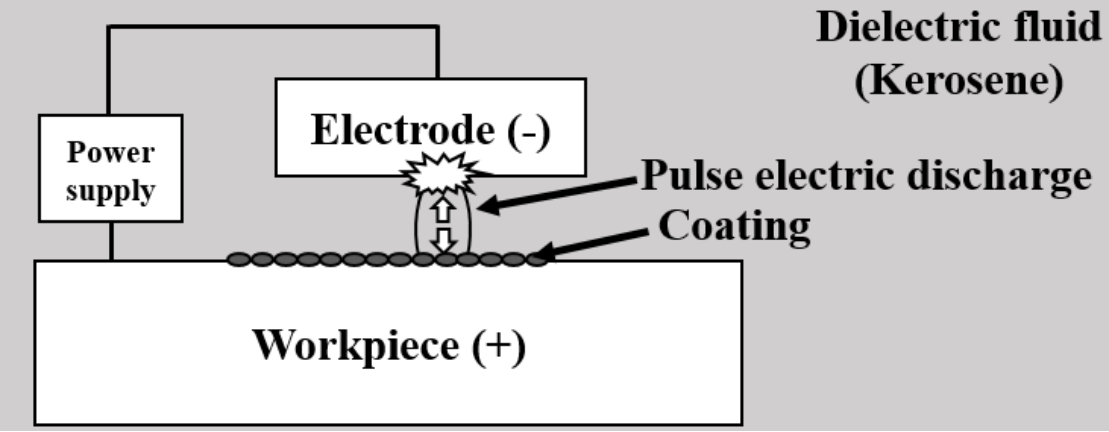

Figure 2.5: The schematic diagram of electrical discharge coating (Ueno et al. ,2016)

The term of material deposition is about the improvement of the surface for a workpiece. Which commonly known as a secondary manufacturing process. Material deposition which can use for various application with the main purpose of enhancing the physical and biochemical properties the workpieces. For the secondary manufacturing process, the material deposition plays a significant character for increasing the strength of workpieces' surface as well as the corrosion resistance and wear resistance (Prakash and Uddin, 2017).

Nowadays, there are a lot of technologies used for material deposition such as carburizing, electroplating process, Physical Vapor Deposition (PVD) and plasma spraying (Kalpakjian and Schmid, 2014). Mussada and Patowari (2017) reported that the existing process of material deposition need to conduct with an inert atmosphere but EDC is not

necessary. By using a suitable controlling parameter, EDC able to modify the surface of a workpiece by deposit a thick or thin layer of material.

According to Chen et al. (2014), most of the research focused on the surface deposition process to create a thick and porous oxide layer on the medical titanium implant surface to enhance the growth of tissue and increase the rate of healing. However, the oxide layer will degrade with time due to the cleaning process and friction. Therefore, EDC process which has a great potential to modify and fix the surface of the oxide layer.

Janmanee and Muttamara (2012) claimed that the EDM able to use for modifying the surface of workpiece. Hence, this technology has been introduced to modify the surface of tooling, molding for rising the lifespan and reduces the manufacturing cost. Table 2.1 shows the differences between EDM and EDC process in terms of the function, polarity, and the machined surface.

Table 2.1: The differences between EDM and EDC (Abhishek and Misra, 2012)

	Electrical Discharge Machining (EDM)	**Electrical Discharge Coating (EDC)**
Definition	EDM is a material removal process that removes material from a workpiece to obtain the desired shape.	EDC is a coating process that deposits a layer on a workpiece to achieve surface modification.
The polarity	The electrode or tool of EDM can be placed in either positive or negative depending on the parametric condition (tool wear rate and material removal rate). But for EDM, the material removal rate should be higher than the tool wear rate.	The electrode or tool of EDM can be placed in either positive or negative. But in the case of EDC, the tool wear rate should be higher than the material removal rate.
The weight of workpiece after machined	The weight of the workpiece will decrease after machined due to the material has been removed.	The weight of the workpiece will increase due to the deposited material, but the weight will also decrease in some case due to the crater formed.
Function	EDM is used to produce a hole or cavity on the dies and molds.	EDC is used to increase the wear and corrosion resistance of dies and molds.

2.2.2 Method of EDC process

According to Funatani et al. (2004), the surface modification by using EDC or EDA can be divided into two main categories which are EDC with powder metallurgical either in green compact or semi-sintered state electrode and powder suspension or Power Mixed Electrical Discharge Machining (PMEDM). Figure 2.6 shows the setup of EDC by powder suspension method and Figure 2.7 shows the basic set up of EDC by powder metallurgy or semi-sintered state electrode method.

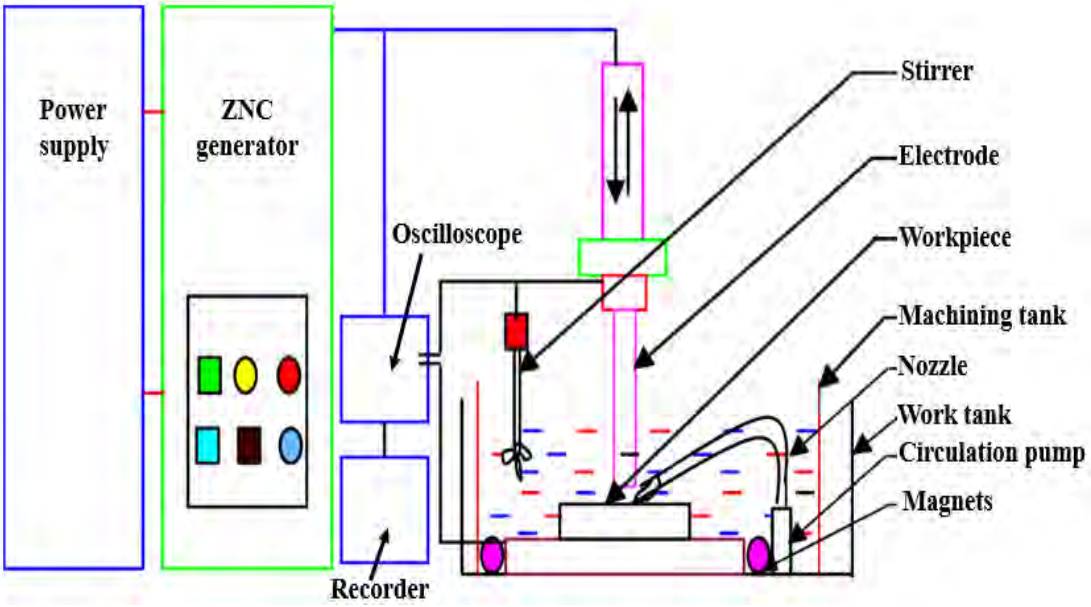

Figure 2.6: EDC by Powder Suspension Method (Kansal et al. , 2007)

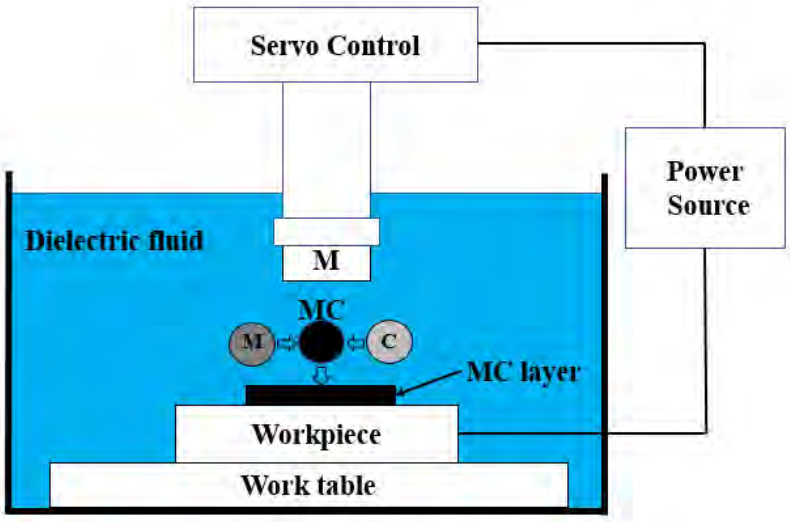

Figure 2.7: EDC by Powder Metallurgy method (Tijo, 2014)