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State of the Art in Processing of Welding with Electric Discharge Machining

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ABSTRACT:

EDM is for machining conductive workpiece materials in order to remove material from the workpiece surface. This method is typically used in modern manufacturing industries such as the automobile and aerospace industry. The basic principle of EDM is that it removes materials from the workpiece through a series of electric sparks that occur between the workpiece and cutting tool. The electrical energy is transformed in to thermal energy through a series of discrete electrical discharges between the electrode and work piece. This thermal energy is absorbed in a dielectric liquid medium.

Keywords: Welding. Electric Discharge Machining**,** NiTi shape memory alloy (SMA).

1. Introduction

The purpose of this research was to investigate micro-EDM induced surface modification and property changes to NiTi shape memory alloy (SMA) and Ti-6Al-4V Titanium alloy. The aim of this research was to find the formation of different compounds on the machined surfaces after the micro-EDM process and compare the surface of these two workpieces. The machined surface was analyzed using the Scanning Electron Microscope (SEM), the Energy Dispersive X-ray Spectroscopy (EDS) and X- ray Diffraction (XRD) techniques. The result obtained from the EDS and XRD techniques may indicate the formation of thin surface coating on the machined surface. Further investigation was carried out to minimize the surface modification and to reduce the changes in mechanical properties of the materials after the micro-EDM process.

The second phase of this research focused on finding the optimal parameter settings for micro-EDM of Ti-6Al-4V and NiTi SMA, so that industries can design machining operations to meet their needs. The identification of optimal parameter settings is based on mostly the machining time and surface finish, which affects the future usefulness and performance of a product. In this study, various operating parameters from a Resistance-Capacitance (RC) type pulse generator, such as: voltage, capacitance, and tool rotational speed (revolutions per minute, RPM) were varied to identify the optimal parameter settings.

2. Literature Review

A few decades ago, product manufacturers had difficulties cutting several materials due to various features such as high strength, hardness and resistance to erosion. Accordingly, manufacturers require supplementary help aside of conventional machining (i.e., pendulum grinding, turning and milling, etc.) in order to cut advanced material. These types of hard-to-cut materials (Titanium, Nickel, etc.) require special machines with high accuracy and an appropriate surface quality. These characteristics of the hard-to-cut materials cause an increase in the price of machining tools [1].

A study indicated that conventional machining is not acceptable in industries, because the MRR and depth of cut are low. For example, using boron nitride tools in conventional machining produces a cutting depth of 0.1 – 0.5 mm, cutting speed of 20 - 30 m/min and feed rate of 0.2 – 0.25 mm/rev. This indicates poor performance of the machining tool [2]

Considering the high cost of the machining discs and the limited success of their performance, a new non-conventional machining called Electrical Discharge Machining (EDM), was innovated in 1770 by Joseph Priestly. This process removes materials from the workpiece by the electro erosion phenomenon. The principle of EDM is based on thermoelectric energy that occurs between the workpiece and electrode (Saxena, Kumar & Shukla, 2014). The recent generation of EDM, micro electro discharge machining (micro-EDM), is one of the non-conventional machining method in the manufacturing field that produces products with complex geometrical profiles with high accuracy [3].

3. Process Parameters and Performance Measures of EDM

One of the challenging problems that constrain expanding application of the EDM technology is improving the surface quality of the workpiece. When advanced materials appear in the field, it is not possible to use existing models and hence, experimental investigations are always required. The essential performance characteristics in the EDM process include Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR). It is difficult to obtain the exact quantification of these parameters because there are several uncertain factors and situations. The optimal selection of process parameters is essential for the process of increasing production cost as it significantly reduces machining time [4].

The process parameters in the EDM are divided in two branches: electrical and non-electrical parameters. The EDM process is of a stochastic thermal nature having a complicated discharge mechanism. Therefore, it is difficult to explain all the effects of these parameters on performance measures [5]. Researchers attempted to optimize the parameters through recognizing the effects on operating variables. Peak voltage, peak current, pulse duration, electrode gap and polarity were categorized under the electrical part

4. Influence of Process Parameters on Performance Measures of EDM

Peak current: Peak current is one of the most important parameters in the EDM process, and it is measured in amperes. A higher value of peak current is required in rough machining operations and in cavities or details with large surface areas [5]. However, even though higher current increases the material removal rate (MRR), it reduces the precision of machining due to excessive wear. A higher amount of current also requires new tool materials because of excessive tool wear during machining [6]

Peak voltage: The discharge voltage in EDM is related to the spark gap and breakdown strength of the dielectric. The open gap voltage will be increased until it creates ionization by the dielectric before the current is flowing. When the current starts to flow, the voltage is dropped and used at the working gap level. The amount of voltage determines the width of the spark gap before work is begun and is fixed based on the leading edge of the electrode and work piece. By increasing voltage, the surface roughness, MRR and TWR will be increased because electric field strength rises. The gap steadily increases and improves the flushing conditions by higher voltage [7].

Pulse duration: (Pulse on-time and pulse off-time): In the EDM process, each cycle has pulse on-time (pulse duration), and pulse off-time (pause interval) which is expressed in microseconds (μs). The machining is performed during on-time, while the removed materials are flushed away from the machining zone during off-time. Pulse on-time has an influence on machining. For example, when pulse on-time is increased, machining makes a broader, deeper and faster crater, which creates poor surface and higher MRR [8].

5. Conclusion

NiTi SMA have a better surface quality than Ti. The amounts of the debris particles on the surface of Ti alloys were more compared to NiTi SMA. This result was observed from SEM analysis that showed the quality of machined surfaces. The machined surface of NiTi SMA was better than Ti because lower number of particles existed on the NiTi SMA surface. Both the workpieces are hard-to-cut materials but micro-EDM was able to successfully machine those materials.

The Ti and NiTi SMA have a biocompatible surface finish with micro-EDM. According to the results from XRD and EDS analyses, the different compounds were found on the surface before and after machining. Because of the lab environment, the oxygen from the air transferred to the machined surface after oxidation with workpiece materials. The dielectric fluid used also had an impact on surface quality. Because of the heat generation during the machining, the EDM oil was decomposed to other materials and released carbon on the machined surface. The amount of oxygen percentage on Ti work piece was higher than NiTi SMA, which showed the better resistance of NiTi SMA. On the Ti surface there were various amount of TiO2 and observed. The other factors that influenced machined surface quality was tool wear rate. The tungsten tool eroded during machining because of the heat generated. Thus, the trace of was left on the NiTi SMA surface after machining using tungsten tool.

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