Hybrid Laser Vs. MAG Welding with Non-conventional machining

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Abstract

In recent year, manufacturing industries are in need of hard and tough-to-cut material for various important application. Some of the common hard-to-cut material are Titanium based alloy, Nickel based alloy, and Shape Memory Alloy that are found to be used extensive in aerospace and biomedical industry. The conventional machining process are difficult for machining of these hard-to-cut materials due to their sole property such as high strength-to-weight ratio, high resistance to wear, and poor electrical and thermal conductivity.

Keywords: Composite , Hybrid Laser, MAG Welding,.

1. Introduction

The human body is a intricate electrochemical system that create an aggressive corrosion environment for metallic implant. The body fluid (include 0.9 % NaCl, organic compound and a small amount of other salt) cause corrosion to metallic implant. Body fluid have high pungency that could be a grave threat for metallic implant. Many researcher have done study on the cytotoxicity of Nickel and Titanium that showed that it is less harmful to the bone structure as compared to other implant alloy such as cobalt or vanadium. Also, Titanium can create a stable Titanium Oxide layer on its surface and has the ability of excellent osseointegration with the bone in an optimal situation. It is known as one of the most biocompatible materials in the biomedical industry [1].Generally, Titanium prevent corrosion from hydroxyapatite and is capable of produce a calcium phosphate-rich layer on its surface. Parts fabricated using the SMA and Titanium alloy are primary used used for biomedical applications. SMA that are used as implant can be harmful and dangerous for the human body. This research attempted to locate different elemental composure material and any harmful substance on the machined surface in order to remove or reduce those that are not biocompatible. This research also investigated the feasibile of using micro-EDM process for machining biomedical implant in these two material.

2. Micro-EDM Principle

During the micro-EDM process, discharge occur between the electrode and workpiece, which causes electrodes to reach the melting phase and evaporate. Since the metal removal of each discharge is very meager, it require high occurrence between 10^3 and 10^6 Hz to increase its strength. The sparking, upon which the removal of material in EDM is based, occurs between the electrode and the work piece. According to Figure 1, with a single spark in the erosion process, positive direct current (DC) reach the electrode and develop an intense electrical field in the gap. Microscopic contaminant differ in the dielectric fluid are attracted by the field and are concentrated on the field's strongest point. These contaminants build a high conductivity bridge across the gap. As the field voltage increase, the material in the conductive bridge heat up. Some piece ionize from the spark channel between the electrode and work piece. At this point, both the temperature and pressure in the channel increase rapidly, generating a spark. A small amount of material melt and evaporate from the electrode and workpiece at the point of contact. A bubble composed of gas by product of vaporise rapidly expand outward from the spark channel. Once the pole send the spark, heating action stop, and the spark channel collapse. Dielectric fluid then rushes into the gap, flashing molten material from both surface. Thus, EDM residue consist of small, solidified ball of material and gas bubble [2].

3. Thermal Model of EDM Process

The overall EDM includes simultaneou interaction of thermal, mechanical, chemical and electromagnetic phenomena. For example, the thermal energy component involve the heat transferred in the process due to conduction and convection. Hence, the EDM can be explained as a thermal process. Material temperature will go up by the action of high energy electric spark melts and vaporise a small area on the electrode surface. Small amount of molten material are removed from the surface at the end of the pulse on time. Figure 1 shows the heat transfer in the EDM.

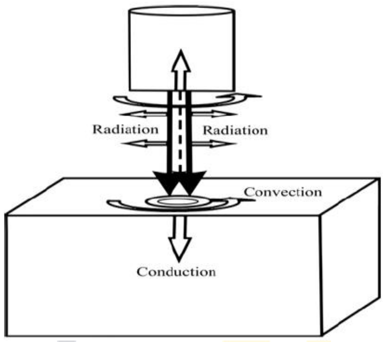

Fig. 1 Thermal Model of EDM [11]

4. Electric Discharge Machine of Ti–6Al–4V

One of the hard to cut material is Titanium (Ti), which is used in divergent application in aircraft and biomedical industry because of its chemical and mechanical property [3]. Because of the high thermal conductive and high strength of the titanium, EDM is an appropriate process for cutting this alloy makes high quality product. According to [4] the properties of Ti–6Al–4V workpiece require more energy to conduct electrical power. The energy absorb by the workpiece causes a temperature rise due to conduction and an eventual dissipation with time. Titanium is a lightweight metal with a higher density. Compare it with other metal, such as Iron, Ti has a higher melting point (Ti melting point is 1,668°C and iron is 1,560°C) and lower modulus of elastic (Ti is around 110×10^9 Pa and steel is 210×10^9 Pa) [5]. Also, Ti can be cold roll to 90% reduce in thickness at room temperature without cracking.

Titanium alloy can be divided into three group: alpha, alpha beta, and beta. The alpha group cannot be used in aircraft appeal and is also not appropriate for heat treatment. Aluminum and tin are the most common alloy in the alpha group. The second group, alpha beta, is harder than the first group because they are strength with heat treatment and suitable for appeal such as aircraft turbine, marine hardware, and chemical process equipment. The hardened titanium alloy are in the third group, which are denser than other types of titanium alloy (density range from 4,800 to 5,050 kg/m^3). However, beta alloy, though the smallest group, are used in broader and more important aircraft part Temperature is one of the important factor that affect material electrical.

Material can quickly absorb the heat because of the low electrical resistance, so EDM can remove heavy material from the work piece [6].

The Ti-6Al-4V property of low thermal conductive and high electrical resistive make it difficult for the workpiece to conduct the amount of electrical energy that is used for the EDM.

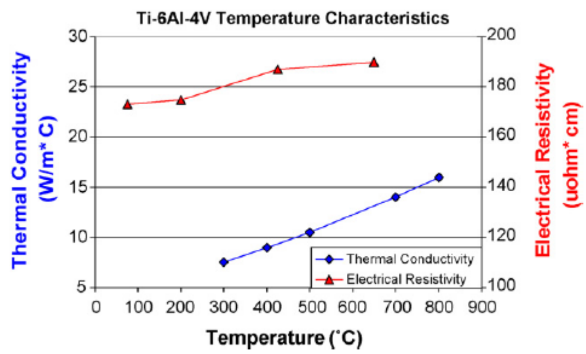

Figure 2. Electrical resistivity and thermal conductive vs Temperature for Ti–6Al–4V. [10]

5. Electrical Discharge Machine of NiTi SMA

In order to extend the application of NiTi, certain machine technology has been developed for manufacture product with high accuracy and complicated shape. Without proper technique, certain difficulty are associated with the machine NiTi alloy in industry. With the use of special equipment, tools, and highly experienced operator, the machining of NiTi become rather expensive. Conventional machine technique such as mill and drill can have consequence influence on the behaviour of the SMA material due to their high thermal and mechanical effect. This sometime leave the material, especially part with low dimension, with excessive degradation in performance. Consequently, certain non-conventional process have been undertaken to fabricate NiTi components [7].

The most preferred of these process is laser machine due to its high speed, accuracy, and the capabile for rapid prototype. However, this method has drawback such as the extense of HAZ and micro crack. Another method is electro discharge machine (EDM), which works well with most Nitinol composition, assure minimal influence on the material due to the intrinsic characteristic of this technique. EDM has a great advantage since it has no contact to the work piece. This kind of machine act independently of the hard and tough of the material having no effect on the power. In some application however, there might be a need for remove the recast surface layer that is formed on the material in the machine zone. This is due to the oxide and contam inant that could have been created from the electrode and dissolved dielectric medium depending on the application. Furthermore, during the EDM process, high temperatures can cause melting at the surface that can ultimately have negative effect on HAZ [8].

6. NiTi Shape Memory Alloy

Nickel – Titanium (NiTi) alloy are the most important class of shape memory alloy and inter-metal binary combination. NiTi alloy are very popular in industry due to property such as super elastic, adaptive response, memorized capability, high damping characteristic, stress hysteresis and magnetic resonance imaging (MRI) compatibile [9]. One of the important characteristic of SMA is the strain increase of nearly 8% heating above austenite finish temperature or unloading in a polycrystalline state. These kind of property of NiTi alloy have resulted in many application in the medical, aerospace and robotic, military, automotive, and biomedical industry.

Conclusion

Titanium and shape Memory alloy are extensively used in aerospace, biomedical and automotive industry due to their high feature strength (strength to weight ratio), superior mechanical and thermal property and excellent corrose resistance. However, these alloy are commonly known as tough to cut material use convents machine step due to the reactive of tool material with these alloy, cut fast limit, chip, and premature failure of the cut tool. Different shape of micro feature were machine on the Ti-6Al-4V and NiTi SMA surface using an identify optimum parameter set. The performance of both material were compared based on the surface quality of micro feature and machine time.

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