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Machined Surface Quality in Nano Aluminum Mixed Electrical Discharge Machining

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Abstract

The development of implants in biomedical engineering application nowadays requires materials with good mechanical and physical properties. Conventional machining of high strength alloy materials is a challenge. Non-conventional machining processes such as electrical discharge machining (EDM) of high strength material have its limitations. Among the limitations are surface modification, induced corrosion, residual stress and reducing of fatigue performance during the EDM process. Nano aluminum mixed electrical discharge machining (PMEDM) is envisaged able to address some of the above mentioned problems. In this study, PMEDM machining performance on biomedical grade titanium alloy workpiece using nano aluminum powder is assessed to establish its improvement for biomedical application. The characteristics analyzed are surface roughness (Ra) and surface morphology. Process variable machining parameters used are peak current, ON-time (pulse duration), gap voltage and nano aluminum concentration. Results of nano aluminum PMEDM on titanium alloy material show slight improvement in terms of surface roughness (Ra) and surface morphology as compared to conventional EDM. PMEDM results show fewer defects in terms of cracks, craters and voids.

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Keywords: PMEDM, Titanium alloy, Implants, Ra, Surface morphology

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1. Introduction

Titanium alloy is still the most widely used hard metal alloy as implants in biomedical engineering due to their excellent biocompatibility, good mechanical characteristic and corrosion resistance even though there are other new emerging materials suitable for biomedical applications [1]. Existing processes of machining implants for biomedical application includes EDM, turning, milling, drilling, forming, forging and alternative machining such as laser and water-jet cutting [2]. The limitations of these processes are the after machining effect on biocompatibility corrosion and residual stress induced during the machining process. Additional processes such as plasma-spraying and grit-blasting are required for surface modification with disadvantages related to poor efficiency. Electrical discharge machining (EDM) is a non-conventional machining process that removes material by spark erosion generated from electrical discharges. Spark erosion occurs when there is an increase in concentration of electrons and ions. Kinetic energy of electrons and ions impact with the surface of workpiece and tool would be converted into thermal energy. Intense localized heat flux leads to extreme instantaneous rise in temperature between 8000°C - 12000°C [3]. This rise in temperature heat will melt, vaporize and remove the material. An indirect side effect of this high temperature spark erosion on the machined surface is a form of surface modification that can be an added advantage suitable for biomedical application. Chen et al [4] in their paper showed the effect of EDM on improving implants surface biocompatibility. They established that EDM process indirectly modified the microstructure on the machined surface improving its osteointegration capability.

The drawback of EDM is its slow machining process with low material removal rate and relatively high electrode wear when machining hard materials with complex shapes since its material removal principle is non-contact electro-discharges with minimal physical forces [5]. Additionally the fatigue strength of the workpiece subjected to EDM machining at high machining parameters has been shown to be poor for orthopedic application [6]. Since during the EDM process, material is heated, melted and cooled down by dielectric fluid to be resolidified, thus, EDM is consider as a surface treatment process required for improvement of oseointegration. The limitation in using EDM as potential machining of implants is the fatigue performance (poor after EDM) [6]. Stráský et al. [7] and Manivasagam et al. [8] during their EDM research found that poor fatigue is due to the strong notch effect of titanium alloys.

To overcome the above EDM limitations, nano aluminium mixed dielectric electrical discharge machining (PMEDM) is hypothesized to provide a potential solution. PMEDM is still in its research infancy applied to improve the EDM machining efficiency. Added metallic powder enhanced the sparks which becomes enlarged. The spark is distributed among the metallic powder particles and the discharge density of spark decrease leading to reduction of crack, craters and voids on the workpiece machined surface [9]. PMEDM can possibly further enhanced surface modification for improvement of osseointegration and implant surface properties. Good osseointegration properties improve bone-bonding ability between implants and living bones to prevent any loosening of the implants. Hence, the objective of this research study is to evaluate, analyse and synthesize PMEDM on biomedical grade titanium alloy using nano aluminium in terms of Ra and surface morphology of machined surface.

Nomenclature

PMEDM: Powder mixed electrical discharge machining
EDM : Electrical discharge machining
Ra : Average surface roughness