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Surface Integrity Characteristics in Wire Electrical Discharge Machining of Titanium Alloy during Main cut and Trim cuts

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Abstract

Ti-6Al-4V grade titanium alloy is the most popular alloy and is used for a wide range of applications in aerospace, marine, power generation and offshore industries etc., because of its very good mechanical properties such as high tensile strength, fatigue resistance, highest strength-to-weight ratio, extraordinary corrosion resistance and toughness even at elevated temperatures. Wire Electrical Discharge Machining (WEDM) is extensively used for machining of complex shapes in the field of die and mould making, medical, aerospace and automobile industries for machining of too hard materials. WEDM is essentially a thermal process with a complex metal removal mechanism, involving the formation of a plasma channel between the wire/tool and workpiece, resulting in the material removal, which also leads to surface roughness, work hardness, over cut, white layer, heat effected zone, surface structural changes, metallurgical transformations and cracking. These properties determine the operational behaviour of the material and can be included in one term called surface integrity. In this Investigation multi cutting pass i.e. rough/main cut and trim/finish cut approach was adopted to improve the quality of surface characteristics of WEDM surface of Titanium alloy. The results show that the WEDMed surface topography shows dominant micro voids, thick white layer and heat affected zone and even micro cracks at high pulse on time and pulse current and these are low at low pulse on time and pulse current during trim cuts. Further surface topography and micro structural changes were observed through scanning electron microscopy (SEM) micrographs.

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*Keywords:*Wire Electrical Discharge Machining (WEDM); Surface Integrity; Titanium alloy; Trim cut; Scanning Electron Microscopy (SEM)

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1. Introduction

Wire EDM is essentially a thermal process with a complex metal removal mechanism, involving the formation of a plasma channel between the wire/tool and workpiece, resulting in the material removal, which also leads to surface roughness, work hardness, over cut, white layer, heat effected zone, surface structural changes, metallurgical transformations and cracking. These properties determine the operational behavior of the material and can be included in one term called surface integrity. Surface integrity plays an important role in operational behavior of the material. Multi cutting pass i.e. rough/main cut and trim/finish cuts approach can improves the surface roughness of the machined surface and thickness of the white layer and heat affected zone. Wire Electrical Discharge Machining (WEDM) is an essential operation in several manufacturing processes in some industries, which gives importance to variety, precision and accuracy. Several researchers have attempted to improve the performance characteristics namely the surface roughness, cutting speed, dimensional accuracy and material removal rate. But the full potential utilization of this process is not completely solved because of its complex and stochastic nature and more number of variables involved in this operation.

Wire electrical discharge machining (WEDM) is broadly used in machining of materials when precision is of major factor. WEDM is an ideal means for manufacturing such tooling because its ability to cut any conductive material regardless of hardness. The productivity of fabricating micro tools can be increased with the use of WEDM technology where more intricate tool geometries can be created with high quality. Material is eroded by series of discrete sparks between the work piece and a tool electrode/wire immersed in a liquid dielectric medium (deionised water). These electrical discharges melt and vaporize diminutive amounts of the work material, which are then ejected and flushed away by the dielectric. Since, the work piece and the electrode do not have mechanical contact, conductive material regardless of their hardness and toughness can be machined by WEDM (1). It consume a continuously travelling wire electrode made of thin brass, copper or coated wire of diameter 0.05–0.3mm (2) which is capable to achieve very small corner radii and competency to machine precise, complex and irregular shape with high degree of accuracy and fine surface finish. Yang, X, Liu, CR et al., studied the machining of titanium and its alloys (3). Kuriakose, Sh and Shanmugan MS et at., studied the characteristics of wire electro discharge machined Ti-6Al-4V surface (4) and Rahman.M.M et al., have done the modeling of machining parameters of Ti-6Al-4V for electric discharge machining using a neural network approach (5). Miller et al. investigated the effect of spark on-time duration and spark on-time ratio on MRR and surface integrity of four types of advanced material such as porous metal foams, metal bond diamond grinding wheels, sintered Nd-Fe-B magnets and carbon–carbon bipolar plates and observed that machining the metal foams without damaging the ligaments and the diamond grinding wheel to precise shape was very difficult (6).

Sarkar et. al. performed experimental investigation on trim cutting of wire electrical discharge machining of γ-Ti Al alloy and the process was modeled using RSM and optimized using Minitab which generally makes use of the desirability function approach. They observed that the surface quality decreases as the cutting speed increases and varies almost linearly up to surface roughness value of 1.22 μm and cutting speed of 13.88 mm/min and beyond this value of cutting speed, surface roughness deteriorates drastically (7). Klink et. al. evaluated the surface integrity of powder metallurgical tool steel by main cut and finishing trim cuts in WEDM and observed that the average surface finish Ra of 0.1 μm and 0.2 μm for CH- and water-based dielectrics is achieved. White layer, characterized by the top porous structure and bottom solid recast, was minimized and visibly clean cut surfaces with less than 0.3 μm rim zone were observed under high resolution SEM (8). Klocke et. al performed EBSD analysis of flexure hinges surface integrity evolution through Wire EDM main and trim cut technologies to reduce the thickness of the thermally influenced zone. Mechanically high demanding applications like flexure hinges with high precision positioning tasks need exact knowledge about the level of thermal damage in the workpiece (9). Liu et. al. evaluated the surface integrity from main cut to finish trim cut in wire EDM of shape memory alloy and observed that the six sigma distributions of surface roughness 'Ra' are very different between main cut and finish trim cut. Thick white layers (2-8 μm) with micro cracks in main cut and very thin white layers (0-2 μm) free of those defects in finish trim cut was observed. However, micro cracks would not propagate into the heat affected zone below the white layer and