Study of Chip Morphology, Flank Wear on Different Machinability Conditions of Titanium Alloy (Ti-6Al-4V) Using Response Surface Methodology Approach

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ABSTRACT

Titanium alloy is having a widespread application in the field of aerospace, marine and automobile industries. However, its machining is still a challenging task for the manufacturing industries due to the chemical reactivity and poor thermal conductivity properties. In this study, machining of titanium alloy (Ti-6AI-4V) was carried out with WM25CT cutting inserts. The effects of cutting speed, feed and depth of cut on cutting force, surface roughness, chip-reduction coefficient and flank wear of the cutting tool were analyzed. The response surface methodology (RSM) approach with central composite design and face centered was used to carry out the experimentation. The second order quadratic equations were developed and compared with the experimented data sets. From the analysis of the chip morphology, it was observed that side flow of chips and gap between the lamella of the chips varied with respect to the change in the process parameters. The type of chip produced also varied according to the variation of the process parameters. Severe nose damage was observed at cutting speed 160 m/min, feed 0.14 mm/rev, depth of cut 0.75 mm. Due to this snarled ribbon type of chips were produced in place of occurrence of the serration in the chips.

KEYWORDS

Chip Morphology, Flank Wear and Cutting Force, Response Surface Method, Titanium Alloy

INTRODUCTION

Titanium alloy is one of the most important materials used in the field of aerospace engineering, automobile and marine sector. Most of the components like engines, turbine blades and airframes are made from titanium alloys. The strength to weight ratio and ability to withstand extremely high temperatures are vital criteria for fabrication of such components. The properties of the titanium alloy have the capability to endure in extreme high temperature. Titanium alloy is double as sturdy as aluminum alloys, on the other hand greatly lighter than steel. Due to its low thermal conductivity, it is difficult to machine (Machado and Wallbank, 1990; Ramesh et al., 2008; Ramesh et al., 2008). Titanium alloy is also highly reactive towards chemicals. It has the affinity to weld with the cutting inserts. The chips coming out during machining will stick to the machined surface. It leads to the premature failure of the cutting inserts, formation of chipping and deteriorates the surface finish of the machined surface of workpiece (Ezugwu and Wang, 1997; Neseli et al., 2011). During machining of titanium alloys most of the chips formed are of serrated type. Such types of chips produced throughout
the machining operation are due to the decrease in the mechanical strength with an increase in the temperature and also due to the low thermal conductivity of the material (Amin and Talantov, 1986; Mantle and Aspinwall, 1998). So as to enrich the quality of the components, a good surfaces finish of the components with high dimensional accuracy is required. A good surface finish improves the fatigue strength, thermal resistance and corrosion resistance of the product Kramer & Hartung (1980).

A great deal of researchers performed the machining of titanium alloy using different techniques to enhance the machinability. Kosaraju & Anne (2013) studied the performance of PVD/TiAlN coated carbide inserts for machining of Ti-6Al-4V using response surface method (RSM) layout with cutting speed, feed, depth of cut and rake angle as process parameters. The goodness fit and model fits for cutting force and surface roughness were 0.968 and 0.970 respectively. Ozel et al. (2010) studied the cutting forces and tool wear of Ti–6Al–4V alloy with multi-layer coated inserts. It was observed that CBN and TiAlN + CBN coated WC/CO inserts exhibited the largest cutting forces at higher cutting speeds. It was observed that CBN coated WC/CO inserts depicted the smallest wear zone. Consequently, CBN coatings lead to reduction in the tool wear during dry machining of titanium alloyed material. Sun et al. (2009) studied the chips formation during machining of titanium alloy, the cutting forces were also measured under different cutting speed, feed and depth of cut. Segmented continuous chips were formed during machining at low cutting speed and higher feed rate. It was observed that, the undeformed surface length of the segmented chip increases linearly with increasing the feed rate of the cutting tool, whereas, it was independent to cutting speed and depth of cut. The cutting force decreases with increasing cutting speed of the cutting tool, this is due to the thermal softening of the material during machining of titanium alloy. Ribeiro et al. (2003) studied the behavior of titanium material. The experiment was carried out and observed that working with a low amount of cutting fluid with dry turning of a cutting speed range of 90 m/min was the best cutting condition for achieving the good surface finish. But increasing the cutting speed to 110 m/min, the cutting edge deteriorate rapidly and the value of surface roughness was also increased. Che-Haron & Jawaid (2005) studied the surface integrity of titanium alloy with uncoated carbide inserts during rough machining. The cutting speed varied from 45 – 100 m/min and feed rates were 0.35 and 0.25 mm/rev with depth of cut remain constant i.e. 2.0 mm. Due to the poor machinability properties of titanium alloy the surface of the machined titanium alloy did not acquire good surface finish, the surface roughness value lies within the limit of 6 microns, severe microstructure alteration was seen from the SEM micrograph and the microhardness on the top white layer surface was increased.

In order to minimize the experimentation and to develop a mathematical model in relation to the input and output factors certain design layout has to be followed. Those experimental design layout use for the experiment ease the number of trial runs, save material and its cost and save the machining time as well (Izelu et al. 2013). Many researchers had used response surface method as experimental plans to formulate the quadratic model, such as Arbizu & Perez (2003) used the response surface methodology to develop a mathematical model for surface roughness during turning operation. Sahin & Motorcu (2008) furnished the quadratic model for surface roughness using RSM with respect to the cutting speed, feed and depth of cut as process variables. Suresh et al. (2002) used RSM combination with the genetic algorithm method for the prediction and optimization of the surface roughness with respect to the machining parameters. Choudhury & El-Baradie (1997) predicted the surface roughness of high strength steel using RSM technique. Ranganathan et al. (2010) applied Artificial neural network in RSM layout to predict the surface roughness of 316 stainless steel as workpiece with varying cutting speed, feed, depth of cut and cutting temperature. Gosai & Joshi (2016) analyzed the material removal rate and surface roughness of the surface during electro discharge machining of titanium alloy using RSM method. Elbah et al. (2016) applied RSM to study the effect of cutting speed, feed and depth of cut over the cutting forces and surface roughness during turning of AISI 4140 steel with the mixed ceramic cutting tool. Da Silva et al. (2016) minimize the burr formation during machining of PH 13-8 Mo stainless steel through RSM approach. Arikatla et
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