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Cutting Force and Surface Finish Analysis of Machining Additive Manufactured Titanium Alloy Ti-6Al-4V

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Abstract

In this paper, the effect of machining parameters such as cutting speed and feed rate on cutting forces and surface roughness during turning of wrought and additive manufactured titanium alloys Ti-6Al-4V (selective laser melting) was studied. It was found that high cutting speeds and feed rates resulted in high cutting forces and poor surface finish. It was also found that higher cutting forces were required for machining selective laser melted titanium alloy (SLM Ti-6Al-4V) as compared to that of conventionally produced wrought Ti-6Al-4V due to the higher strength and hardness of SLM Ti-6Al-4V. After machining, surface roughness of additive manufactured titanium alloys was found to be low as compared to wrought Ti-6Al-4V because of the high hardness and brittle characteristics of additive manufactured titanium alloys.

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Keywords: Cutting Force; Surface Finish; Additive Manufacturing; Machining;

1. Introduction

Titanium alloys are widely used in aerospace, automobile, marine, medical and chemical industries because of their superior properties such as high corrosion resistance, biocompatibility and high strength to weight ratio [1-5].

Conventional manufacturing of titanium alloys are always difficult and expensive due to some crucial material properties like poor thermal conductivity and high chemical reactivity [6-8]. Thus, the use of titanium alloys is

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limited in various industries due to its expensive processing route. Recently, Additive Manufacturing (AM) has gained huge attention in manufacturing sector because of its freedom of design, low material wastage and high productivity [9-12]. Various additive manufacturing processes like selective laser melting, selective laser sintering, and electron beam melting are being widely used. The main draw backs in these technologies is the poor surface quality of the fabricated components as a result of rippling effect on the molten material, staircase effect due to layer by layer fabrication and sticking of non-melted powder particles to the surface [13]. To overcome these problems, post machining of additive manufactured components are often necessary as surface finish has a great effect on the functional performance of the component. In order to successfully machine additive manufactured components to the required surface finish and tolerance, proper selection of process parameters are required.

In this research paper, the effect of machining parameters like cutting speed and feed rate on cutting forces and surface roughness during machining of additive manufactured Ti-6Al-4V is studied. Machining of wrought titanium alloy is also carried out alongside with AM Ti-6Al-4V to comparatively study their machinability characteristics.

2. Materials and methods

2.1 Materials

Ti-6Al-4V cylindrical rods used in this research were procured from Timet, France. The initial dimensions of the rod were 70mm in diameter and 600mm in length. The alloys was received in rolled condition with a post mill annealing heat treatment at 750ºC (2 hrs) followed by air cooling. A cylindrical rod of 70mm diameter and 75mm length was fabricated using the SLM 125HL machine with a build chamber of size, 125x125x75mm and with a laser power of 100/200 W,YLR-Laser. The fabricated cylindrical rod is heat treated in vacuum furnace at 730ºC followed by rapid furnace cooling to reduce the residual stresses developed during fabrication.

2.2 Machining trails

The turning trails were performed on Nakamura-Tome AS-200 supplied by Nakamura precision industries. The main spindle power of the machine is about 15KW with a maximum speed of 4500 rpm. The experimental set up of turning tests is shown in fig. 1. All the cutting tools used were tungsten carbide supplied from Iscar Tools Limited and were designated as IC907. It has an ISO range –P/M/K: (P15 –P40) with designation "DNGG 150401-SF".

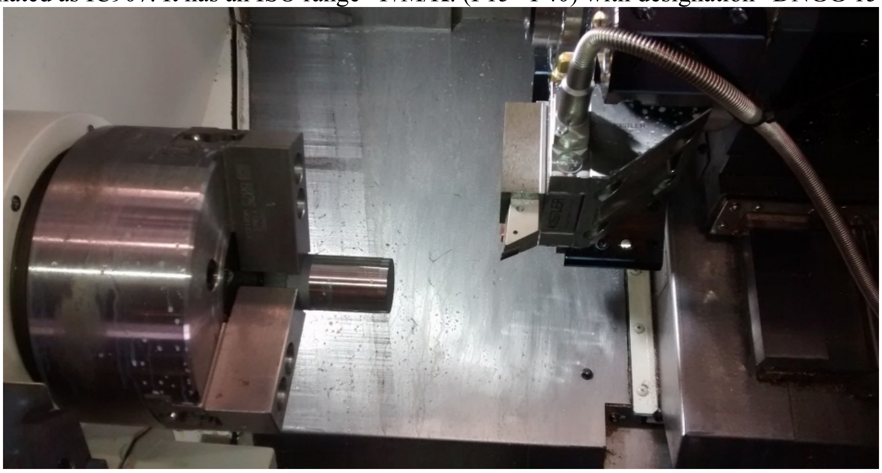

Fig. 1. Experimental set up for machining trails