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Predicting surface quality of γ-TiAl produced by additive manufacturing process using response surface method†

Abdulrahman Al-Ahmari[1,2,*], Mohammad Ashfaq[1], Abdullah Alfaify[2], Basem Abdo[1], Abdulrahman Alomar[2] and Abdelnaser Dawud[2]

[1]*FARCAMT Chair, Advanced Manufacturing Institute, King Saud University, Saudi Arabia*
[2]*Industrial Engineering Department, College of Engineering, King Saud University, Saudi Arabia*

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Abstract

Electron beam melting (EBM) has been found to be a promising technology for producing complex shaped parts from gamma titanium aluminide alloys (γ-TiAl). The parts produced by this process are projected to have dimensions very close to the desired final shapes. However, the surface roughness of the parts produced by EBM is excessively rough. In many applications, it is necessary to improve the quality of manufactured parts using a convenient post process. This paper determines process parameters of end milling when it is used as a post process for the parts produced by EBM. Design of experiments has been used to study the effect of the selected input parameters of end milling (spindle speed, feed rate, depth of cut and coolant type) on the surface roughness of γ-TiAl parts. Response surface methodology is used to develop a predictive model for surface roughness. Effects of the selected milling process are investigated. This paper also optimizes the selected process parameters to minimize the value of the obtained surface roughness.

Keywords: EBM process; End milling; Response surface method; Factorial design; Surface quality

1. Introduction

Additive manufacturing (AM) has emerged as a promising fabrication technology for metal parts [1]. AM Technologies can fabricate complex shaped components using three dimensional Computer aided design (CAD) data starting from a precursor powder that is consolidated layer-by-layer. Working layer-by-layer according to the given CAD model offers a high geometrical freedom and the possibility to create very complex parts with internal cavities and channels. The consolidation can be reached by sintering or by melting using either a laser or an electron beam as an energy source.

Titanium aluminides alloy (TiAl) fall in the class of materials known as intermetallic alloys that are, compounds mainly formed by two metals. Their crystal structure and properties are completely different from their parent metals [2]. TiAl alloys based on the gamma phase (Gamma Titanium alloys) are new intermetallic alloys that contain 44-48 atomic percent Al (32-35 in weight percent), with element additions of Cr, or Mn to increase ductility, and Nb to improve strength and oxidation resistance. Gamma titanium aluminide alloys (γ-TiAl) have unique properties such as low density, high strength, high temperature, specific strength, high stiffness and good corrosion, creep, and oxidation resistance that are highly attractive for dynamic applications at high temperatures [3, 4]. γ-TiAl alloys show approximately half the density of Ni superalloys, high strength/weight ratio, and high refractoriness. Furthermore, they show fatigue resistance values close to 100% of yield strength [6].

Classic examples of applications of γ-TiAl include turbine blades, turbo charger wheels and valves for combustion engines, seal supports, cases, metal cutting tools, missile components, nuclear fuel, divergent flaps in nozzles of high speed gas turbine engines and artificial joint prostheses. Due to its attractive properties mentioned above, it has been considered as a potential replacement for Ni-based superalloys at temperatures ranging from 600 to 900ºC. Heat resistant γ -TiAl have been identified as possible alloys for high-performance automotive components, and they are intended for a wide usage in aerospace applications, especially in the hot parts of aircraft engines [5, 6].

In spite of their numerous advantages, γ-TiAl alloys show some drawbacks such as low ductility, which typically ranges between 0.3 and 4% in terms of elongation, brittleness, and low inherent formability at room temperature, together with low fracture toughness [7].

Electron beam melting (EBM) is an additive manufacturing

*Corresponding author. Tel.: +966 114676664, Fax.: +966 11467969
E-mail address: alahamri@ksu.edu.sa
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