Review Article

Institution of MECHANICAL ENGINEERS

Journal of ENGINEERING MANUFACTURE

Proc IMechE Part B:
J Engineering Manufacture
1–13
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DOI: 10.1177/0954405416640176
pib.sagepub.com
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Developments in cutting tool technology in improving machinability of Ti6Al4V alloy: A review

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Abstract

Ti6Al4V is the most widely used titanium alloy and is a demanding material in applications requiring high specific strength and corrosion resistance, that is, aerospace, automobile and biomedical industries. However, the poor machinability of this alloy, resulting from its low thermal conductivity, high hardness at elevated temperatures, high chemical reactivity with the cutting tool and low elastic modulus, restricts its usage. As a result, the tool life in machining of Ti6Al4V is substantially less than conventional materials such as steel and aluminium. This work reviews the various techniques employed in improving the machinability of Ti6Al4V alloy, from the perspective of cutting tool technology. The focus is onto the parameters affecting tool life in machining of Ti6Al4V alloy with some trending techniques and their feasibility, considering the economics to develop the best techno-economic method.

Keywords

Ti6Al4V, machining, tool life, carbide tools, surface treatment, cryogenics

Date received: 26 August 2015; accepted: 29 February 2016

Introduction

Titanium in its pure form is soft and has low mechanical strength and is used only for applications requiring moderate mechanical properties, high corrosion resistance and good weldability.[1] On the other hand, the titanium alloys exhibit exceptional mechanical strength, hardness, good corrosion resistance and low density making them useful in applications requiring high specific strength and good corrosion resistance such as aerospace and automotive.[2–4] The titanium alloys, due to their good biocompatibility, find application in biomedical implants.[5] These materials replace steels and aluminium alloys in many applications which usually require weight and/or space saving provide increase in system efficiency by raising the service temperature and due to their high chemical inertness, and eliminate the need of protective coatings that are used in steels. Exceptional corrosion resistance of titanium is due to its protective oxide film that results in its extensive application in seawater, marine, chemical industries, automobile industries, missile components, spacecraft, hydrocarbon processing, power generation, nuclear waste control, metal ore extraction, naval components, armour plates, anodes, food processing, pharmaceuticals, sports equipment, biomedical implants and other surgical equipment, and many other components.[6,7]

Titanium in its pure form exhibits variation in physical structure with transition from hexagonal close packed (hcp; α) phase to body-centred cubic (bcc; β) phase when heated to a temperature of 882 °C. Thus, a number of alloying elements are added to titanium for a desired combination of properties. The alloying elements, such as Aluminium (Al) and Oxygen (O), when added to titanium, results in increasing the phase change temperature, and are thus called ‘α stabilizers’. Tin (Sn) and Zirconium (Zr) are also added in small amount to stabilize the α-phase and provide strength. The elements such as Vanadium (V), Chromium (Cr), Molybdenum (Mo) and other transition metals are called ‘β stabilizers’ as they decrease the phase-transformation temperature. Titanium alloys are thus classified as ‘α’, ‘α-β’, ‘β’. The ‘α-β’ alloys have intermediate properties of both ‘α’ and ‘β’ alloys and includes ‘near α’ and ‘near β’ alloys depending on the composition of stabilizing elements. The broad

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