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Workpiece Preheating Approach to Reduce Chatter and Improve Machinability of Titanium Alloy - Ti6Al4V

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ABSTRACT

Though classified as a group of "difficult-to-cut" material, titanium and its alloys have wide applications in the aerospace industry owing to their high strength-weight ratio which is maintained up to elevated temperatures and their exceptional corrosion resistance. As a result, titanium and its alloys have been the subject matter of many research works, especially with the objective of reducing machining cost. In this work, experimental investigations have been conducted to determine the influence of preheating using induction heating on machinability of titanium alloy Ti-6Al-4V ASTM B348. Uncoated straight cemented carbide grade inserts were used for machining. The cutting speed was varied in the range from 40 to 160 m/min; with varying depths of cut and feed rates. Experiments on end milling conducted on VMC were design to look into vibration and chatter, cutting forces, tool wear and surface finish. A data acquisition system was used to monitor chatter, cutting force and workpiece temperature attained during preheating. It has been found that machining with preheating in the 330 – 360°C temperature range yield the best surface finish. Apart from that up to 60% reduction of chatter acceleration amplitude has been achieved during preheating as a result of increased plasticity and consequently improved damping capacity of the system. Preheating also helped in increasing tool life by 30% to about 70% and in reducing surface roughness by 40 to 55%.

1. INTRODUCTION

Characteristic of titanium and its alloys are very unique. High specific strength, which is maintained at elevated temperature, fracture resistance characteristic, and their exceptional corrosion resistance, made them very useful materials for aerospace and petrochemical applications. However, high cost and poor machinability are major constraints towards their wide spread applications. Ezugwu et al. [1] stated that success in the machining of titanium and its alloys depends largely on overcoming the principal problems faced during machining these materials, namely high cutting temperature, high cutting pressures, small chip-tool contact length (which is about 1/3 that of the contact area for steel at the same feed rate and depth of cut) and chatter. High cutting temperature due to high resistance of titanium alloys to deform at elevated temperature and their low thermal conductivity (1/6 of steel) to remove the heat from the cutting zone leads to high cutting temperatures with the hot spot very close to cutting edge. On the other hand, high cutting pressure is attributed to high resistance to plastic deformation and small chip-tool contact length. The formation of chatter is associated with the formation of serrated type of chip. Chatter leads to fluctuation of cutting force and contact stresses acting over small contact areas lead to micro and macro failures of the tool. Chatter is also undesirable because of its adverse effects on surface finish, machining accuracy and tool life [2]. Talantov and Amin [3, 4] established that chatter arises in the system when the frequency of the chip tooth serration coincides with any one of the natural frequencies of the system, e.g. the spindle and tool holder. Alternating phases of compression and adiabatic shear along a narrow rotating shear zone leads to the formation of 'cyclic' or serrated teeth [4]. Chip tooth serration affect high dynamic loading on the tool causing catastrophic failure of the tool and high surface roughness during machining. Nakayama [5] attributed the serrated tooth chip formation to the lack of ductility of the workpiece material causing heat concentrations and vibrations. Nakayama [5] and Konig et al [6] also explained the explained the mechanism of formation of the saw-toothed chip. They observed that this type of chips are formed when the critical shear stress is exceeded under compressive stress and shear loads. Many methods of