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Surface Grinding of Ti-6Al-4V Alloy with SiC Abrasive Wheel at Various Cutting Conditions

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Abstract

Ti-6Al-4V alloy is mostly used in biomedical and aerospace industries, as well as in automotive and cutting implements, like scissors and knives due to its high strength-to-weight ratio and excellent resistance to corrosion in many environments. However, Ti-6Al-4V alloy is referred as difficult-to-cut material due to its unique combination of low thermal conductivity and high chemical reactivity with most cutting tools, especially with ceramics, and rapid work hardening during machining,. This will accelerate tool wear and generally adversely affects surface quality of the component. This becomes more critical in grinding operation due to conventional abrasive wheels that have poor thermal conductivity and small dimension of chips, which in turn contributes to more heat to be concentrated in the cutting zone. Depending on the temperature gradient and workpiece, this heat can cause damage to the component surface. So, it is important to control the amount of heat entering the workpiece and prevent damages like burning, surface cracks and other metallurgical alterations in the workpiece. In this context, this work investigates the surface quality of the Ti-6Al-4V alloy in terms of surface roughness e microhardness, after surface grinding with silicon carbide wheel under various cutting conditions. The morphology of the machined was also analyzed in a Scanning Electron Microscope to understand the cutting mechanisms. Conventional and MQL coolant delivery techniques were tested. A specially designed nozzle was tested in the experiments with the MQL. Results showed that surface roughness is dependent on both radial depth of cut and coolant system; and the lowest results were recorded after machining with the combination of the lowest depth

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of cut and MQL technique. With respect to microhardness, little variation was observed after machining with the MQL technique, unlike when machining with conventional method, irrespective the depth of cut employed.

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Keywords: Grinding; Ti-6Al-4V alloy; MQL technique; Depth of cut; Surface roughness; Microhardness.

1. Introduction

Grinding is a finishing machining process that can provide smooth surfaces and very accurate dimensions on the machined components, compared to other machining process that uses geometrically defined cutting edges, such turning, for example. However, grinding is a low efficiency process since the specific energy is much larger than other metal-cutting operations, which means that a large amount of energy is used to remove a low volume of material [1]. On other hand, grinding process could achieve quickly the needed workpiece geometry and finishing required in one single pass, as the creep feed operation in materials like Ti-6Al-4V alloy. The most part of the energy spent in the grinding process is dissipated into heat that, depending on the quantity, is transferred to workpiece, thereby causing damage of it surface integrity. This damage can be reduced by applying a proper coolant to remove the heat generated as well as lubricate wheel-workpiece interface, so that the friction is reduced [2]. Therefore, the cutting fluid plays an important role in preserving the integrity (surface and shape) of the workpiece and, so, it becomes practically indispensable in the grinding process.

Besides the type of cutting fluid used in the process, proper selection of coolant delivery and its flow rate are equally important to improve grinding process efficiency. Several works focusing on investigation of type of fluid, delivery technique and nozzle positioning to improve efficiency of grinding process have been found in the specific literature [2, 3].

Since the 1990 decade, due to environmental appeals to reduce/eliminate cutting fluids, dry machining and Minimum Quantity of Lubricant (MQL) technique have been attracting attention of machining researchers as an alternative way to the use of conventional cutting fluids on grinding operations. Benefits of using MQL technique in grinding have been reported by [4, 5, 6, 7]. These authors in general observed lowest grinding wheel wear and improved finishing. However, the use of MQL technique have been more extensively studied in the machining of steel, nickel and titanium alloys, regarding to the usage of nanofluids, super-abrasive wheels (diamond and cubic boron nitride – cBN) and, most of them, whit Al2O3 grinding wheel, as summarized in [8]. Few works reported results for the study using combination of the MQL technique and silicon carbide wheel in surface grinding of the Ti-6Al-4V alloy, what was the one of the motivation of this study.

When grinding titanium, the use of cutting fluid is even more necessary to prevent occurrence of surface burning [9]. Furthermore, it also important to guarantee that proper penetration of coolant in cutting zone, thus preventing metal being picked up on the abrasive grits [10]. Ti-6Al-4V alloy is referred as difficult-to-cut material due to some characteristics, such as chemical affinity, low elasticity modulus, low thermal conductivity, and high tendency of hardening during machining [11]. Also, it has high chemical affinity with most of cutting tools, especially with ceramics. Despite of several works carried in grinding of titanium and its alloys, there is not yet a common sense in the literature with regard the appropriated abrasive wheel type, since aluminum oxide and silicon carbide are the typical conventional abrasives available. With regard aluminum oxides, it could be used different kind, as also mono crystalline grains or seeded gel ceramic grains, within different shapes. These materials have poor thermal conductivity, relatively low fracture toughness and high reactivity with titanium alloys [12]. According to [13], due to the poor thermal properties of titanium alloys, most of the heat being generated during the intense cutting deformation process is concentrated in a very narrow area of the primary cutting band. In the study about grinding of Ti-6Al-4V [10] with aluminum oxide wheel under different lubri-coolant techniques and various cutting conditions (table speed – v_w – of 20, 30 and 40 m/min, depth of cut values of 0.002, 0.005 and 0.007 mm and v_s = 15 m/s, which was kept constant), reported that the abrasive grains retained sharpness for a longer period, and thus, metal removal takes place mostly by shearing and fracturing hence providing sharp ridges and higher roughness values