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Influence of cutting speed and cooling method on the machinability of commercially pure titanium (CP-Ti) grade II

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ABSTRACT

The present investigation aims in highlighting the influence of cutting speed and an eco-friendly cooling technique during finish turning of CP-Ti grade 2. Experiments were performed at three distinct machining modes viz. dry cutting (DC), flood cooling (FC) and minimum quantity lubrication (MQL) using carbide inserts. Water soluble oil and vegetable oil were used as cutting fluids with FC and MQL respectively. The work material was turned at three different cutting speeds i.e. 51, 67 and 87 m/min whereas feed rate and depth of cut were kept as constant at 0.12 mm/rev and 0.5 mm respectively. A comprehensive exploration on the cooling effects of vegetable oil based MQL method on some of the key machinability aspects such as cutting force, tool wear, friction coefficient, chip morphology, chip reduction coefficient, micro hardness of machined surface, surface roughness and machining temperature is reported. The aforesaid turning responses were recorded and compared in order to exhibit the feasibility of MQL approach in comparison with dry and flood cooling approach. The results obtained during the investigation clearly established the superiority of implementing MQL for achieving improved machinability within a specified range of process parameters.

1. Introduction

Titanium and its alloys have become best material choices in aerospace, marine, petro chemical, medical, nuclear and energy industries due to their inherent assets such as highest strength-to-weight ratio and excellent resistance to corrosion and deformation under high temperature and pressure [1]. However, the foremost challenge that encounter during titanium machining includes generation of high temperature at cutting zone owing to its low thermal conductivity. The chemical affinity of these alloys are also reported more than that of other similar materials. Therefore, titanium and its alloys are specifically characterised as hard-to-cut type material. Poor thermal conductivity leads to rapid upsurge in temperature near machining zone particularly at chip-tool interface region. High temperature at cutting zone sturdily accelerates tool wear and hence reduces the tool life to a great extent [2]. Further, titanium and its alloys are capable of maintaining their strength even at higher temperature (because of highest strength-to-weight ratio) which at the same time contributes to deteriorate the performance of cutting tool inserts while machining at higher cutting speeds. Therefore, the most preferable range of cutting speed in titanium machining was suggested between 30–60 m/min [3,4]. High chemical affinity of titanium alloys often offers severe tool damage at pre mature stage beyond the aforementioned speed limit. Therefore, in order to attain a reasonable tool life along with good surface quality even at high cutting speeds, an efficient and effective cooling or lubrication approach should be applied. In such situations, cutting fluids such as water soluble oil and vegetable oil are strategically employed as cooling media to reduce the temperature at chip-tool interface region. It also helps in improving surface quality and wear resistance in combination with substantial reduction in cutting forces [1–7]. Priarone et al. [6] investigated the effect of lubrication technique on tool wear and surface quality during machining of Ti-48Al-2Cr-2Nb intermetallic alloy. They noticed a significant reduction in both the aforesaid machining characteristics after implementing MQL method in comparison to dry cutting. The percentage reduction in tool wear and surface roughness was perceived nearly 50% and 30% respectively. In a different study conducted by Dhar et al. [8] revealed a notable diminution in machining temperature (approximately 5–10%) by adopting MQL approach. Similarly, Vikram et al. [9] also tested the performance of TiCN and ZrN coated tools during hard turning of AISI 4340 alloy steel in both dry and MQL cutting conditions. The results indicated a remarkable decrease in the cutting force, machining temperature and

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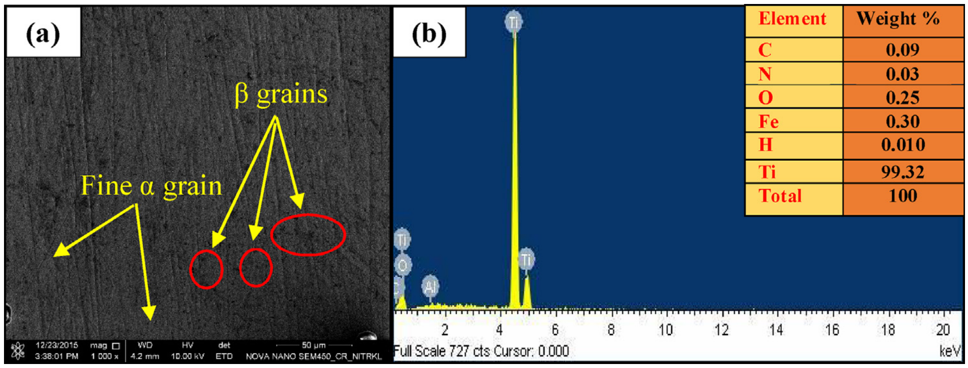

Fig. 1. FESEM images of (a) Microstructure and (b) EDS spectra of CP-Ti grade 2.

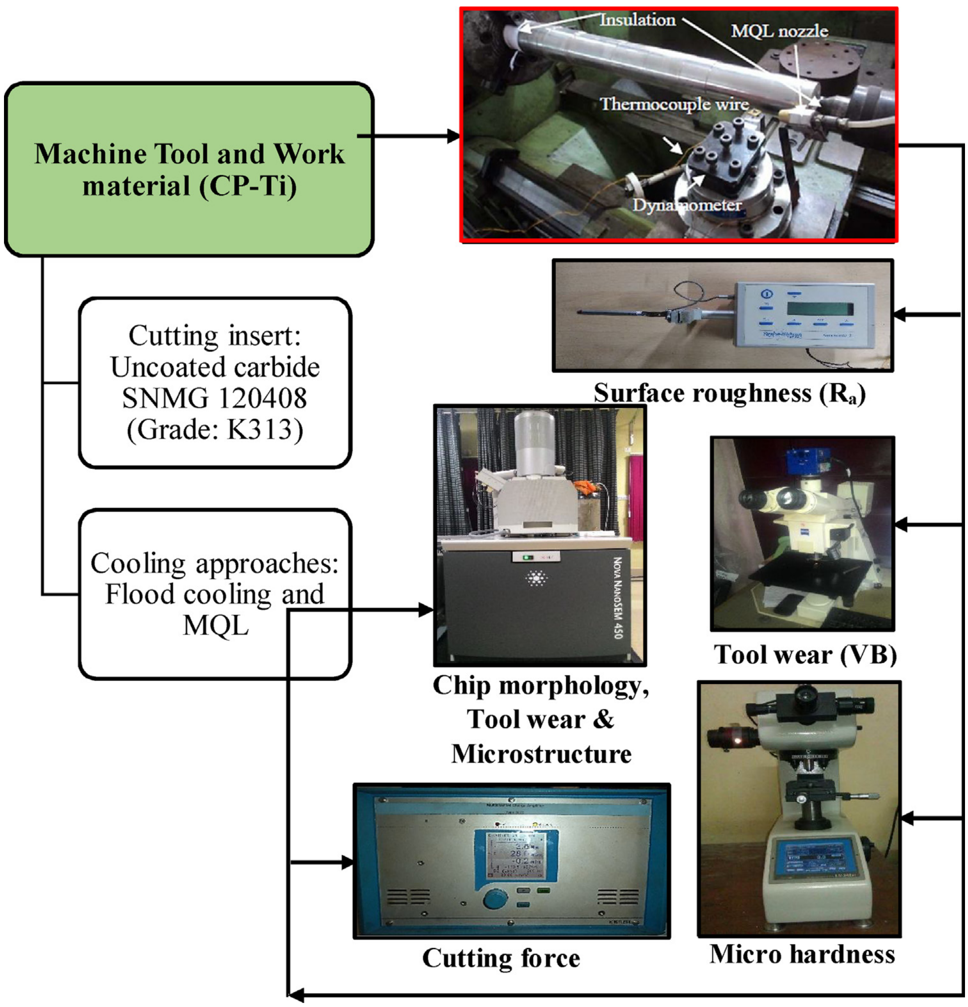

Fig. 2. Photographic view of the present investigation.

surface roughness (roughly 42%, 29% and 39% respectively) with the minimal fluid application when compared to its dry machining counterpart. Thus, the world wide consumption and disposal of cutting fluids are interestingly enhanced. The consumption of cutting fluids in the U.S.A. was recorded about 100 million gallons/year whereas in Germany it was about 2 million gallons/year [10,11]. The rapid growth in utilization of cutting fluids upraised a serious problem due to some of its adverse effects. Since, most of them are not biodegradable and hence they introduce an adversarial and hostile situation to men, machine and environment. Continuous interaction of machine tool operator with cutting fluid possibly cause serious lung and skin diseases [12,13]. Indecorous removal and dumping of these cutting fluids might result in ground, air and water pollution. Additionally, the costs associated with cutting fluids are quite higher than that of labour and overhead costs. Past research indicated that, about 16% of the total production cost is covered by the cost of cutting fluid used during the process. These costs reach up to 30% when machining difficult-to-cut type materials like titanium and its alloys [14,15].

An extensive work has been reported based on critical analysis of an economic and eco-friendly machining of hard-to-cut materials such as titanium and nickel based alloys with an objective to accomplish considerably improved machinability [16–20]. In this regard, the capability of coolant in bringing down the machining