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Drilling of titanium aluminide at different aspect ratio under dry and wet conditions

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ABSTRACT

To increase the wide use of intermetallic titanium aluminides for various fields of engineering application, a broad understanding of the machinability of these material is essential. The present work is focussed on the drilling of this intermetallic alloy at low and high aspect ratio under dry and wet environments. The machinability in dry and wet conditions were assessed based on the thrust force, torque, burr formation, surface quality, tool condition and chip morphology. The supply of cutting fluid is found to be effective in reducing the thrust force and torque and producing quality surface. Burr, being an important factor in drilling have also been studied, and the findings show the presence of uniform burr with and without roll back in dry and wet condition respectively. Surface defects formed and their intensity during both the machining environments were analysed. Built up edge formation on the drill tool was detected in all cutting conditions. The transformation of chip shape as the depth of hole progresses is also detailed in the present work. Furthermore, the study demonstrates the feasibility of drilling titanium aluminide in dry and wet environment. The overall results indicate that dry environment is not viable for high aspect ratio drilling.

1. Introduction

The advancement in the materials engineering lead to the application of more and more hard to machine materials and composite material in the recently developed aircraft engines and its parts. Titanium (Ti) and Nickel (Ni) based super alloys occupies the major portion in aerospace structures and engines due to their excellent properties like corrosion resistance, high toughness, etc. Extensive studies has been conducted to improve the engine performance by using these alloys and any additional improvement is almost exhausted. The necessity of new material which are stronger and lighter to resist extremely challenging environments in the next generation engines were growing in engineering applications [1]. The foremost need among them were to improve the efficiency and enhancement in fuel consumption which could substantially reduce the CO_2 emission and thus fulfilling the environmental regulations [2,3]. These requirements initiated the research activities which lead to the development of new advanced materials like intermetallic titanium aluminide (TiAl) alloys.

Intermetallic TiAl are exceptional class of material with superior mechanical properties at elevated temperature. This lead to the extensive application of these materials in the development of critical components for high performance aircraft engines. In order to develop and establish new fields of application, the understanding of machining of these materials is very much important. There has been extensive studies in understanding the microstructure, oxidation, fatigue behaviour, mechanical and thermal properties of TiAl, whereas when the machining (conventional and non-conventional) of TiAl is considered, the available literature is found to be scarce [4]. The high material and processing cost, along with their poor machinability restricts the wide usage of this material, despite having attractive mechanical and thermal properties. Because of their low ductility along with low thermal conductivity, high hardness and brittleness at room temperature, low fracture toughness and chemical reactivity with many tool materials, TiAl alloys are also considered as difficult to machine material [5–7].

Even thou TiAl have attractive properties, its poor machinability has been reported in literature during conventional and non-conventional machining processes [7]. During turning of TiAl, surface cracking, formation of hardened layer was observed by some researchers [8,9]. As the workpiece temperature increases, the transition of the chip formation from segmented to continuous chips during turning of TiAl was observed by Uhlmann et al. [6].

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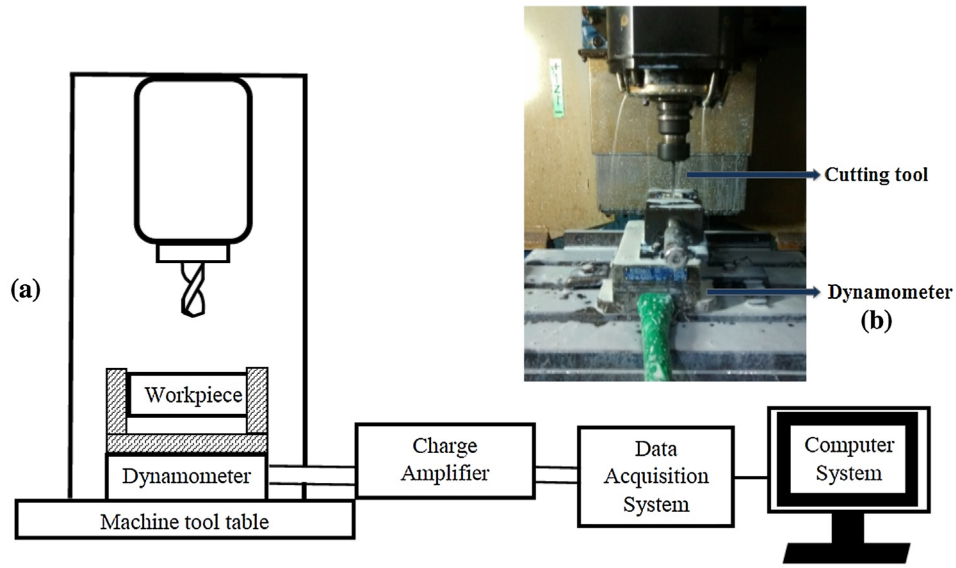

Fig. 1. Experimental set up.

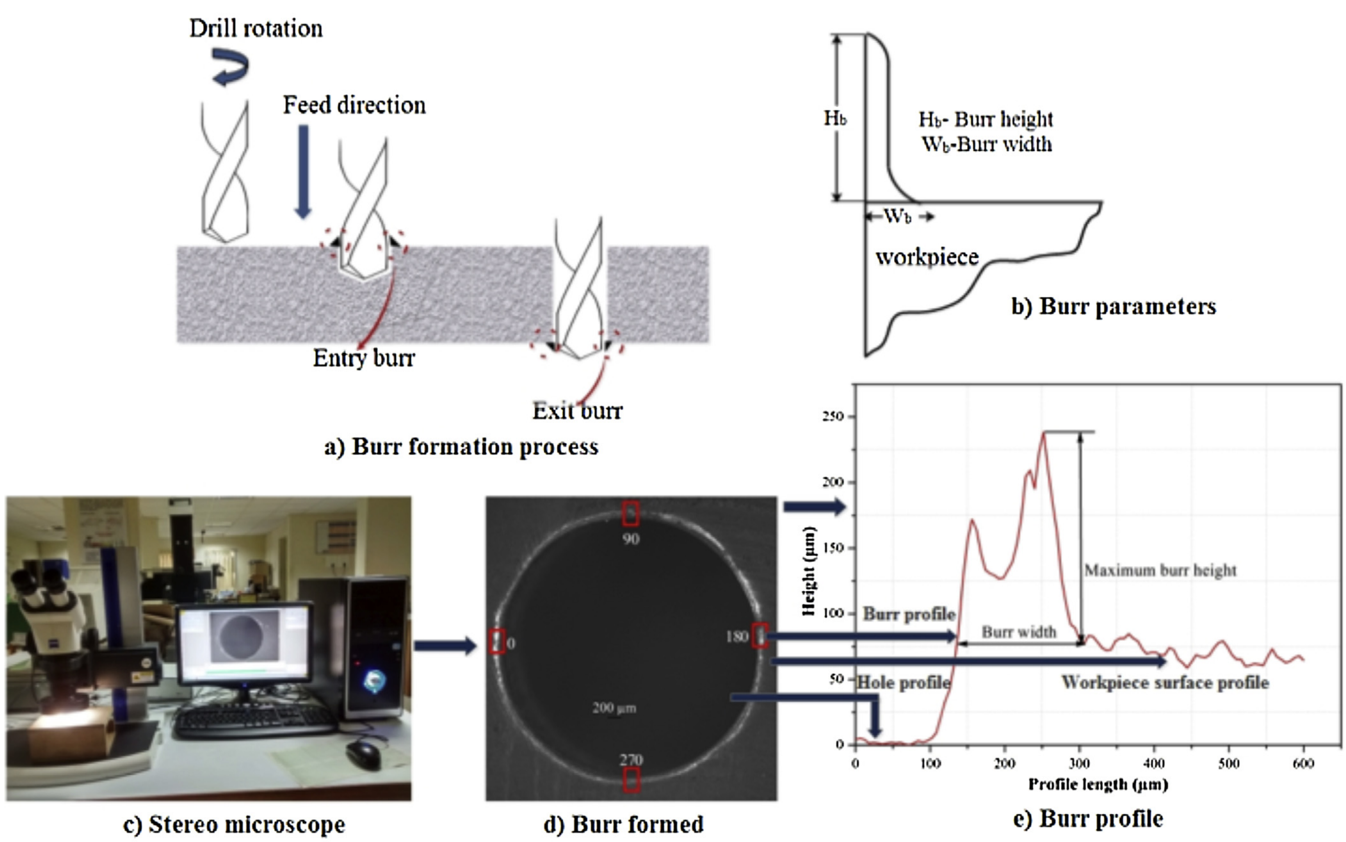

Fig. 2. Burr profile measurement.

Klocke et al. [3,7] studied the machinability while turning of TiAl by evaluating tool wear, thrust force, chip morphology and surface quality. The results indicated that the presence of strong frictional and adhesive processes between tool and workpiece which lead to the poor tool life. Settineri et al. [10] found out that the tool wear is mostly abrasive and also observed micro-chipping and chipping of cutting edges.

During the milling of TiAl, Mantle and Aspinwall [11] observed work surface alterations including material pull out, fracture, smear and deformation of lamellae. Priarone et al. [12] observed prominent corner wear than flank wear along with micro-chipping of the cutting edge. The adherence of work material to the cutting tool was also observed by them. Settineri et al. [10] observed the adhesion and chipping at the end of the tool life. Hood et al. [13] studied