Abstract

Tool wear mechanism of difficult-to-cut materials
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Titanium alloys (Ti), Cast Graphite Iron (CGI), Carbon Fiber Reinforce Plastics (CFRP) and CFRP/Ti Stack are difficult-to-cuts materials which have been extensively used and attracted attention in aerospace, automobile, chemistry, biomedicine, sport and other industrials. Those materials has distinguished properties i.e. Ti is a light-weight metal (4.3 g/cm$^3$ in density) which has a low thermal conductivity, 6.7 W/m.K (50.8 W/m.K for steel), CGI has superior physical and mechanical properties compare to gray cast iron which common used in automotive industrial, CFRP and CFRP/Ti are light-weight materials with high corrosion resistance, better mechanical properties. However, the common drawback of the materials is poor machinability.

Firstly, with titanium alloy Ti64, the flank wear mechanism was investigated by examining the microstructural impact on flank wear attained. By machining four bars with distinct microstructures including elongated, mill-annealed, solution treated & annealed and fully-lamellar microstructures, the root causes of flank wear are determined to be the hard $\alpha$-phase and the lamellar colonies. The hard $\alpha$-phase are not supported by the surrounded phases whereas the lamellar structure offers constraints with its microstructures. For crater wear, it supposed that there are 2 main wear mechanisms happened at the same time, they are dissolution and diffusion. With Titanium machining, the diffusion rate is smaller dissolution, so diffusion mechanism is dominant in crater wear. Secondly, the poor machinability of CGI with cBN tool is explained by lack of Al$_2$O$_3$ formation layer in rake face when cut in high speed (600 and 800 m/min). The unusual phenomenon in flank wear improvement when cut CGI at high speed seems to be high cutting temperature generated less brittle CGI. Thirdly, with CFRP and CFRP-stack, the dominate wear mode in machining CFRP and CFRP/Ti stack are combination of flank wear and edge rounding and the main wear mechanism is the abrasive.

Finally, two methods to improve the machinability were applied in machining these difficult-to-cut materials: the super-hard ceramics coating tools and minimum quantity lubrication (MQL). The number of coating materials: BAM, AlTiN, ZrN, (AlCrSi/Ti)N and uncoated carbide are examined in drilling and turning processed with Ti64 and CFRP/Ti stack. The nanocomposite (AlCrSi/Ti)N with alternating layers show significant improvement. With the MQL method, the wear evaluation of dry, minimum quantity lubrication (MQL) and MQL with nanofluid in turning the most common titanium (Ti) alloy, Ti-6Al-4V, in a solution treated and aged (STA) microstructure are investigated. In particular, the nanofluid evaluated here is vegetable (rapeseed) oil mixed with small concentrations of exfoliated graphite nanoplatelets (xGnP). This
work focuses on turning process which imposes a challenging condition to apply oil droplets directly onto the tribological surfaces of a cutting tool due to the uninterrupted engagement between tool and work material. This preliminary experimental result shows that MQL and in particular MQL with the nanofluid improve the machinability of Ti alloys even for turning process. However, to attain the best performance, the MQL conditions such as nozzle orientation and the concentration of xGnP must be optimized.