

International Journal of Machine Tools and Manufacture

2014

On the mechanics of chip formation in Ti-6Al-4V turning with spindle speed variation

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Abstract:

Titanium alloys are hard-to-cut materials and need to be machined at relatively low cutting speeds with obvious negative consequences on the profitability of machining. In order to enhance material removal rate (MRR), a strategy that relies on higher depths of cut could be chosen if vibrational issues due to regenerative chatter did not occur. A lot of research was done to suppress regenerative chatter without detrimental effects on productivity. One of the most interesting chatter suppression methods, mainly due to its flexibility and relative ease of implementation, is spindle speed variation (SSV), which consists in a continuous modulation of the nominal cutting speed. Sinusoidal spindle speed variation (SSSV) is a specific technique that exploits a sinusoidal law to modulate the cutting speed. The vast scientific literature on SSV was mainly focused on cutting process stability issues fully neglecting the study of the mechanics of chip formation in SSV machining. The aim of this work is to fill this gap: thus, finite element method (FEM) models of Ti-6Al-4V turning were setup to simulate both SSSV and constant speed machining (CSM). The models consider both the micro-geometry of the insert and the coating. Numerical results were experimentally validated on dry turning tests of titanium tubes exploiting the experimental assessment of cutting forces, cutting temperatures and chip morphology. Tool-chip contact pressure, tool engagement mechanism and the thermal distribution in the insert are some of the analysed numerical outputs because they cannot be easily assessed by experimental procedures. These quantities were useful to compare thermo-mechanical loads of the insert both in CSM and SSSV machining: it was observed that the loads significantly differ. Compared to CSM, the modulation of the cutting speed involves a higher tool-chip contact pressure peak, a higher maximum temperature and higher temperature gradients that could foster the main tool wear mechanisms.

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