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FEM simulation of Ti6Al4V turning with SSSV

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Titanium alloys are well known as hard to machine materials, mainly because of their poor thermal conductivity, and need to be cut at relatively low cutting speeds, with obvious negative consequences on the profitability of machining.

To enhance productivity, an increase in depth of cut should be pursued. This often determines the onset of a vibration phenomenon known as *regenerative chatter*. Regenerative chatter must be suppressed with no detrimental effects on machining times. One of the most interesting chatter suppression methods, due to its flexibility and relative ease of implementation, is the Sinusoidal Spindle Speed Variation (SSSV) that consists in a continuous modulation of the nominal spindle speed with a sinusoidal law. The scientific literature on SSSV always deals with models aimed at investigating the vibration dynamics of the machine-tool-workpiece mechanical system. No previous study is available that describes the chip formation mechanisms and the thermal and mechanical load on the tool.

The purpose of the present research is to investigate the physics of the interaction between the tool and the workpiece, dealing both with the thermal aspects and the mechanical phenomena related to the adoption of SSSV in Ti6Al4V turning. A 2D FEM (Finite Element Method) simulation model of the cutting process has been built, in order to accurately simulate a variable speed machining operation.

The tool-chip contact pressure, the temporal evolution of tool engagement mechanism and the temperature distribution along the rake face are, for instance, some of the outcomes that have been analysed, considering different cutting speed modulations. The spatial and temporal distribution of temperature on the tool have been also analysed, thanks to a second, purely thermal, FEM model.

The models have been experimentally validated by means of dry turning tests of titanium tubes, under orthogonal cutting conditions.

The results clarify how the tool-workpiece engagement varies during the spindle speed variation period. In particular the variable cutting speed and feed rate cause a variable thermal and mechanical load on the tool rake face and cutting edge. The finite elements analysis shows that these loads are never focused on the same tool zone and that the thermal load is linked to the speed variation while the mechanical load to the feed variation. Moreover, a friction coefficient tuning has been performed to determine the best value according to a spectrum analysis of both the experimental and the FEM cutting forces.

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