 ICCES, vol.19, no.3, pp.95-96

3D finite element analysis of hot ultrasonically assisted turning of modern alloys

R. Muhammad*, A. Maurotto, M. Demiral, A. Roy and V.V. Silberschmidt

Summary

Analysis of the cutting process in machining of modern engineering materials (Ti- and Ni-based alloys), which are hard-to-cut materials, is a challenge that needs to be addressed. Machining of these alloys with conventional techniques is difficult and often results in tool failure due to the high cutting forces imposed on the tool. In a machining operation, cutting forces causes severe deformations in the proximity of the cutting edge, producing high stresses, strain, strain-rates and temperatures in the workpiece.

Ultrasonically assisted turning (UAT) is an advanced machining process, which has shown several advantages especially in the machining of high strength engineering materials [1-3]. Typically, the yield strength of a material reduces with an increase of temperature, thus, reducing the cutting forces required to cut the materials [4, 5]. To increase the metal removal rate and to further reduce the cutting forces, a hot ultrasonically assisted turning (HUAT) process is developed, where the temperature sensitive material properties of the workpiece is exploited to enhance the machining process. In HUAT, critical machining parameters are the vibro-impact interaction parameters, namely the frequency, and amplitude of vibration as well as on the amount of heat supplied to the workpiece during machining.

Analysis of the cutting process in machining of modern engineering hard-to-cut materials (Ti- and Ni-based alloys) is a challenge that needs to be addressed. Machining of such alloys with conventional techniques is difficult and often results in tool failure due to high cutting forces acting on the tool. In a machining operation, cutting forces cause severe deformations in the proximity of a cutting edge, producing high stresses, strains, strain rates and temperatures in the machined workpiece.

Ultrasonically assisted turning (UAT) is an advanced machining process, which has shown several advantages especially in the machining of high-strength engineering materials [1-3]. The process has a vibro-impact character that changes the type of deformation in the process zone. One of the important material parameters defining its machinability is its yield stress. Typically, the latter reduces with an increase of temperature, thus, reducing the cutting forces required to cut the materials [4, 5]. To increase a metal removal rate and to further reduce cutting forces, a hot ultrasonically assisted turning (HUAT) process is developed; it exploits temperature-sensitive material properties of the workpiece to enhance the machining process. In HUAT, critical machining parameters are the ones of vibro-impact interaction, namely, the frequency and amplitude of vibration, as well as on the amount of heat supplied to the workpiece during machining. Our experiments have demonstrated significant force reduction achieved with HUAT.

Finite element models have been developed to elucidate the underlying mechanics of both UAT [3] and HUAT process . These models allow us to study chip formation, cutting forces, stresses as well as the effects of heating and cutting conditions on cutting forces and stresses in the processing of Ti- and Ni-based alloys. The obtained numerical results are validated with experimental data.

Keywords: finite element, UAT, HUAT, modern alloys, cutting forces, stresses, hot machining

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