Computational aspects of the finite element simulation of chip formation

Attila KOSSA, Gabor STEPAN

Department of Applied Mechanics
Budapest University of Technology and Economics
Muegyetem rkp. 5., H-1111 Budapest, Hungary
e-mails: kossa@mm.bme.hu, stepan@mm.bme.hu
web pages: http:// http://www.mm.bme.hu/~kossa, http://www.mm.bme.hu/~stepan

ABSTRACT

Improving the manufacturing quality in metal cutting processes requires the complete understanding of the chip formation phenomena, which may be analysed using finite element method (FEM) in addition to experimental tests. Numerous papers have been published in the last years presenting finite element analyses (FEA) of metal machining processes including the simplest orthogonal cutting. Most of the numerical studies were performed using the commercial FE software ABAQUS/Explicit [1]. The numerical models adopted by authors differ paper by paper. Therefore, one may conclude that there is no consensus on developing the FE-model to analyse the chip formation. There are plenty of computational aspects be considered in order to obtain accurate numerical results. One of the most important among them is the constitutive model used to represent the material characteristics. Usually, elastic-viscoplastic constitutive equations are adopted including thermal softening effect. The most widely used expression to calculate the Mises' equivalent stress is the Johnson-Cook material model [2]. Another extremely important aspect is the fracture model, which includes the damage initiation criterion and the damage evolutionary law, respectively [3]. The contact model adopted to represent the contact phenomena between the chip and the tool also strongly influences the overall numerical results. Some other aspects, which have to be considered in the FEA (without providing a comprehensive list) are: temperature rise due to plastic deformation and friction; effect of heat generation; modelling the material degradation after damage initiation; heat transfer with the environment; region in the mesh for which element deletion is allowed; introducing sacrificial layer in the mesh to facilitate chip separation; temperature-dependence of the material parameters; 2D vs. 3D modelling of the problem; plane strain vs. plane stress elements in 2D; effect of the element size; influence of the friction coefficient; element type; adaptive remeshing; rigid tool vs. deformable tool.

This article addresses to summarize the key questions in FEA of chip formation processes in orthogonal cutting. The benefits and drawbacks of every ingredient of the computational model is discussed and presented. In addition, finite element simulations demonstrate the corresponding numerical results for various finite element models.

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