 ICCES, vol.17, no.3, pp.93-93

On the New Plasticity Theories for Metal Deformation under High Strain, High Strain Rate and High Temperature

Liangchi Zhang

Summary

Understanding the deformation mechanisms of metals under the coupled attack of high strain, high strain rate and high temperature (coupled H3 effect) has become more and more important to the development of new manufacturing technologies. High speed machining (HSM), a new technology to cut high hardness materials, is a typical example, as HSM has become an essential process in making ultra-precision, high-integrity components for devices and structures in the automotive, aeronautical, aerospace and biomedical industries. Nevertheless, due to the high machining speed in HSM, many problems which do not appear in conventional machining will take place. New plasticity theories are required to more accurately describe the mechanical behaviour of metals under the coupled H3 effect. In general, the dynamic behaviour of a material is a function of state variables such as plastic strain, strain rate, temperature, and some structural parameters related to deformation history. Thus the new plasticity theories must reflect the complicated relationships among the main mechanical state variables of a material. Over the past decades, quite some empirical constitutive models have been proposed based on the conventional phenomenological theory, of which the Johnson-Cook (J-C) model is the most widely used. However, it has been reported that the J-C equation cannot describe many experimental observations/measurements when a material is subjected to HSM.

This presentation will discuss new constitutive models for describing the dynamic plasticity of FCC and HCP metals using the thermal activation mechanism of dislocation motion. In the FCC model development, the constitutive parameters were directly linked with the characteristics of microstructures of materials. To determine the globally optimized parameters, an improved multi-variable optimization method of constrained nonlinear programming was used based on the flow stress of the material experimentally measured. For HCP metals, the constitutive parameters of the material are determined by a new efficient method composed of a global genetic algorithm and a local penalty-function algorithm, which guarantees that the constitutive parameters are a globally optimal solution in their theoretically allowed ranges. A comparison with some previous models and experimental results shows that the new models are simple to apply and are much better in terms of its prediction accuracy.