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Critical Conditions for the Initiation of Dynamic Recrystallization Prediction: Analytical and Finite Element Modeling

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Abstract : Large-size forged blocks made of medium carbon high-strength steels are extensively used in the automotive industry as dies for the production of bumpers and dashboards through the plastic injection process. The manufacturing process of the large blocks starts with ingot casting, followed by open die forging and a quench and temper heat treatment process to achieve the desired mechanical properties and numerical simulation is widely used nowadays to predict these properties before the experiment. But the temperature gradient inside the specimen remains challenging in the sense that the temperature before loading inside the material is not the same, but during the simulation, constant temperature is used to simulate the experiment because it is assumed that temperature is homogenized after some holding time. Therefore to be close to the experiment, real distribution of the temperature through the specimen is needed before the mechanical loading. Thus, We present here a robust algorithm that allows the calculation of the temperature gradient within the specimen, thus representing a real temperature distribution within the specimen before deformation. Indeed, most numerical simulations consider a uniform temperature gradient which is not really the case because the surface and core temperatures of the specimen are not identical. Another feature that influences the mechanical properties of the specimen is recrystallization which strongly depends on the deformation conditions and the type of deformation like Upsetting, Cogging...etc. Indeed, Upsetting and Cogging are the stages where the greatest deformations are observed, and a lot of microstructural phenomena can be observed, like recrystallization, which requires in-depth characterization. Complete dynamic recrystallization plays an important role in the final grain size during the process and therefore helps to increase the mechanical properties of the final product. Thus, the identification of the conditions for the initiation of dynamic recrystallization is still relevant. Also, the temperature distribution within the sample and strain rate influence the recrystallization initiation. So the development of a technique allowing to predict the initiation of this recrystallization remains challenging. In this perspective, we propose here, in addition to the algorithm allowing to get the temperature distribution before the loading stage, an analytical model leading to determine the initiation of this recrystallization. These two techniques are implemented into the Abaqus finite element software via the UAMP and VUHARD subroutines for comparison with a simulation where an isothermal temperature is imposed. The Artificial Neural Network (ANN) model to describe the plastic behavior of the material is also implemented via the VUHARD subroutine. From the simulation, the temperature distribution inside the material and recrystallization initiation is properly predicted and compared to the literature models.

Keywords : dynamic recrystallization, finite element modeling, artificial neural network, numerical implementation
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