Influence of the geometry of hat-shaped specimens on the formation of adiabatic shear bands

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ABSTRACT

The deformation behaviour of ductile metals is determined by phenomena at different physical length scales. In most ductile metals subjected to high strain-rates, the development of adiabatic shear bands (ASB) is one element of that process. In ASBs, the highly localized shear deformation occurs in a narrow band which exhibits very large strains relative to the neighbouring material. Since the deformation time is very small, the process happens adiabatically. The resulting temperature increase by plastic work causes thermal softening and further localization of plastic deformation. ASBs are observed in many applications such as machine chips, forging, ballistic impact loading and fracture.

In the past, a dozen of experimental techniques have been developed to characterize the process of ASB formation. One often used technique is based on the dynamic deformation of hat-shaped specimens in a split Hopkinson pressure bar (SHPB) setup [1]. Figure 1 shows a sketch of the specimen with an indication of characteristic lengths. Due to the specific geometry of this specimen, shear strains are concentrated in a narrow region. This technique is especially popular among metallurgists because even materials that do not localize spontaneously in shear can be forced up to shearing failure. On the other hand, the determination of material properties from these experiments is not straightforward because of the complex stress state in the shearing region.

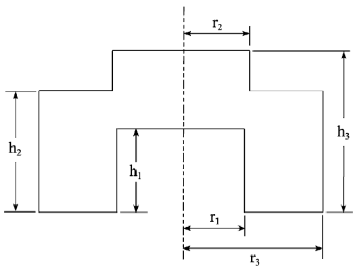

Figure 1: Hat-shaped specimen

More insight in the stress distribution in the specimen is needed in order to better understand the experimental data obtained by this technique. Furthermore, as the nucleation and propagation of ASBs depends on the stress condition [2], knowledge of the stress distribution is crucial. Several researchers used different specimen dimensions in their experiments. Moreover, the outcome of these experiments is affected not only by the testing material but also by the specimen geometry. In [1] the stress distribution of one particular specimen geometry was investigated using FE simulations.

The goal of this contribution is to relate the specimen dimensions with the stress distribution in the specimen. This has previously been done for other specimen geometries: e.g. truncatedconic specimens [2], dogbone-shaped tensile specimens [3] and double shear specimens [4]. In addition, the existence of an optimal specimen geometry to achieve an as pure as possible shearing stress state, is studied.

The main tool in this study is the FE method. A 3D axis-symmetric model has been defined, using ABAQUS/explicit. The load is applied by a uniform velocity of the boundaries of the specimen. Strain-rate dependency of the material behaviour is modelled by the Johnson-Cook phenomenological model. Heat generated due to the plastic work is included, while heat conduction is not implemented. To overcome difficulties from extensive element distortion, ALE adaptive meshing is used. Figure 2 shows the distribution of the shear stress in the shear region of a sample.

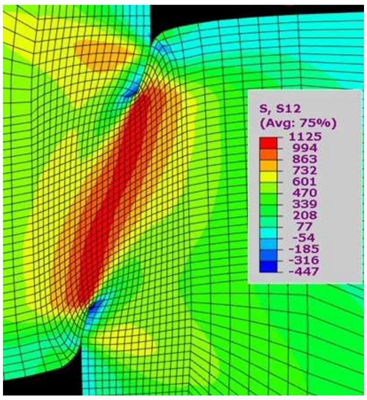

Figure 2: Simulation of the shear stress

Attention is paid on the stress tri-axiality as well as on the ratio of the hydrostatic pressure (related to r_2-r_1, Figure 1) to the shear stress in the shear region.

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