

EXPERIMENTAL CHARACTERIZATION OF SHEET METALS IN FLOW BEHAVIOR UNDER UNIAXIAL AND BIAXIAL COMPRESSION LOADING

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1. Introduction

The plastic deformation behavior of textured sheet metals under biaxial compression loading is mostly unknown, since the technical implementation of biaxial compression in experimental setups is challenging. Experimental data under biaxial compression loading of textured sheet metals may well be essential to describe their tension / compression asymmetry. There are yield criteria to account for this asymmetry, and for the Bauschinger effect – but accurate modeling relies on accurate experimental data. Various testing methods have been devised to complement conventional tensile testing. Yet there is no systematic work so far that describes the ‘third quadrant’ (σ – σ plane) under biaxial compressive loading. In this study, an experimental setup is presented that will help bridge this gap.

2. Experimental Setup

The biaxial/uniaxial compression setup is presented in Figure 1. The strain-controlled test

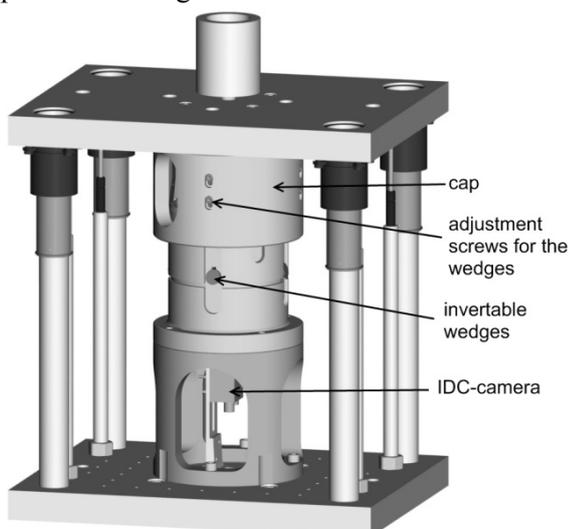


Fig. 1: biaxial/uniaxial compression test rig

rig can be used in a conventional universal testing machine. In this study, a Zwick UPM-1475

provided the compressive force. A four-columned housing guides the upper part to the bolted lower part to prevent tilting. Four independent plungers are located inside the housing (Fig. 2a). The movement of each plunger is controlled by four wedge-shaped parts inside the cap. Each plunger is guided in a channel. On the tip of each plunger, two pairs of strain gages are attached; one pair measures the elastic deformation due to deformation force, and the second pair (which is oriented at 90° to the main strain gage) is used for temperature compensation. Each plunger is calibrated for the investigated sheet thickness. The wedges inside the cap can be changed - this feature allows to use wedges with different angles in each direction, which in turn creates the possibility to initiate different strain ratios. In the study presented here, three sets of wedges were used with angles of 6.6°, 13.0° and 19.1°. To move the plungers simultaneously, a LabVIEW code was developed. The graphical user interface displays the live force of each plunger. A low elastic pre-stress of around 100 N in each direction is adjusted to clamp the specimen in a properly aligned position prior to testing.

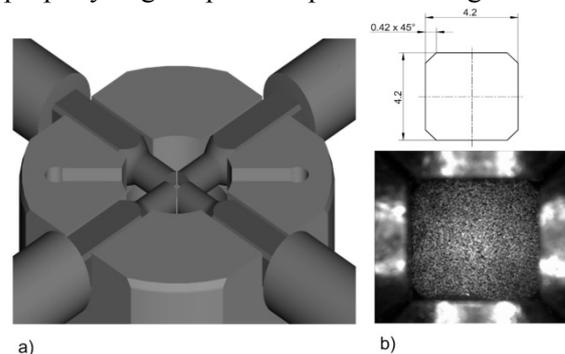


Fig. 2: a) plunger configuration b) specimen geometry and specimen with Speckle pattern

The strain measurement during the test is realized with a 2D DIC (digital image correlation) system. A mini CCD camera is placed under the plungers to detect the speckle pattern on the surface of the specimen (Fig. 2b). The speckle

pattern is applied with an airbrush system to obtain a finely dispersed, homogeneous speckle pattern. In all compression tests discussed below, the strain rate was set to 10⁻³ 1/s and specimen thickness was 1 mm.

3. Experimental Results and Discussion

Figure 3 shows the stress-strain curves in uniaxial tension and compression, as well as for biaxial compression (loading path 1:1) for a sintered, quasi-isotropic material (with a nearly ideally isotropic texture coefficient of 1.027; further details will be presented elsewhere). The quasi-isotropic material was used to validate the specimen geometry and the test rig; there should be no tension compression asymmetry for this kind of material.

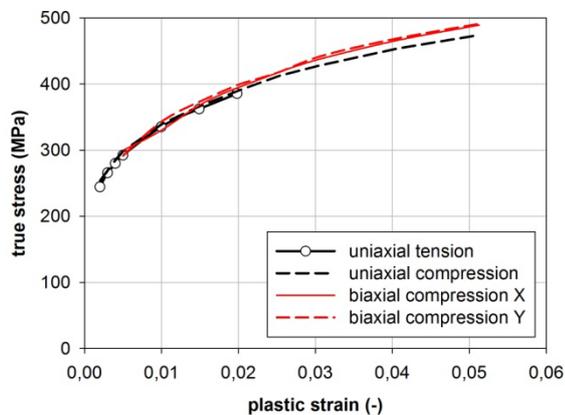


Fig. 3: stress-strain curves in uniaxial tension/compression and biaxial compression (loading path 1:1) for a quasi-isotropic material

The material behaviour is in good agreement with what is expected for an isotropic material. For uniaxial tension and compression, the measured flow stress is identical. The biaxial load case with the same plunger velocity in each loading direction also shows the same flow stress up to a plastic strain of about 0.025. The variation in flow stress at higher plastic strains is most likely due to the increasing friction between the plungers and the specimen. Clearly, our novel test rig allows measuring initial flow stresses under uniaxial and biaxial compression loading on sheet metal material.

The experimental procedure was also applied to a typical engineering material, a deep drawn steel DC06. The material was annealed during

manufacturing and ‘skin-passed’ to prevent stretcher strain marks in the forming process. A detailed discussion for the DC06 and two aluminium alloys are presented in [1, 2]. A comparison of the measured values with the non-quadratic yield criterion Hill 1990 [3] highlights a distinctive tension compression asymmetry, Fig. 4. Our new testing approach allows a detailed characterization of this asymmetry under biaxial loading conditions.

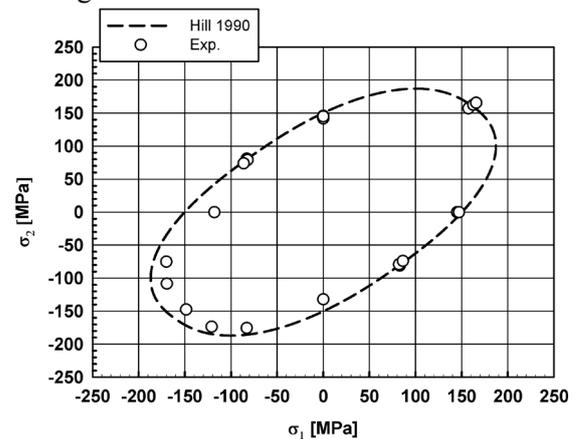


Fig. 4: yield surface for a DC06 sheet material for an equivalent plastic strain of 0.002; comparison of experimental data points with Hill’s 90 criterion

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References

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