Deviating mechanical behaviour of sheet metal with a thickness of about the crystallite size

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Deviating mechanical behaviour of sheet metal with a thickness of about the crystallite size

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Introduction
Due to miniaturisation, for instance in the electronic industry, ever thinner metal sheets are being processed (figure 1). Consequently, only a few crystals may be present within the thickness of the sheet.

Objective
The subject of this poster is the mechanical behaviour of plate specimens with varying thickness (t) and grain size (d), all having initially the same texture and a low dislocation density. In this work the ratio between thickness and grain size (λs) is less than two, in literature [1, 2] most research was only done for λs larger than two.

Microstructure
Typical grain structures and (001) pole figures of the specimens, having different grain sizes and thickness, are shown in figure 2. The specimens have a regular grain structure and a {001}{100} cube texture; the strength and sharpness of the textures of the different specimens are very much the same.

Results
The stress-strain curves, shown in figure 3(a), were measured using a Kammrath & Weiss 10 kN micro tensile stage equipped with an 500 N loadcell. The true stress versus λs, at a true strain of 0.05 and 0.1, is shown in figure 3(b). As can be observed, the stress does only slightly increase for λs < 1 and increases significantly for λs > 1.

For λs < 1, the specimens can be considered as a two dimensional arrangement of grains, there are only "vertical" grain boundaries. All crystals have two free surfaces, the deformation and rotation of the central parts of the crystals, are almost not obstructed.

The reason for the increase in strength beyond λs > 1 is that "horizontal" grain boundaries are introduced into the material. As a result, crystal deformation and rotation becomes significantly more constraint, the strength of the material increases significantly.

The effect of grain size refinement on the flow stress for bulk material is described by the Hall-Petch relation, the stress is linearly proportional to the grain size.

Hall-Petch relation:

\[
\sigma(\epsilon) = \sigma_0(\epsilon) + k(\epsilon)d^{-1/2}
\]

The flow stress, for a specific grain size and strain (deformation), and slopes differ for specimens with different thickness as is shown in figure 4. From this, one can conclude that the Hall-Petch relation is no longer valid. In Hall-Petch type relations, if they exist anyhow for specimens with λs < 3, parameters will be different for different λs.

Future work
Investigate the grain statistics effect, using specimens with constant grain size and varying geometry, in the range of 1 < λs < 8.

References:

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