Fracture behavior of high strength pearlitic steel wires

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Motivation
Pearlitic steel plays a very important role in industrial applications, for instance as railroad steel or in structural applications and thus, the interest to increase the strength of the material. One possibility to increase the strength of pearlitic steels is through deformation hardening. Earlier studies already investigated the increase in strength of pearlitic steels with increasing deformation and smaller cementite lamellas spacing [1]. More recently, severe plastic deformation is used to increase the strength of pearlitic steels further, for instance high pressure torsion (HPT) deformation [2]. It has been shown that with increasing deformation the material increases its strength significantly. Utilizing wire drawing, even higher strengths were realized [4]. The wires presented here were drawn to strains up to 6.2 resulting in an ultimate tensile strength of 7 GPa which is the highest strength ever reached for a bulk material [2]. Additionally, Li et al. [2] revealed that after a certain strain the cementite lamellas dissolved in the ferrite matrix and a part of the graphite from the cementite decays the grain boundaries.

In this investigation the directional dependence of the fracture toughness and the appearance of the corresponding fracture surfaces gives an insight into the dominating fracture mechanisms.

II. Results

Fracture surfaces of samples in drawing direction

Fracture surfaces of the samples in perpendicular direction

Load-displacement curves

III. Conclusion

The investigated pearlitic steel wires show a very low fracture toughness in drawing direction. The value is comparable to the one of pearlitic steel deformed via high pressure torsion material [3].

- Decreasing load in drawing direction is not much plastic deformation present in the samples. This is also seen in the estimated plastic zone size which is relatively small compared to the micro-bending beam measurements (less than 5%).
- The fracture surfaces for wires A and B show a similar appearance. In contrast to that, a different fracture structure would be expected according to Li et al. [4], who reported that for wire A, with a drawing strain of 3.1, there are still cementite lamellas present, but for wire B, with a drawing strain of about 6.7, the cementite lamellas are dissolved.
- The fracture toughness perpendicular to the drawing direction is significantly larger than the one in drawing direction. The calculated values for the perpendicular direction represent a lower boundary due to the crack deflection.

- The difference in fracture toughness of the perpendicular direction is due to the thin material bridges left at the edges of the FIB pre-notch.

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References


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