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# Derivation of Effective Flow Curves of Ferrite/Pearlite C60 Steel Wires by a Multiscale Approach

**Gottfried M. Laschet[1], V. Kripak[2], J. Dierdorf[3], F. Hoffmann[4] and U. Prahl[4]**

[1] ACCESS e.V., Intzestraße 5, D-52072 Aachen, Germany, g.laschet@access.rwth-aachen.de
[2] Steel Institute, RWTH Aachen University, Intzestrasse 1, D-52072 Aachen, Germany
[3] Institute of Metal Forming, RWTH Aachen University, Intzestrasse 10, D-52072 Aachen, Germany
[4]Institute of Metal Forming, TU Bergakademie Freiberg, Bernhard-von-Cotta Str. 4, D-09599 Freiberg, Germany

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Hot-rolled C60 steel is widely used for wire applications. The production chain involves various process steps such as continuous casting, hot rolling, followed by a direct annealing to produce a ferrite-pearlite microstructure suitable for wire cold drawing in various steps. Three different C60 wires are studied here. After hot rolling at 900°C (∅=8mm) different cooling rates are applied: $\dot{T}$=180°C/min for wires W1 and W3 and $\dot{T}$=5°C/min for wire W2. Wire W3 is further cold drawn to ∅=6 mm. The impact of different annealing and additional drawing on the ferritic-pearlitic wire microstructures is characterized by using scanning electron microscopy. Since pearlite is a eutectoid phase mixture, three length scales are specified here: the nano-scale of a ferrite-cementite bi-lamella of pearlite, the micro-scale of the ferrite/pearlite microstructure RVE and the macro-scale of the wire. In order to derive the effective flow behaviour of pearlite, uniaxial tensile and shear tests of the bi-lamella are performed at the nanoscale. The ortho-rhombic cementite phase has an anisotropic elasto-plastic behaviour [1], whose yield curve is taken from nano-indentation tests. The hardening model of the ferrite phase [1] is extented to contain a kinematic contribution with backstress, expressed via the grain boundary dislocation density [2]. Moreover, to model the Bauschinger effect, observed for wire W3, the total pre-strained dislocation density is splitted in a forward and reverse contribution [3]. Effective anisotropic hardening curves are determined for the pearlite by adopting a mean lamella spacing. In a further step, 3D RVEs are generated by Laguerre-Voronoi tessellation for the microstructures W1 and W2 and a dedicated RVE with elongated pearlite/ ferrite grains in rolling direction is generated for wire W3. Effective flow curves of the C60 wires are then evaluated in rolling and transverse direction and compared with experimental compression and tensile test curves: Both heat-treated wires W1 and W2 have a quasi-isotropic hardening behaviour with a noticeable hardening increase for wire W1, compared to wire W2; whereas wire W3 presents a pronounced anisotropic and strongly increased hardening behaviour.

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