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DUCTILE-BRITTLE TRANSITION IN ULTRAHIGH-STRENGTH STEELS – ESTIMATION & APPLICATION

Sakari Pallaspuro[1, *], Yang Li[2], Haiyang Yu[3], Ann-Christin Hesse[4], Zhiliang Zhang[5] and Jukka Kömi[1]

[1] Materials and Mechanical Engineering, Centre for Advanced Steels Research, University of Oulu, Pentti Kaiteran katu 1, 90570 Oulu, Finland
* sakari.pallaspuro@oulu.fi & https://www.oulu.fi/university/researcher/sakari-pallaspuro
[2] School of Architecture and Civil Engineering, Xi'an University of Science and Technology, 58 Yanta Road, Xi'an 710054, China
[3] Department of Materials Science and Engineering, Uppsala University
P.O. Box 256, SE-751 05 Uppsala, Sweden
haiyang.yu@angstrom.uu.se & https://katalog.uu.se/profile/?id=N21-515
[4] Institute of Joining and Welding, Technical University Braunschweig, Langer Kamp 8, 38106 Braunschweig, Germany, a.hesse@tu-braunschweig.de
[5] Department of Structural Engineering, Norwegian University of Science and Technology (NTNU)
Richard Birkelands vei 1A, 7491 Trondheim, Norway
zhiliang.zhang@ntnu.no & https://www.ntnu.edu/employees/zhiliang.zhang

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Structural integrity demands a sufficient level of toughness from steels maintained through various environmental exposures, such as low temperatures and hydrogen uptake. Elimination of the weakest links in the microstructure is one way to mitigate materials susceptibility to brittle failure. Here, we present novel methods with lath-like microstructures for i) quantifying the effects of microstructural factors on the (impact/fracture) toughness transition temperatures (T_{28J}/T_0) [1], ii) predicting ductile-brittle transition (DBT) via multiscale modelling with a coupled cellular automata finite element method (CAFÉ), and iii) how elevated hydrogen contents affect fracture toughness at low temperatures with conventional displacement rates. The results show that the coarsest grains in the effective grain size distribution are the primary propagators of failure, and that the toughness transition temperatures can be accurately estimated utilising a reference toughness concept [1]. Furthermore, the CAFÉ method can accurately reproduce experimental DBT curve of a low-carbon ultrahigh-strength steel [2], and hydrogen embrittlement is present even at sub-zero temperatures, causing an increase in T_0 and a small decrease in deformation capability, and that H can affect the $T_0 – T_{28J}$ correlation [3].

REFERENCES

[1] S. Pallaspuro, A. Kaijalainen, S. Mehtonen, J. Kömi, Z. Zhang, D. Porter, Effect of microstructure on the impact toughness transition temperature of direct-quenched steels, Mater. Sci. Eng. A. 712 (2018) 671–680.

[2] Y. Li, S. Pallaspuro, X. Ren, J. He, J. Kömi, Z. Zhang, A multi-barrier model assisted CAFE method for predicting ductile-to-brittle transition with application to a low-carbon ultrahigh-strength steel, Mech. Mater. 153 (2021) 103669.

[3] S. Pallaspuro, H. Yu, A. Kisko, D. Porter, Z. Zhang, Fracture toughness of hydrogen charged as-quenched ultra-high-strength steels at low temperatures, Mater. Sci. Eng. A. 688 (2017) 190–201.