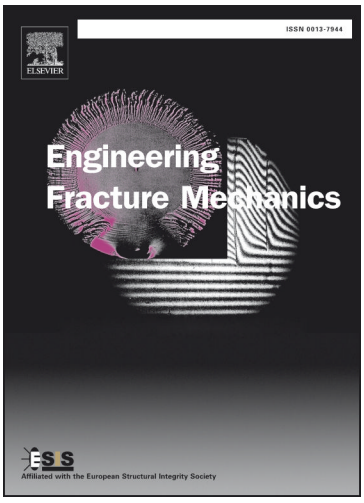


# Crack growth rate of inclined and deflected surface-cracks in round-bar specimens of copper processed by equal channel angular pressing under cyclic loading

M. Goto, T. Yamamoto, S.Z. Han, S. Kim, J-H. Ahn, J. Kitamura, T. Iwamura, J. Lee

PII: S0013-7944(17)30423-X
DOI: http://dx.doi.org/10.1016/j.engfracmech.2017.07.024
Reference: EFM 5626

To appear in: *Engineering Fracture Mechanics*

Received Date: 26 April 2017
Revised Date: 13 July 2017
Accepted Date: 14 July 2017

Please cite this article as: Goto, M., Yamamoto, T., Han, S.Z., Kim, S., Ahn, J-H., Kitamura, J., Iwamura, T., Lee, J., Crack growth rate of inclined and deflected surface-cracks in round-bar specimens of copper processed by equal channel angular pressing under cyclic loading, *Engineering Fracture Mechanics* (2017), doi: http://dx.doi.org/10.1016/j.engfracmech.2017.07.024

# Crack growth rate of inclined and deflected surface-cracks in round-bar specimens of copper processed by equal channel angular pressing under cyclic loading

**M. Goto[a*], T. Yamamoto[a], S.Z. Han[b*], S. Kim[c], J-H. Ahn[b], J. Kitamura[a], T. Iwamura[a], J. Lee[e]**

[a]*Department of Mechanical Engineering, Oita University, Oita 870-1192, Japan*

[b]*Structural Materials Division, Korea Institute of Materials Science, Changwon 642-831, Republic of Korea*

[c]*Department of Materials Science & Engineering, ReCAPT, Gyeongsang National University, Chinju 660-701, Republic of Korea*

[e]*Department of Metallurgy& Advanced Materials Engineering, Chagwon National University, Changwon 641-773, Republic of Korea*

[*]Corresponding authors: Tel.: +81 97 554 7772; Fax: +81 97 554 7764;

*Email address:* masagoto@oita-u.ac.jp (M. Goto), szhan@kims.re.kr (S.Z. Han)

ABSTRACT

For low-cycle fatigued, ultrafine grained copper, processed by equal channel angular pressing, a unique crack growth direction, either inclined at 45° or perpendicular to the loading direction, was observed around the circumference of round bar specimens. In addition, the perpendicular cracks showed a 45° deflected crack face toward the center of the specimens. To clarify the growth behavior of such inclined and deflected cracks, the role of the deformation mode at the crack-tip areas was discussed in terms of the surface damage caused by cyclic stressing and the mixed-mode deformation at the crack tips. The preexistent sear-bands/shear-cracks around the crack tips and the in-plane shear-mode deformation at the crack tips assisted the formation of shallow inclined- and deep deflected-cracks. To quantitatively estimate the severity of mechanical damage at the crack tips, the comparative stress intensity factor range under combined mode I, II and III conditions were calculated. The crack growth rate along the growth direction at the surface and bottom for inclined and deflected surface-cracks was discussed in terms of the comparative stress intensity factor range.

*Keywords:* Fatigue; Crack growth rate; Stress intensity factor; Mixed mode; Equal channel angular pressing