Study of the stress intensity factors in the bulk of the material with synchrotron diffraction

P. Lopez-Crespo[*], J. Vazquez-Peralta[*], C. Simpson[‡], B. Moreno[*], T. Buslaps[¥], P. J. Withers[‡]

* Department of Civil and Materials Engineering, University of Malaga, C/Dr Ortiz Ramos, s/n, 29071 Malaga, Spain
‡ School of Materials, University of Manchester, Oxford Road, Manchester M13 9PL, UK
¥ ESRF, 6 rue J Horowitz, 38000 Grenoble, France

ABSTRACT. In this work we present the results of a hybrid experimental and analytical approach for estimating the stress intensity factor. It uses the elastic strains within the bulk obtained by synchrotron X-ray diffraction data. The stress intensity factor is calculated using a multi-point over-deterministic method where the number of experimental data points is higher than the number of unknowns describing the elastic field surrounding the crack-tip. The tool is tested on X-ray strain measurements collected on a bainitic steel. In contrast to surface techniques the approach provides insights into the crack tip mechanics deep within the sample.

KEYWORDS: SIF, LEFM, synchrotron X-ray diffraction, Overload, MPOD

REFERENCES

[1]   R.J. Sanford, J.W. Dally, A general method for determining mixed-mode stress intensity factors from isochromatic fringe patterns, Eng. Fract. Mech. 11 (1979) 621–633.

[2]   A.D. Nurse, E.A. Patterson, Determination of predominantly mode II stress intensity factors from isochromatic data, Fatigue Fract. Eng. Mater. Struct. 16 (1993) 1339–1354.

[3]   G. Nicoletto, Experimental crack tip displacement analysis under smallscale yielding conditions, Int. J. Fatigue. 8 (1986) 83–89.

[4]   F.A. Diaz, J.R. Yates, E.A. Patterson, Some improvements in the analysis of fatigue cracks using thermoelasticity, Int. J. Fatigue. 26 (2004) 365–376.

[5]   A. Shternlikht, F.A. Díaz-Garrido, P. Lopez-Crespo, P.J. Withers, E.A. Patterson, Mixed Mode (KI + KII) Stress Intensity Factor Measurement by Electronic Speckle Pattern Interferometry and Image Correlation, Appl. Mech. Mater. 1-2 (2004) 107–112.

[6]   P. Lopez-Crespo, R.L. Burguete, E.A. Patterson, A. Shterenlikht, P.J. Withers, J.R. Yates, Study of a crack at a fastener hole by digital image correlation, Exp. Mech. 49 (2009) 551–559. doi:DOI 10.1007/s11340-008-9161-1.

[7]   P. Lopez-Crespo, P.J. Withers, F. Yusof, H. Dai, A. Steuwer, J.F. Kelleher, T. Buslaps, Overload effects on fatigue crack-tip fields under plane stress conditions: surface and bulk analysis, Fatigue Fract. Eng. Mater. Struct. 36 (2013) 75–84.

[8]   F. Yusof, P. Lopez-Crespo, P.J. Withers, Effect of overload on crack closure in thick and thin specimens via digital image correlation, Int. J. Fatigue. 56 (2013) 17–24.

[9]   P.F.P. deMatos, D. Nowell, Experimental and numerical investigation of thickness effects in plasticity-induced fatigue crack closure, Int. J. Fatigue. 31 (2009) 1795–1804.

[10]   J. Garcia-Manrique, D. Camas, P. Lopez-Crespo, A. Gonzalez-Herrera, Stress intensity factor analysis of through thickness effects, Int. J. Fatigue. 46 (2013) 58–66.

[11]   D. Camas, P. Lopez-Crespo, A. Gonzalez-Herrera, B. Moreno, Numerical and experimental study of the plastic zone in cracked specimens, Eng. Fract. Mech. Accept. Publ. (2017). doi:http://dx.doi.org/10.1016/j.engfracmech.2017.02.016.

[12]   S.M. Barhli, L. Saucedo-Mora, C. Simpson, T. Becker, M. Mostafavi, P.J. Withers, T.J. Marrow, Obtaining the J-integral by diffraction-based crack-field strain mapping, Procedia Struct. Integr. 2 (2016) 2519–2526.

[13]   H.L. Ewalds, R.J.H. Wanhill, Fracture Mechanics, Arnold, London, 1984.

[14]   A. Steuwer, M. Rahman, A. Shterenlikht, M.E. Fitzpatrick, L. Edwards, P.J. Withers, The evolution of crack-tip stresses during a fatigue overload event, Acta Mater. 58 (2010) 4039–4052.

[15]   P. Lopez-Crespo, M. Mostafavi, A. Steuwer, J.F. Kelleher, T. Buslaps, P.J. Withers, Characterisation of overloads in fatigue by 2D strain mapping at the surface and in the bulk, Fatigue Fract. Eng. Mater. Struct. 39 (2016) 1040–1048.

[16]   P. Lopez-Crespo, A. Steuwer, T. Buslaps, Y.H. Tai, A. Lopez-Moreno, J.R. Yates, P.J. Withers, Measuring overload effects during fatigue crack growth in bainitic steel by synchrotron X-ray diffraction, Int. J. Fatigue. 71 (2015) 11–16.

[17]   M. Zanganeh, P. Lopez-Crespo, Y.H. Tai, J.R. Yates, Locating the crack tip using displacement field data: a comparative study, Strain. 49 (2013) 102–115.

[18]   I.M. Robertson, Measurement of the effects of stress ratio and changes of stress ratio on fatigue crack growth rate in a quenched and tempered steel, Int. J. Fatigue. 16 (1994) 216–220.

[19]   V. Chaves, Ecological criteria for the selection of materials in fatigue, Fatigue Fract. Eng. Mater. Struct. 37 (2014) 1034–1042. doi:10.1111/ffe.12181.

[20]   T.L. Anderson, Fracture mechanics: fundamentals and applications, 2nd ed, Boca Raton: CRC Press, 1994.

[21]   Y. Murakami, Stress Intensity Factors Handbook, Pergamon Press, Oxford, 1987.

[22]   M. Mokhtarishirazabad, P. Lopez-Crespo, B. Moreno, A. Lopez-Moreno, M. Zanganeh, Evaluation of crack-tip fields from DIC data: a parametric study, Int. J. Fatigue. 89 (2016) 11–19.

[23]   P. Lopez-Crespo, A. Shterenlikht, E.A. Patterson, P.J. Withers, J.R. Yates, The stress intensity of mixed mode cracks determined by digital image correlation, J. Strain Anal. Eng. Des. 43 (2008) 769–780. doi:DOI: 10.1243/03093247JSA419.