Refinement of ultrasonic TOFD methods to size rough defects

Stewart Haslinger[1], Michael Lowe[2], Peter Huthwaite[1], Fan Shi[3], Richard Craster[4]

[1]Department of Mechanical Engineering, Imperial College London, Zimbabwe, [1]Department of Mechanical Engineeering, Imperial College London, United Kingdom, [1]Department of Mechanical and Aerospace Engineering, Hong Kong University of Science & Technology (HKUST), Hong Kong, [1]Department of Mathematics, Imperial College London, United Kingdom

Ultrasonic NDE techniques, such as time-of-flight diffraction (TOFD) and Pulse-Echo (P-E), are well understood when defects are smooth and straight. However, in environments where there are extreme changes in temperature and pressure, for instance in the nuclear energy industry, the damage that occurs is often not uniform and more difficult to characterise using standard parameter settings. Optimal incident angles for longitudinal ultrasonic waves for TOFD techniques were determined in the 1980s [1] but largely based on theoretical (GTD [2]) and experimental investigations of smooth defects. Changing the incident angle reduces the expected amplitude of the tip-diffracted signals one collects from the receiving transducer, and this knowledge is useful when trying to estimate tilt angles for smooth defects. However, rough defects produce tip-diffracted signals that are more complicated than for their smooth counterparts, largely due to multiple scattering effects. We show how this complexity may be used advantageously when varying the beam angle from the standard range. The scattered amplitudes produced by rough defects are much larger when insonified by longitudinal waves at incident angles lower than the industry-standard values. Statistical characterisation of the roughness and the scattering signatures are used to obtain upper bounds for the dimensions of rough defects. In addition, the increase in signal amplitude has practical benefits for both accessibility and human factors. Numerical and experimental validations are provided. References [1] J.A.Ogilvy & J.A.G. Temple, Diffraction of elastic waves by cracks: application to time-of-flight inspection, Ultrasonics 21 (1983), pp. 30-40. [2] J.B.Keller, Geometrical theory of diffraction, JOSA 52 (1962), pp. 116-130.