A MODIFIED THREE POINT BEND SPECIMEN

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Fracture toughness testing is today used in several countries in integrity assessment work of structures of older steels with unknown toughness properties, the majority erected more than half a century ago. The most common type of test specimen employed is the three-point-bend specimen, which is plane-parallel and of constant thickness. Many typical profiles in older structures, such as angle sections in beams and girders, have however slightly tapered sides, seen in cross section. Samples taken from such profiles are presently machined to produce a plane-parallel shape and it is not uncommon to remove all the original surfaces of the sample. The cross sectional thickness of a fully machined specimen is therefore, in practice, only 60-70% of that of the original sample. In older and inhomogeneous steels an unfairly low toughness might then be obtained, as the toughness of the material near the surface often has been found to be superior.

The aim of the present project is to modify the standard three-point bend specimen, as given e.g. in ASTM E-1820 [1], so as to better accommodate steel samples with tapered sides. The modified specimen will allow a more reliable effective toughness to be determined since the full sample thickness can be used and in particular the critical surface features will be preserved. The cross section of the modified specimen, inscribed in a typical tapered profile, is shown in Fig. 1.

FIGURE 1. Cross section of modified three-point-bend specimen. W is specimen high, B is specimen thickness of the lower half, and αB is thickness at the top of the specimen

The project comprises development, calibration and testing of the modified three-point-bend specimen, including derivation and verification of expressions allowing calculation of fracture toughness from experiment for both linear and non-linear behaviour, in short, to determine the stress intensity factor K_I and the J -integral for the modified specimen as functions of relevant parameters.

The calibration work will be both analytical and numerical. The first part of the project, which is reported here, is analytical and aimed at obtaining a first and rough estimate of the order of influence of the modified geometry on crack tip parameters. To this end, the method by Kienzler and Herrmann [2] to obtain approximations of stress intensity factors in cracked beams, has been used. These authors have shown that very simple and close approximations can be obtained with

elementary bending theory and estimations of the strain energy release as a crack is widened. In short, the stress intensity factor is obtained through

$$K_I = \left[-\frac{k E}{B} \frac{\partial U}{\partial h} \right]_{h=0}^{1/2} \quad (1)$$

where k is a dimensionless factor of proportionality to be determined, E Young's modulus, B specimen thickness, U strain energy and h half the width of the crack. First, a value of k has been obtained for the standard three-point-bend specimen by including both bending and shear force energy in U and comparing the result with K_I as given in [1]. A close fit in the crack length range $0.5 \leq a/W \leq 0.6$, where a is crack length, allows $k = 1.32$, which is the value obtained by Bazant [3] for pure bending of a single edge notched beam of constant thickness. With this value of k and U including bending and shear force energy, K_I has been calculated with Eq. (1) for the modified specimen with various taper angles. In Fig. 2 is shown a) the very close approximation of the geometry function of K_I obtained with the method in [2] compared to the present standard [1] and b) normalised geometry functions for the modified specimen type with taper in the range $0.5 \leq \alpha \leq 1$, or between an anticipated maximum taper, corresponding to the same line load intensity along the loading devices on both sides of the specimen, and a plane specimen. The influence of tapered sides is found to be small and even negligible in practice where other uncertainties may introduce errors with greater influence than the taper.

FIGURE 2. Geometry functions of the stress intensity factor for standard and modified three-point-bend specimen.

References

1. ASTM E-1820-01. Standard Test Method for Measurement of Fracture Toughness. General Book of ASTM Standards, Sect. 3, ASTM, Philadelphia 2001.
2. Kienzler, R. and Herrmann, G., *Acta Mech.*, vol. **62**, 37-46, 1986.
3. Bazant, Z.P., *Engng. Fract. Mech.*, vol. **36**, 523-525, 1990.