General Discussion

C. E. Turner[1] (*written discussion*)—In discussing the determination of fracture toughness by impact testing the role of strain rate is clearly of prime importance. For high-strength steels, aluminium alloys and mild steels above the ductile-brittle transition the energy absorbed in Charpy and slow-bend tests of the same size of test piece is broadly similar. It commonly is accepted that for low-strength steels below the ductile-brittle transition temperature, impact seems a more critical condition than static loading.

The relative difficulty of starting a brittle crack and ease of propagating it in mild steel was well shown in the Robertson test and has been expressed quantitatively by Eftis and Krafft in their presentation[2] of K_{Ic} as a function of $\dot{\epsilon}$. This picture seems to have been accepted generally though with little direct confirmation. The dynamic toughness values that have been reported for low-strength steels up to about 1 in. thick, in the transition temperature range, (for example, footnotes 2–5) have been low. One design philosophy proposes reliance on avoidance of initiation, perhaps measured by crack opening displacement (COD) (footnotes 6, 7) rather than control of propagation or arrest. The choice of design philosophy for fracture rate effects is complicated by the role of mechanical and metallurgical damage (for example, strain aging) which appears to destroy the high resistance normally found to static initiation, thus allowing a crack to "jump in" and propagate dynamically, as for example in the original Wells-British Welding Research Association wide plate test. Current studies, however, notably the Heavy-Section Steel

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[2] Eftis, J. and Krafft, J. M., "A Comparison of the Initiation with the Rapid Propagation of a Crack in a Mild Steel Plate," *Transactions*, American Society of Mechanical Engineers, Vol. 87D, 1965, p. 257.

[3] Crosley, P. B. and Ripling, E. J., "Dynamic Fracture Toughness of A533 Steel," American Welding Society/American Society of Mechanical Engineers Conference, Chicago, April 1968.

[4] Radon, J. C. and Turner, C. E., "Fracture Toughness Measurements by Instrumented Impact Test," *Engineering Fracture Mechanics*, Vol. I, 1969, p. 411.

[5] Turner, C. E. and Radon, J. C., "Fracture Toughness Measurements on Low Strength Structural Steels," *2nd International Conference for Fracture*, Brighton, April 1969.

[6] Nichols, R. W., "The Use of Critical Crack Opening Displacement Techniques for the Selection of Fracture Resistant Materials," *Symposium on Fracture Toughness Concepts for Weldable Structural Steel*, Culcheth, April 1969.

[7] Wells, A. A., "The Specification of Permissible Defect Sizes in Welded Metal Structures," *2nd International Conference on Fracture*, Brighton, April 1969.

Technology (HSST) program and related work in USA suggest further complicating aspects of thickness, stretch zone, and rate spectrum effects that give rise to doubt whether the above picture is complete.

It may be asked also whether we should attempt to characterize parent material by selecting a numerical value of toughness, be it Charpy or some other measure, adjusted to provide an umbrella under which all uncertainties shelter and by which we hope to be safeguarded, or whether for each effect such as strain rate, metallurgical damage from weldments, and even thickness, separate tests should be made to get a value of toughness realistic for each and every circumstance. The answer will depend on whether we are discussing tests for design purposes or for quality control. However, in the past C_v values have been based on the "umbrella" philosophy by empirical correlations of parent plate tests directly with real or simulated service behavior. Fracture mechanics concepts tend to be based on the philosophy of studying the worst case. This difference of viewpoint must not be overlooked in trying to relate the two approaches, nor indeed when conducting Charpy or similar tests on local regions of "damaged" material. The acceptable toughness levels aimed at by the umbrella and "worst case" philosophies, whether by a temperature criteria, energy level, or other measure, must be surely quite different, this difference reflecting the importance of the factors that are being covered by the current umbrella type Charpy values.