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DISCUSSION

S. T. Rolfe[1] (*written discussion*)—As the authors well know, I agree completely with their conclusion that existing linear elastic fracture mechanics technology is applicable to medium-strength steels. This fact has been well documented, not only by the work of the authors and their colleagues at Westinghouse, but also by numerous investigations at the Applied Research Laboratory of U.S. Steel Corp.[2–7] In fact, research in progress[8] indicates that, providing certain conditions of restraint are satisfied, the usefulness of the fracture mechanics approach may be extended even further than the authors propose. The data shown in Fig. 4 that are invalid according to the criteria for plane strain behavior substantiate this fact. Thus, the authors' conclusion regarding the general applicability of fracture mechanics to medium- (and low-) strength steels is well founded.

The authors correctly note that there is no correlation between yield strength and K_{Ic} for the alloys studied. However, the K_{Ic} data shown in Fig. 5, along with test results of five structural steels having room-temperature yield strengths in the range 39 to 246 ksi, have been analyzed by Barsom and Rolfe[6] to develop an empirical correlation between slow-bend K_{Ic} test

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[2] Rolfe, S. T., Barsom, J. M., and Gensamer, M., "Fracture Toughness Requirements for Steels," presented at the *First Annual Offshore Technology Conference*, Houston, Tex., 18–21 May 1969.

[3] Barsom, J. M. and Rolfe, S. T., "K_{Ic} Transition-Temperature Behavior of A517F Steel," presented at the *National Symposium on Fracture Mechanics*, Lehigh University, Bethlehem, Pa., 25–27 Aug. 1969.

[4] Shoemaker, A. K. and Rolfe, S. T., "The Static and Dynamic Low-Temperature Crack Toughness Performance of Seven Structural Steels," presented at the *National Symposium on Fracture Mechanics*, Lehigh University, Bethlehem, Pa., 25–27 Aug. 1969.

[5] See p. 124.

[6] Barsom, J. M. and Rolfe, S. T., "Correlations Between K_{Ic} and Charpy V-notch Test Results in the Transition-Temperature Range," *Impact Testing of Metals, ASTM STP 466*, American Society for Testing and Materials, 1970.

[7] Barsom, J. M., Imhof, E. J., Jr., and Rolfe, S. T., "Fatigue-Crack Propagation in High-Yield Strength Steels," presented at the *National Symposium on Fracture Mechanics*, Lehigh University Bethlehem, Pa., 25–27 Aug. 1969.

[8] Novak, S. R. and Rolfe, S. T., "Experimental Analysis of Sub-Thickness K_{Ic} Specimens to Establish Engineering Crack-Toughness Values (K_{Ie})," Progress Report to ASTM Committee E-24, Cleveland, Ohio, 23 Sept. 1969.

results and standard Charpy V-notch (CVN) impact test results in the transition-temperature region. This empirical correlation is shown in Fig. 18. It should be emphasized that this correlation, as well a previously published upper-shelf K_{Ic}-Charpy V-notch correlation based on results obtained on eleven steels having yield strengths in the range of 110 to 246 ksi[2,5], are both empirical.[9] Because of differences in loading rate and notch acuity between the K_{Ic} and Charpy tests, no theoretical justification for the correlation currently exists. However, various investigations[10,11,12] have shown that for the particular geometry of the Charpy V-notch test specimen, maximum constraint exists at the tip of the notch. Therefore, it is not unreasonable to expect that the conditions of constraint ahead of the notch in the Charpy V-notch and K_{Ic} test specimens are similar. Thus, although the authors state that there is no correlation between yield strength and K_{Ic} ,an empirical correlation that is based in part on their data does exist between Charpy V-notch impact energy and K_{Ic}.

The authors' example problem is extremely useful in demonstrating the application of fracture mechanics to problems involving fatigue loading. A similar analytical procedure for relating subcritical crack growth to inspection requirements that involves both fatigue and stress corrosion has been presented by Sinclair and Rolfe.[13] In this procedure, various assumptions regarding the frequency of loading of structures were made so that crack-size/time curves could be developed to predict the life of a structural member. This procedure, as well as the example problem described by the authors, demonstrates the relative importance of stress level, yield strength, material properties, and initial crack size with respect to the time required for a crack to grow to a given size.

In conclusion, the authors' paper, as well as numerous other studies of the fracture and fatigue behavior of medium-strength steels, conclusively demonstrates the usefulness of the fracture mechanics approach as a quantitative tool that can be used for the prevention of failure of structures fabricated from medium-strength steels. For this, the authors are to be complimented.

[9] See also Fig. 14 of Rolfe and Novak paper on p. 124.

[10] Clausing, D. P., "Effect of Plane-Strain Sensitivity on the Charpy Toughness of Structural Steels," AD836314 L, 15 May 1968 (available from Defense Documentation Center).

[11] Hollomon, J. H., "The Notched-Bar Impact Test," *Transactions*, American Institute of Mining, Metallurgical, and Petroleum Engineers, Vol. 158, 1944, pp. 310–322.

[12] Gross, J. H., "The Effect of Strength and Thickness on Notch Ductility," *Impact Testing of Metals, ASTM STP 466*, American Society for Testing and Materials, 1970.

[13] Sinclair, G. M. and Rolfe, S. T., "Analytical Procedure for Relating Subcritical Crack Growth to Inspection Requirements," presented at *Conference on Environmental Effects in Failure of Engineering Materials*, Metals Engineering Division, American Society of Mechanical Engineers, Washington, D.C., 31 March-2 April 1969.

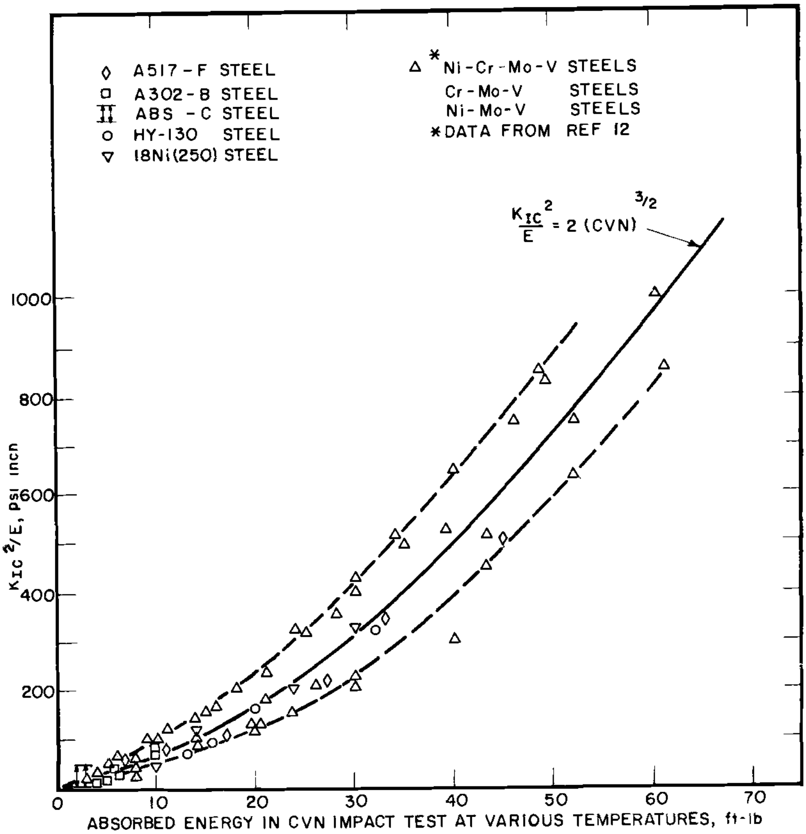

FIG. 18—*Relation between* K_{Ic} *and CVN values in the transition-temperature region.*