Toughness of High-Density Polyethylene in Plane-Stress and Plane-Strain Fracture

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Under uni-axial tension, high-density polyethylene (HDPE) often fractures in a ductile manner. The fracture occurs after extensive plastic deformation and necking that are known to be involved in crack growth of ductile materials in the plane-stress condition. In the plane-strain condition, such as a pressurized pipe, HDPE often fractures in a very brittle manner, showing the toughness much lower than that in the plane-stress condition [1]. At present, no standard methods are available to quantify the fracture toughness of HDPE in both conditions.

This paper proposes the use of essential work of fracture (EWF) [2] to quantify the fracture toughness of HDPE. The paper will show that in both plane-stress and plane-strain conditions, the specific work of fracture is a linear function of the specimen ligament length. Therefore, fracture toughness in the two conditions can be determined through linear extrapolation of the specific work of fracture to zero ligament length. Results obtained in the study show that toughness of HDPE in the plane-stress condition is about one order of magnitude higher than that in the plane-strain condition. Interestingly, the plane-strain fracture toughness is very close to the toughness of pressurized polyethylene pipe that was estimated using numerical simulation based on data from the small-scale steady-state (S4) test.

The study also applied the EWF concept to quantifying the role of deformation mechanisms involved in the fracture process. The study concludes that the high plane-stress fracture toughness mainly comes from the uniform plastic deformation. Necking, in spite of its contribution to the excellent ductility in tensile test, has a very small effect on the superior toughness.

References

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[2] B. Cotterell and J.K. Reddel, “The essential work of plane stress ductile fracture”, Int J Fract, **13**, 267-277, 1977.

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