

## DWTT properties for high strength line pipe steels

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### ABSTRACT

High strength line pipe steels need to have good crack arrestability to arrest cracks in the pipe body even if brittle fracture occurs at welds, or running ductile fractures occur in the pipe body. The drop weight tear test (DWTT) is one of the major test methods to evaluate crack arrestability of brittle and running ductile fractures. In order to obtain a good DWTT shear area for high strength line pipe steels, it is important to clarify the conditions of brittle fracture occurrence because the shear area decreased remarkably once brittle fracture occurs. In this study, the conditions of brittle fracture occurrence such as slant fracture for high strength line pipe steels were investigated. Separation was formed when a ferrite and bainite dual-phase microstructure was formed. Slant fracture was formed when a bainite single phase was formed. The suppression of slant fracture and remarkable separation is important for improving DWTT properties. Excellent DWTT properties were obtained for X100 line pipe steel with respective thicknesses of 19 mm, 16 mm and 14 mm.

**KEYWORDS:** High strength line pipe, DWTT, separation, slant fracture, texture, ferrite, bainite

### INTRODUCTION

Recently, high strength line pipe steels, with yield strength of X80 or higher, have been used for many pipeline projects because of the reduced cost for the transportation of natural gas. Crack arrestability of brittle and running ductile fractures is needed as one of the required properties for high strength line pipe steels. For example, cracks must be arrested, even if brittle fracture occurs from the welds such as girth welds. Cracks must also be arrested if the line pipe body is subject to ductile fracture.

The DWTT (Drop Weight Tear Test) (Eiber et al. (1979)) is one of the major test methods used to evaluate the crack arrestability of brittle fracture. This test evaluates whether a ductile crack is transferred from a brittle fracture after a brittle crack is initiated just under the notch. Previous results (Amano et al. (1986)) indicated that the crack speed became lower than 450 m/s and that the crack was subsequently arrested in the full crack burst test, for line pipes with a DWTT shear

area of more than 40%. However, a DWTT shear area of 85% or higher is required for specifications such as those of the API (American Petroleum Institute) because DWTT shear area scattering taken into account in a circumferential direction. The key problem when evaluating crack arrestability of brittle fracture using DWTT is the fact that brittle fracture does not often occur just under the notch. Because high strength line pipe steels involve low carbon chemistry and clean and pure steels, it is very difficult to initiate brittle fracture under the notch, thus invalidating this test. To solve this problem, the precrack DWTT or Chevron notch DWTT are proposed (Wilkowski et al. (1978) and Maxey et al. (1985)). For the former, it is easy to initiate brittle fracture after the ductile fracture is initiated using a three point bend test, whereas for the Chevron notch DWTT, because the notch dimension differs from the press notch DWTT, a brittle fracture is easy to initiate due to severe stress constraint.

Conversely, the required Charpy V-notch energy (Maxey et al. (1976), Subcommittee Summary report-AISI (1974) and Poynton (1974)) for crack arrestability of running ductile fracture was proposed in comparison with the full crack burst test results and the Charpy V-notch energy of the line pipe body, and the Charpy V-notch energy correlated with that of the full crack burst test results up to X70 grade. However, the safety factor such as 1.3 or 1.7 was multiplied to the required Charpy V-notch energy for high strength steels with a grade of X80 or higher because the Charpy V-notch energy did not correlate with the full crack burst test results (Demofonti et al. (2004)). Likewise, for the X100 or X120 grades, the required energy multiplied by the safety factor did not correlate with the full crack burst test results. Based on these results, the HLP (High grade Line Pipe) Committee for the ISIJ (Iron and Steel Institute of Japan) proposed that precrack DWTT energy was used as the required energy for crack arrest of a running ductile fracture instead of Charpy V-notch energy (Sugie (1988) and Makino (2001)). CSM (Centro Sviluppo Materiali) also proposed that crack propagation energy defined as the integral of load vs. displacement after the maximum load for the DWTT was suitable for the required energy for crack arrest of a running ductile fracture (Demofonti et al. (2004)). Another research group proposed that the CTOA (Crack Tip Opening Angle) is effective for evaluating a running ductile fracture (Fonzo et al. (2002)).

Therefore, the DWTT is the important method used to evaluate the