講演番号	052

文献番号	20225052

Relationship between Delayed Fracture Behavior and Microstructure in Ultra-high Strength Steel Sheets

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KEY WORDS: **Materials, High-strength steel, Fracture,** Delayed fracture, Hydrogen embrittlement [D3]

Ultra-high strength steel sheets (UHSS) with tensile strength exceeding 1180 MPa have been applying to automotive structural parts for compatibility of improved crash safely and reducing body weight. Among various types of UHSS, dual phase (DP) steel sheets composed of ferrite and martensite phases or complex phase (CP) steel sheets containing retained austenite have been widely used owing to their excellent elongation. However, hydrogen embrittlement including delayed fracture has been a concern in automobile components made from these sheets. Previously, we have reported that the delayed fracture behavior of the ultra-high strength DP and CP steel sheets were investigated by a sustained tensile-loading test during hydrogen charging. This report introduces the findings that summarize these results.

The sustained tensile-loading test results for the tempered marutensite single phase and DP steel sheets are plotted in Fig. 1 in terms of the time to fracture as a function of the applied stress, respectively. For the DP steel, the time to fracture varied widely, although it tended to decrease with increasing applied stress. The critical applied stress for fracture of the DP steel, i.e., 400 MPa, was higher than that of the single phase steel. The scattering of the time to fracture and the high critical applied stress for fracture appear to be characteristics of the delayed fracture behavior of the DP steel under the sustained tensile-loading test. The etched cross section near the fracture initiation area in the DP steel is shown in Fig. 2. The arrows in the figure denote the cracks formed during the sustained tensile-loading test. As shown in Figs. 2(b) and 2(c), most of the cracks were observed in the martensite phase or the interface between martensite phases and at the root of the notch-shaped martensite. On the other hand, no cracks were observed in the ferrite grains, suggesting that each crack related to the martensite is interconnected by cracks formed in the ferrite during main crack propagation. Hence, it appears that the nucleation sites of the cracks are the martensite or its interface, and the martensite properties of DP steel sheets play important roles in the delayed fracture behavior.

For CP steel sheets containing retained austenite, the results of delayed fracture behavior have reported by the same evaluation method as the DP steel sheets. The fracture time of the CP steel sheets with a large amount of retained austenite (CP-A steel) was longer than that of the CP steel sheets with small amount of retained austenite (CP-B steel). However, the fracture time of the CP-A steel significantly decreased at applied stress below the yield stress in the sustained tensile-loading test after pre-loading. These result suggest that the effect of transformation of retained austenite induced plastic deformation is large in the CP steel sheets.

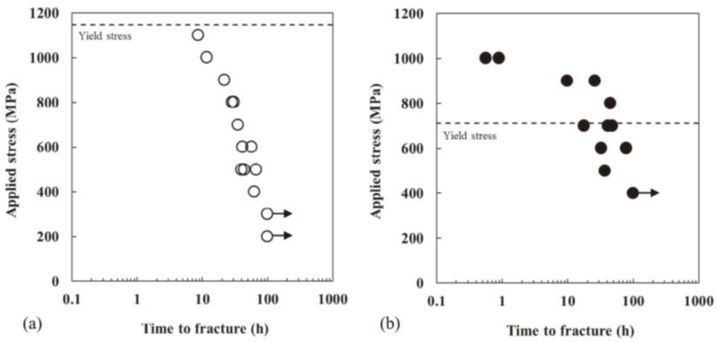

Fig. 1. Time to fracture versus applied stress in sustained tensile-loading test: (a) single phase steel and (b) DP steel.

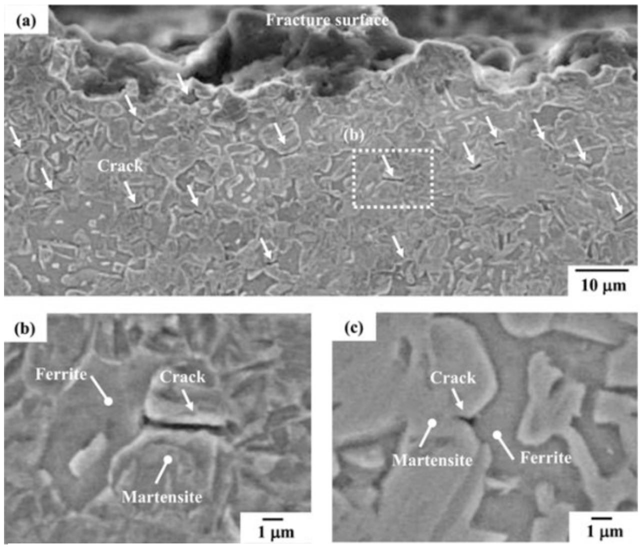

Fig. 2. SEM images of cross section near fracture surface of DP steel subjected to sustained tensile-loading test: (a) general view, (b) magnified view of crack, and (c) magnified view of crack at other area.