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Splitting in dual-phase 590 high strength steel plates Part II. Quantitative analysis and its effect on Charpy impact energy

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ABSTRACT

The influence of splitting on Charpy impact energy was investigated by analyzing the primary fracture (from the Charpy V-notch) and splitting (secondary fracture) surfaces at different test temperatures quantitatively. The morphology of splitting at the primary fracture surface of Charpy impact specimens made of dual-phase (DP) 590 hot-rolled steel in TL direction at +60 °C and −30 °C were surveyed by scanning electron microscope (SEM). The broken Charpy impact specimens in both TL and LT directions at different test temperatures were studied by examining sliced images obtained from micro-radiography imaging system. Three-dimension (3D) and plane sliced images of specimens were analyzed using GEHC microview software. Results show that fracture appearance inside the splitting is cleavage. The length and depth of the splitting increased with decreasing test temperature. Splitting width decreased first then the trend becomes irregular when test temperature falls due to variation of steel ductility and reaction between splitting and the primary crack. The surface areas of splitting and primary crack changed with test temperature as well. Splitting area increased with decreasing test temperature, while the surface area of the primary crack decreased as the test temperature was lowered. Influence of splitting on the impact energy in upper shelf of DP590 hot-rolled steel is small. In the ductile-to-brittle transition temperature (DBTT) range, splitting tends to increase the Charpy impact energy and consequently reduced the DBTT of DP590 hot-rolled steel.

1. Introduction

Automobile manufacturers are always striving toward improving vehicle fuel efficiency through reduction of vehicle weight to meet customers' increasing demand for modern styling, comfort, functionality and high technical specification. Dual-phase steels whose microstructure consists primarily of both ferrite and martensite are good candidates for auto bodies due to their high strength to weight ratio and superior formability and weldabilty [1–3].

Charpy V-notch impact test is often used to assess the energy absorption capacity of structure steels. In hot-rolled steels with finishing temperature in two phase region, splitting in the form of single or multiple secondary cracks parallel to the plate surface is often encountered during Charpy tests [4]. In the investigation of Charpy V-notch impact property of H75-3 steel, Roessler [5] reported that the delamination of the plate caused by splitting reduced the notch impact strength in the upper shelf region. Silva [6] observed severe splitting running parallel to the primary crack propagation direction with varying lengths in all test specimens of API X70 and X80 pipeline steels. Delamination of interfaces positioned normal to the primary crack front decreased the effective thickness of the test piece, promoting plane stress conditions deep inside the specimen, which could make the determination of J_{1c} more difficult. Ray et al. [7] studied the mechanical properties and fracture behavior of a high-strength low-alloy (HSLA) steel and showed the splitting on the fracture surface of Charpy specimens in TL direction associated with low impact energies. Investigating the Charpy impact toughness of a dual-phase 12 wt.%Cr steel (3CR12), Knusten and Hutchings [8] Grobler and Van Rooyen [9] found planar-oriented splits, parallel to the rolling plane, occurred in TL Charpy impact specimens during impact test resulting in a decrease in the impact energy as well as the DBTT. Knusten and Hutchings

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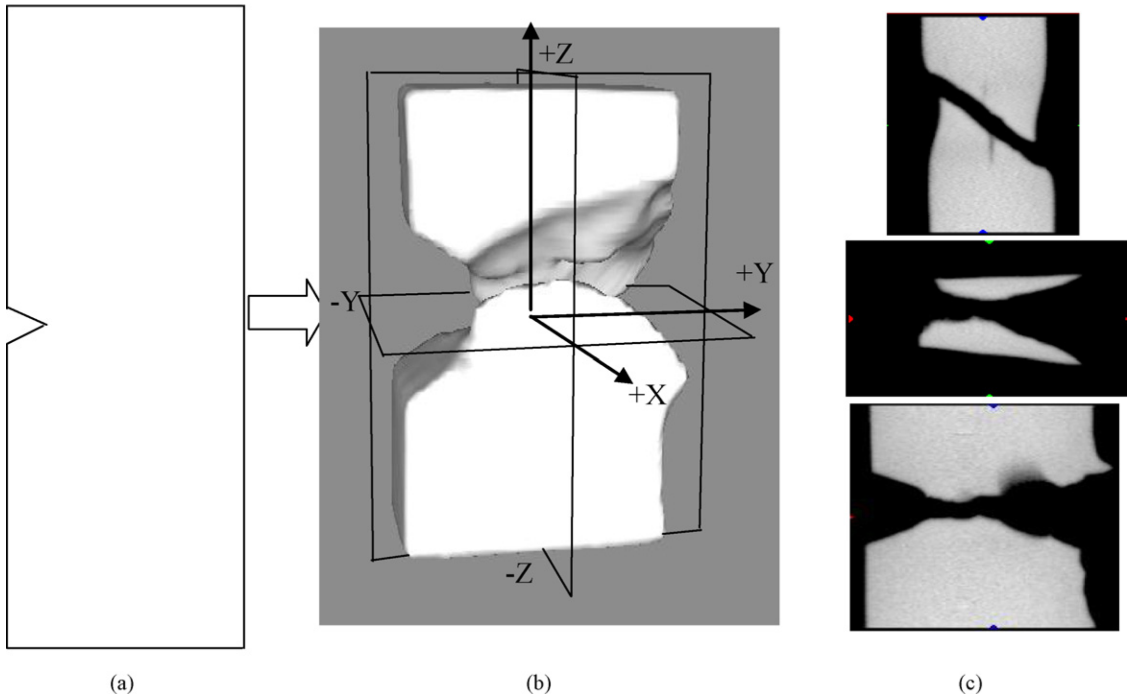

Fig. 1. Schematic diagram of broken impact specimen scanned by using micro-radiography imaging system through plane slice: (a) schematic diagram of scanned region on a whole impact specimen (part between dash lines), (b) 3D image of the scanned region, and (c) plane slice image (sliced in *XZ*, *YX* and *ZY* plane, respectively).

[8] suggested that non-metallic inclusions, particularly manganese sulfides, facilitate low energy modes of fracture associated with the splitting phenomenon. Grobler and Van Rooyen [9] argued that splitting was caused by transgranular cleavage as well as by decohesion of ferrite–ferrite and ferrite–martensite grain boundaries and not related to the presence of inclusion in the microstructure. Krishnadev et al. [10] found that large central splitting in a J_{1c} test specimen of quenched and tempered HY-130 steel was related to the presence of segregation bands enriched with manganese which resulted in lower toughness. da Costa Viana and de Souza [11] used the crystallite orientation distribution function in quantifying the influence of texture on the splitting in a severely controlled rolled HSLA steel plate. To deal with a fracture anomaly in ISO-V impact specimens of hot-rolled steels, Feldmann and Hulka [12] employed

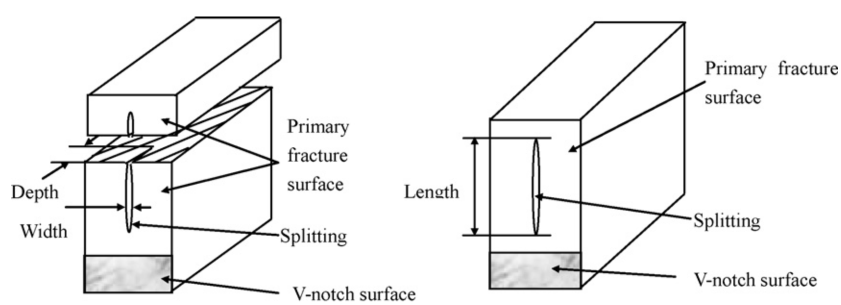

Fig. 2. Nomenclatures of splitting from broken impact specimen (shown with a single splitting).

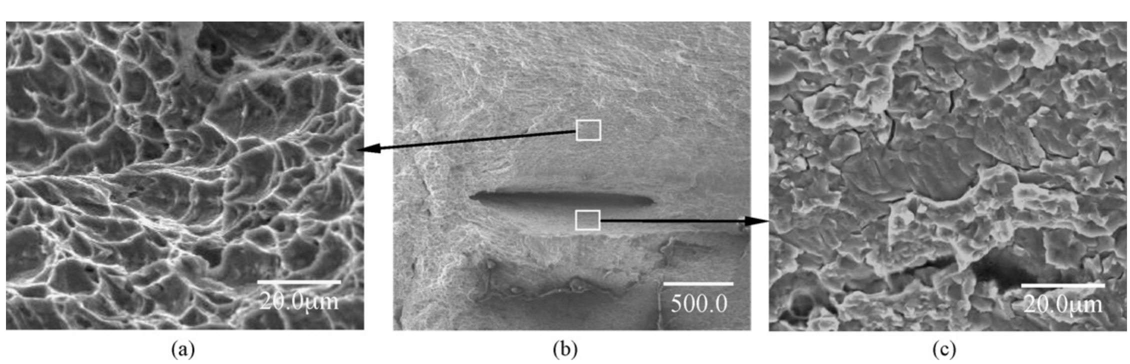

Fig. 3. SEM image of splitting in TL impact specimen at +60 °C: (a) outside the splitting or surface of the main crack, (b) top view of the splitting, and (c) inside the splitting or surface of the secondary crack (sample tilted 49.2°).