Abstract

Achieving superior impact toughness in high-strength pearlitic steels is extremely desirable and challenging due to the brittle character of the intervening cementite lamellae. Besides the ‘Hall-Petch’ type lamellar strengthening, a systematic understanding of various micro-toughening mechanisms through cleavage cracking resistance is essential to develop an integrated microstructure for toughness improvement. In the present study, both thermal as well as thermo-mechanical processing routes were adopted to correlate the processing and microstructural parameters with the mechanical properties of high carbon pearlitic steel. The primary parameter that governs the impact toughness of the steel was found to be the pearlite nodule size, also termed as the “effective grain size”.The role of nodule size refinement in improving the impact toughness isdiscussed in terms of frequent cleavage crack deflection at the nodule boundaries. Besides, the present work also deduced that a threshold misorientation angle of 12° is suitable to determine the pearlite nodule size from the electron backscattered diffraction (EBSD) maps. Other microstructural parameters controlling the toughness are the pearlite morphology (lamellar or spheroidized), interlamellar spacing, and the cementite lamellae orientation with the crack path. It appears that both the spheroidized and fine lamellar pearlite are more effective crack arresters than their coarse lamellar pearlite counterparts. Besides, the variation of crack growth resistance with the pearlite lamellae orientation and the ferrite-cementite interface (habit) plane is also presented, relating to the mechanism of interface decohesion.

The present study also fine tunes the thermo-mechanical processing route of the pearlitic steel to shape an optimum strength-toughness combination through appropriate microstructural design. A fully lamellar coarse pearlite microstructure leads to poor strength and toughness. Hot deformation prior to the isothermal treatment breaks down the lamellar pearlite to a spheroidized structure. Moreover, reducing the hot deformation temperature not only refines the pearlite nodule size but also increases the spheroidized pearlite fraction, which thereby improves the toughness of the steel. However, no proportionate increase in yield strength was obtained due to insignificant change in the interlamellar spacing. Remarkable refinement in lamellar spacing and increase in the spheroidization amount was ensured when the hot deformation was carried out just below the eutectoid temperature, owing to the strain induced pearlite transformation.

Thepresence of a mixed microstructure of fine lamellar pearlite along with spheroidized pearlite constituents simultaneously improves both the yield strength and toughness of the steel. Optimum strength-toughness combination was attained when the hot deformation strain (just below the eutectoid temperature) was increased up to 45%. Subsequent increase in strain creates deformation bands and traces of strain induced bainite in the microstructure, which again deteriorates the tensile elongation of the steel.

Keywords: Pearlitic steel; Spheroidization; Strain Induced Pearlite (SIP) Transformation; Mechanical Properties; EBSD; Nodule size; Orientation relationship; Micro-toughening mechanisms