Mechanism of Improving Heat-Affected Zone Toughness of Steel Plate with Mg Deoxidation after High-Heat-Input Welding

Longyun Xu (xulongyun@shu.edu.cn), **Jian Yang** * **(**yang_jian@t.shu.edu.cn**)**

State Key Laboratory of Advanced Special Steel, School of Materials Science and Engineering, Shanghai University

【Introduction】 Nowadays, oxide metallurgy technology developed by using of Mg deoxidation has been considered as an effective method to improve the heat-affected zone (HAZ) toughness of steel plates after high-heat-input welding. This technology is to make use of oxide particles or other kinds of inclusions and precipitate particles as the nucleation sites of intragranular acicular ferrite (IAF), or for pinning the growth of austenite grain in HAZ of steel plate during the welding process. It is currently unclear about the influence of Mg content on the characteristics of TiN particles in HAZs of steel plates after high-heat-input welding. Furthermore, the relationship between TiN particles and HAZ toughness was needed to be illustrated. To clarify the austenite grain growth behavior during HAZ thermal cycle is helpful to deeply understand the mechanism of improving the HAZ toughness of steel plate with Mg deoxidation.

【Experimental】 Three experimental steel samples with conventional Al deoxidation, low-content Mg deoxidation, and high-content Mg deoxidation termed as A, LM, and HM, respectively, were investigated in the present study. To evaluate the HAZ toughness of the experimental steel plates, the simulating welding experiments of 400 kJ/cm were carried out by use of Gleeble 3800 thermal simulation tester. The roles of micron size inclusions and nanoscale particles on improving the HAZ toughness of steel plate after high-heat-input welding were observed by use of SEM-EDS and TEM-EDS. Also, the growth behavior of austenite grains during the thermal cycles of HAZ was studied through in situ observation experiment by use of high-temperature laser scanning confocal microscopy (HT-LSCM). Furthermore, the effect of Mg content in steel on the control mechanism of formation IAF and the inhibition of austenite grain growth was comprehensively illustrated.

【Results】 It was found that intragranular acicular ferrite (IAF) and polygonal ferrite (PF) contributed to the improvements of HAZ toughness in steels with Mg deoxidation. With the increase of Mg content in steel, the oxide in micron size inclusion was firstly changed to MgO-Ti2O3, then to MgO with the further increase in Mg content in steel. The formation of nanoscale TiN particles was promoted more obviously with the higher Mg content in the steel.

The growth rates of austenite grains at the high-temperature stage (1400~1250 ºC) during the HAZ thermal cycle of steels with conventional Al deoxidation and Mg deoxidation containing 0.0027 and 0.0099 wt% Mg were 10.55, 0.89, 0.01 μm/s, respectively. It was indicated that nanoscale TiN particles formed in steel with Mg deoxidation were effective to inhibit the growth of austenite grain. The excellent HAZ toughness of steel plates after welding with a heat input of 400 kJ/cm could be obtained by control of the Mg content in steel to selectively promote the formation of IAF or retard the growth of austenite grain.

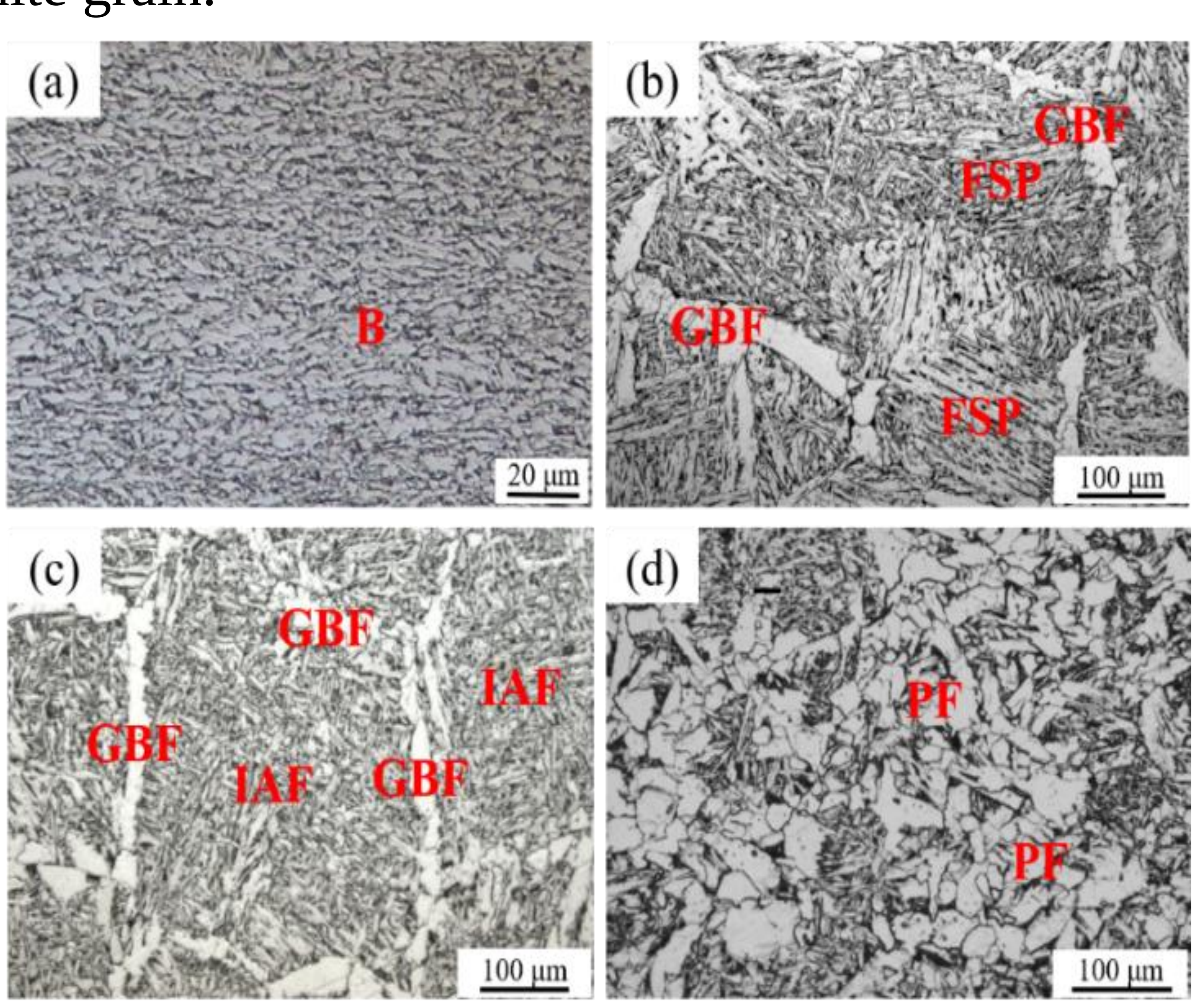

Fig.1 Microstructures of base metal (a) and HAZs after simulated high-heat-input welding of 400 kJ/cm for (b) A, (c) LM and (d) HM. Bainite (B), grain boundary ferrite (GBF), ferrite side plate (FSP), intragranular acicular ferrite (IAF), polygonal ferrite (PF).

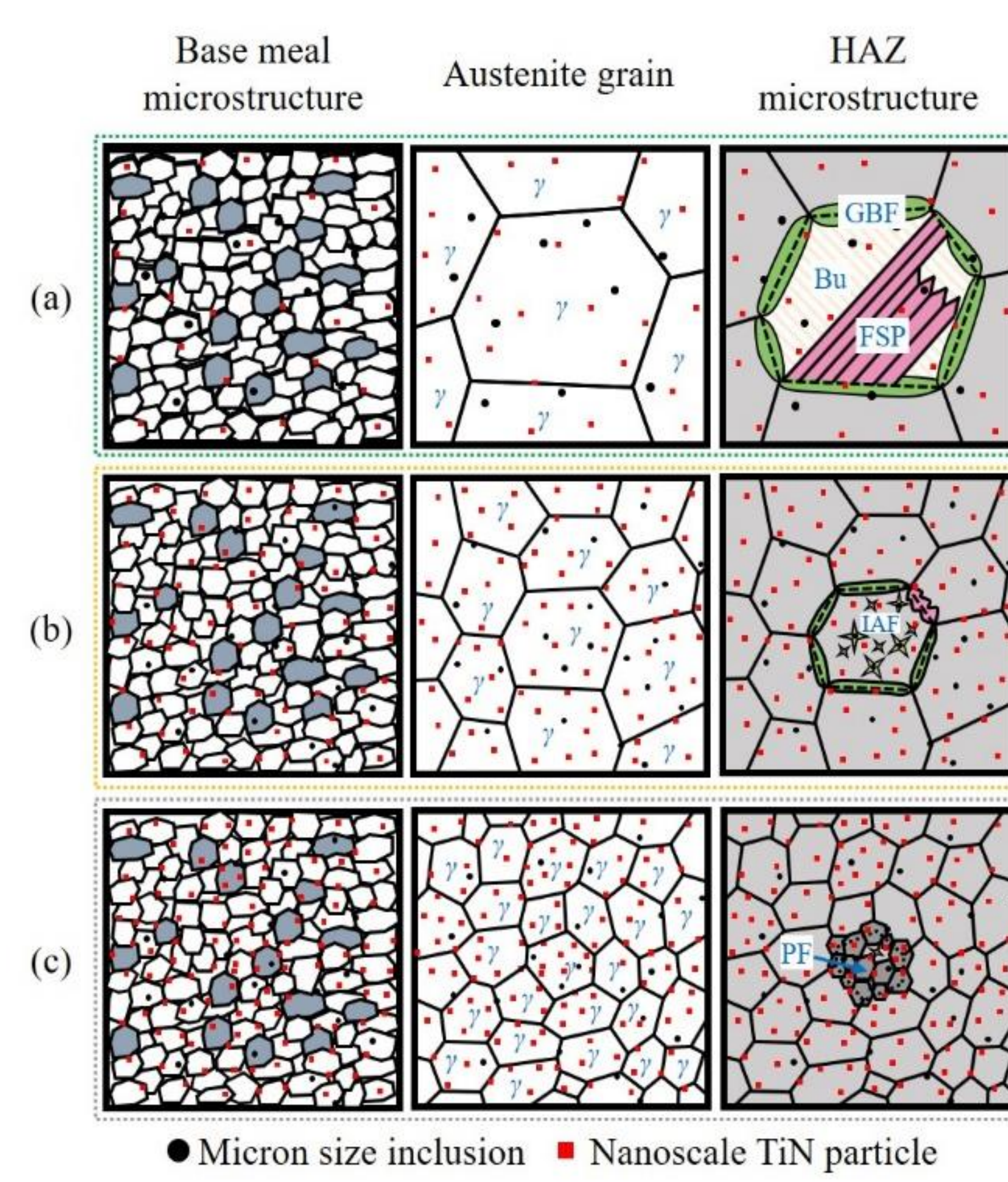

Fig. 2 Schematic diagram of the mechanism for improving the HAZ toughness by inclusion control with Mg deoxidation: (a) A, (b) LM and (c) HM.