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MS-4-P-1896 TEM Study of Inclusions on the Nucleation of Acicular Ferrite in Weld Metal

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The welding of steel parts by Submerged Arc Welding (SAW) is one of most traditionally processes used in manufacturing of structural components. High levels of strength and toughness can be achieved if SAW weld metals are mainly composed by acicular ferrite (AF), a microconstituent whose its nucleation depends of the existence of a non-metallic inclusion distribution. However not all of these particles take effectively part in the formation of ferrite laths during the iron gamma-alpha phase transformation, being also autocatalytic nucleation a important mechanism for acicular ferrite formation. SAW was carried out on low-carbon steel substrate to produce a bead-on-plate weld metal with different heat input welding (HI: 1, 2 and 3 $kJ.mm^{-1}$). Disks with 50-100 µm thick were carefully cut from cylinders with 3 mm diameter, which were machined parallel to the welding direction. Thin foil samples were obtained after double-jet electropolishing using Struers Tenupol-3. Transmission Electron Microscopy (TEM) observations were carried out in a Philips CM120, operated at 120 kV and equipped with EDAX DX-4 Materials Thin System for EDS microanalysis.

Figure 1 shows TEM bright field micrographs of the typical interlocking laths of AF, where each ferrite lath have usually measured between 1-10 µm length and 0.5-2 µm width. In these micrographs some of the inclusions appeared to be acted as substrate for acicular ferrite formation, i.e. some ferrite laths grow outwards from the particles while other ones seem like non-nucleant inclusions. That behaviour may be associated to size, shape and composition of the inclusions, become their effect on the formation of AF quite complex.

The role of the inclusions was investigated by TEM according to nucleant or non-nucleant behaviour for acicular ferrite. Figure 2 shows examples of both kinds of particles where clearly 1 and 2 no contribute to formation of ferrite laths, unlike of the particles 3 and 4. A nucleant particle may be able to form one or more AF laths on its surface. In general, larger and more intricate inclusions (lower roundness) are more efficient to nucleate AF laths than smaller and rounder ones. However, increasing of roundness was observed in the nucleant inclusions formed with higher HI, Figure 2(b), suggesting that effect may be related to composition of these particles. Figure 3 shows mean amounts (%wt) of elements such as Al, Si, S, Ti and Mn determined by EDS in the nucleant and non-nucleant particles. Non-metallic inclusions are essentially complex oxides but presence of higher concentration of titanium is expected for improving their nucleant AF behaviour in the SAW weld metal.

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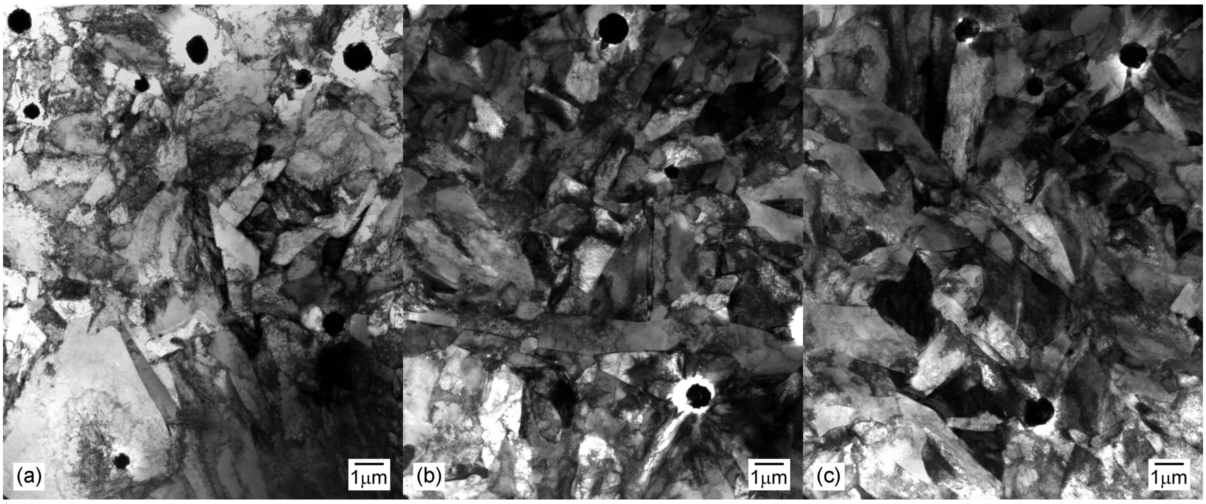

Fig. 1: Typical thin foil TEM BF micrographs showing AF laths and rounded non-metallic inclusions in weld metal. SAW performed under different heat input (HI): 1 kJ.mm^{-1} in (a), 2 kJ.mm^{-1} in (b) and 3 kJ.mm^{-1} in (c).

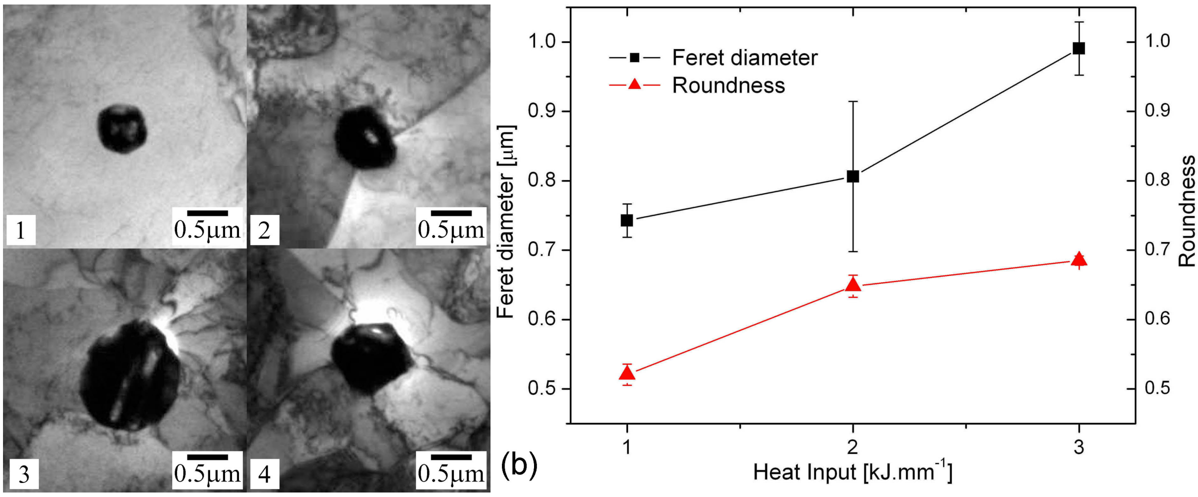

Fig. 2: TEM BF micrographs showing examples of non-nucleant (1-2) and nucleant (3-4) particles. Effect of heat input on the size and morphology of nucleant particles for AF in (b).

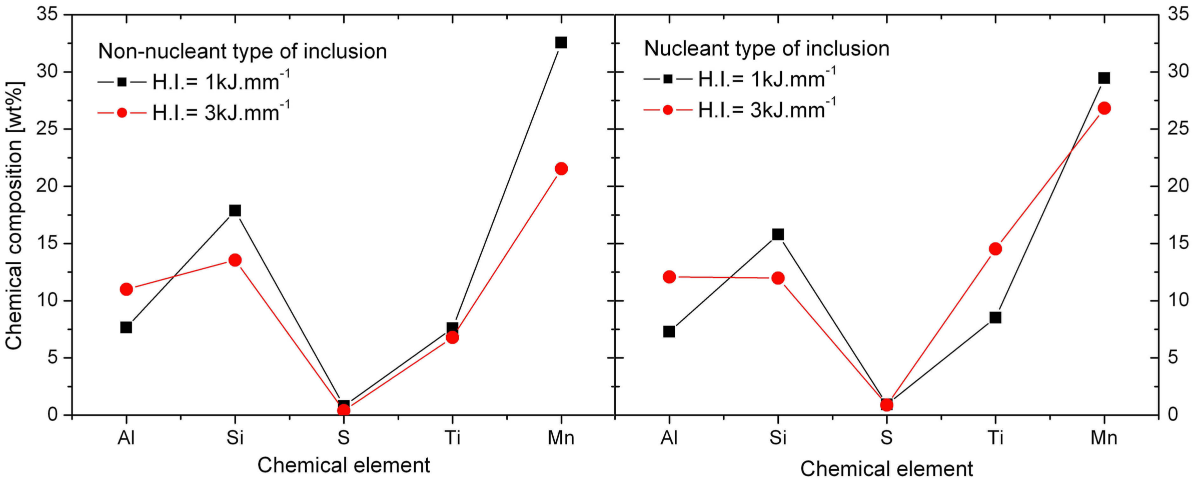

Fig. 3: Variation of mean composition (%wt) of non-nucleant and nucleant particles for acicular ferrite laths with different SAW heat inputs.