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Effect of molybdenum on recrystallization behavior of Fe30Mn5Al1C- x Mo lightweight austenitic steels

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A R T I C L E I N F O

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A B S T R A C T

Lightweight austenitic steels are among the materials of interest which can potentially reduce the CO_2 emissions and improve the fuel efficiency in automotive sector. Understanding the recrystallization behavior of these steels would open the door for a spectrum of structural applications that need a strength-ductility balance. In the present work, the recrystallization behavior of cold rolled Fe-30Mn-5Al-1C- (0–3 wt%) Mo austenitic steels after annealing at 600–1200 °C was investigated through EBSD, FESEM, TEM and hardness. The solubility of molybdenum in austenite and the equilibrium phases is determined through thermodynamic calculations. Alloying with more than 0.5 wt% Mo increased the recrystallization temperature by ~ 100 °C. M_2C type carbides precipitated in 2-Mo and 3-Mo alloys leading to grain refinement and delay in recrystallization. The hardness increased with increase in Mo content and decreased with increase in annealing temperature. At 1200 °C, due to grain growth all the alloys have similar grain size and hardness.

The development of steels with superior strength and ductility, to minimize the carbon-di-oxide emissions and improve the efficiency has been the goal of automotive sector. Lightweight steels based on Fe-Mn-Al-C system are finding interest due to their high specific strength and ductility. They offer reduced weight due to the lower atomic mass of aluminum and the dilation of iron lattice due to solute aluminum. The addition of aluminum and manganese alters the stacking fault energy of the steel and changes the deformation mechanism, which leads to better mechanical properties. These alloys are categorized based on the phases in their microstructure viz., ferritic, duplex (ferrite + austenite) and austenitic steels [1–5]. The austenitic class of steels drew attention owing to the precipitation hardening by intra-granular κ-carbide, $(Fe, Mn)_3AlC_x$ [6,7]. However, on long term aging the κ-carbide precipitates at the grain boundaries and deteriorates the mechanical properties [8, 9]. Among the alloying additions, silicon accelerates the formation kinetics of κ-carbide [10,11], while molybdenum retards it [12]. It was also reported that alloying with up to 3 wt%Mo decreased the yield strength and beyond 4 wt% Mo increased it [13]. It was also shown that alloying with chromium along with molybdenum increased the resistance to pitting corrosion without loss in ductility [14].

The role of molybdenum in the precipitation of κ-carbide and control of mechanical properties is important. Static recrystallization is known to affect the grain size and thereby the mechanical properties. There is no literature on static recrystallization behavior of molybdenum alloyed lightweight austenitic steels. In the present work, we investigate the role of molybdenum on recrystallization behavior and hardness of Fe-30Mn-5Al-1C-*x*Mo lightweight austenitic steels.

Commercially pure iron, manganese, aluminum, molybdenum and graphite were vacuum induction melted to produce the alloys with four different Mo concentrations, Fe-30Mn-5Al-1C-*x*Mo (x = 0, 0.5,2 and 3 wt%). The chemical composition of the alloys obtained through ICP-MS presented in Table.1. The as cast alloys were homogenized at 1200 °C for 3hr, hot-forged and then hot-rolled to plates of 7 mm thickness. The hot-rolled plates were homogenized at 1100 °C for 2hr and cold rolled to 80% reduction in thickness. The cold rolled alloys were isochronally (1 h) annealed in the temperature range of 600–1200 °C under argon atmosphere to investigate the recrystallization behavior. EBSD (FESEM, JEOL, 7500 M) was used to characterize the microstructural evolution during annealing along with fraction recrystallized. Grain orientation spread (GOS) approach with GOS of 0–1.5° is used to distinguish recrystallized and deformed grains in the microstructure. The specimens for EBSD were prepared by grinding through a series of SiC papers and finish polishing by fine alumina (<0.5 μm) followed by electro polishing in 10% perchloric acid in methanol for 10 s at 20 V. The precipitates

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