The Study of Austenite Grain Size Effect on the Microstructure Development and Mechanical Properties of a High-Mn Austenitic Steel

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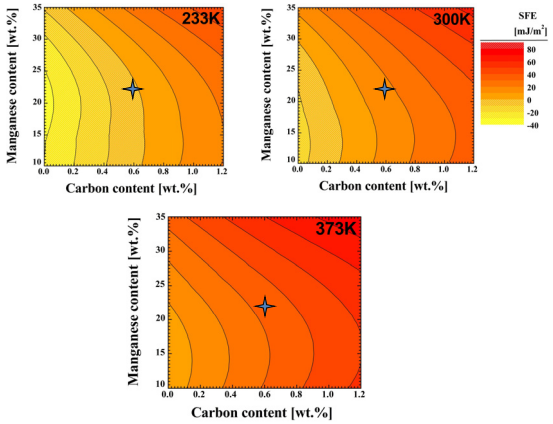
Introduction

•The desired mechanical properties of high-Mn austenitic steels are achieved through adjustment of different parameters like chemical composition, temperature, grain size, and finally Stacking Fault Energy (SFE).
• Among all other parameters, the austenite grain size affects the overall flow behavior, the occurrence of the Portevin–Le Chatelier (PLC) effect, and the mechanical twinning.

Material and Experiments

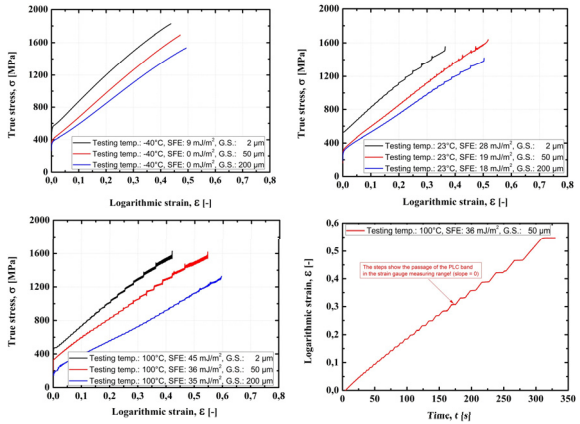
• Hot rolled Fe-22Mn-0.6C TWIP steels;
• Annealing at 900°C and 1030°C for 30 and 60 minutes (Avg. G.S. 2 µm, 50 µm and 200 µm);
• Tensile tests at -40°C, 23°C and 100°C with the targeted strain rate of 0.003 s^{-1};
• Microstructural investigation using LOM;
• Predication of SFE using subregular solution thermodynamic model.

Composition-Dependent SFE Maps



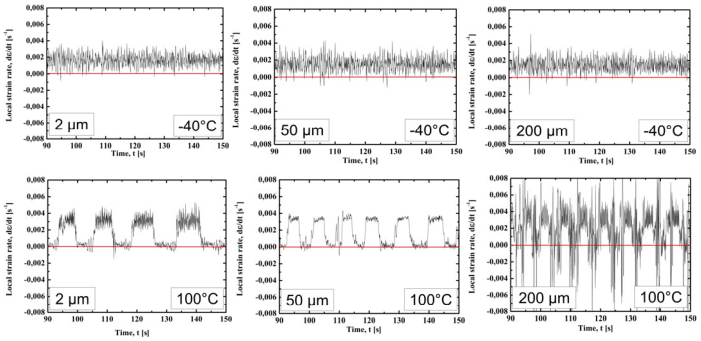
• These maps have been designed with the assumption of a very coarse-grained material, i.e. no effect of grain size on SFE is available here!

Flow Curves and Strain-Time Relationship



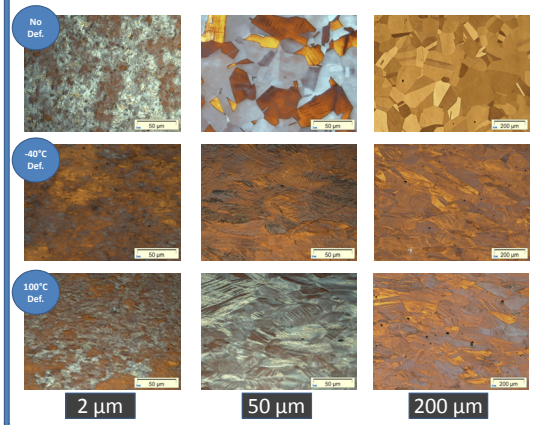
• Grain size has a maximum increasing effect of 9 mJ/m² by decreasing the grain size from 50 µm to 2 µm.
•The PLC effect in the flow curves occurs and is being intesified by increasing the temperature from -40°C to 100°C.
• Increasing the grain size decreases the stress level as usual, but also changes the nature of the PLC effect.

PLC Effect



• Serrations are expected to be the result of the mechanical twinning.
• Zero values for the local strain rate show the passage of the PLC band outside the strain gauge measuring length.

Microstructures



Results

• The local strain rate diagrams indirectly demonstrate the variations of the twinning intensity and the PLC effect by increasing the grain size from 2 µm to 200 µm at 100°C.
• PLC band formation is strongly suppressed at -40°C (almost no zero value for the local strain rate).
• The micrographs show that the twin-density increases by increasing the temperature from -40°C to 100°C independent of the grain size.

Conclusions

• Grain size has a minor effect on SFE, but a major role in the flow behavior, the occurrence of PLC effect and the mechanical twinning.
• A new method using the calculation of the local strain rate was used for better understanding of the role of grain size on plastic deformation.
• Although the predicted SFE value at -40°C tests are too low for the mechanical twinning (12-80 mJ/m² has been suggested by other investigators for the happenning of TWIP effect), it is very unlikely that the unstable local strain rate is the result of martensitic transformation. The microstructural investigations confirms this fact by showing a considerable fraction of twins.

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