Thesis

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Effects of Strain Rate and Temperature on the Mechanical Behavior of Advanced High Strength Steels

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The advanced high strength steels are normally used in parts and components specifically designed to protect the passengers in a case of a car crash. In such events, the materials are most likely subjected to high rate deformations. It is therefore important that the high strain rate deformation behavior of these steels is well known to facilitate design of optimally safe structures for better protection of the passengers against the impacts. In this work, the high strain rate behavior of various DP, TRIP, and TWIP steels was characterized using the Hopkinson Split Bar (HSB) technique. The HSB devices at the Tampere University of Technology were also enhanced to cover high strain rate tensile tests at temperatures ranging from -150 °C to +250 °C. The mechanical behaviors of TRIP and TWIP steels are strongly influenced by the strain and stress induced martensitic phase transformations and mechanical twinning, all of which are sensitive to temperature and strain rate. Therefore the strain rate and temperature dependent mechanical behaviors of these steels were characterized in this work at strain rates ranging from 10^{-3} s^{-1} to 10^{3} s^{-1} and at temperatures ranging from -150 °C to 250 °C both in compression and tension. The TRIP steels showed rather low strain rate sensitivity, but their temperature dependence appeared to be much more complex than that of the DP or TWIP steels. On the other hand, the DP and TWIP steels showed stronger strain rate sensitivities, but their behavior seems to be much less sensitive to the changes in temperature. The mechanical behavior of the studied TWIP steels was also found to be strongly dependent on the deformation mode, i.e., compression or tension. The effects of grain size and heat treatments on the deformation behavior of the TWIP steels were also studied. For better understanding of the relationships between the mechanical behavior and microstructures of the advanced high strength steels, some of the deformed TWIP specimens where characterized by transmission electron microscopy. The incidence of twinning was found to increase significantly with lowering temperature and increasing strain rate. The phase transformations in the TRIP steels were characterized by x-ray diffraction, and the phase transformation rate with respect to plastic strain was found to increase with decreasing temperature and strain rate. The reasons for the observed behaviors of the studied steels are discussed in the thesis in details. Also a numerical model is presented to describe the behavior of the TRIP and DP steels at different strain rates and temperatures.