Chapter 8

Summary and suggestions for future work

8.1 Conclusions of the present work

A one-time electropulsing of the ECAP material produces a bimodal grain distribution with decreased dislocation density caused by electromigration of defects. Repeated pulsing for five times of the sample produces more uniform grains by the coalescence of sub-grains. Formation of bimodal grain size distribution and decrease in defect density in ECAPed material lead to enhanced ductility.

Nanostructured bainite produced by prolonged austempering of high carbon low alloy steel precipitates some carbides in bainite phase and at the same time leads to reduced dislocation density. The bainite plate thickness is found to be dependent on the dynamic nature of dislocation density and austenite block size, which were not included in the empirical equations developed in the earlier works. Nanostructured bainite produced by prolonged austempering, annihilates dislocations, as a result of which the thickness of plates at the edge of sheaf is increased. The V1-V6 variant pair related to K-S orientation relationship is the most dominating pair in the high carbon low alloy nanostructured bainitic steel.

On deformation of nanostructured bainitic steel, homogeneous distribution of carbon in austenite in longer-austempered sample leads to a gradual strain-induced martensitic transformation. This in turn adds to ductility because of transformation-induced plasticity, while, inhomogeneous distribution of carbon behaves opposite by forming martensite in the early stage of deformation.

Electropulsing of high carbon bainitic steel leads to precipitation of carbides with different morphologies along with bainite and martensite phase. Estimation of growth kinetics of precipitates confirms that observed sizes are not feasible by only thermal effect during heating as well as cooling. The kinetics of carbide precipitation are accelerated due to enhanced mobility by athermal effect of electropulsing along with the thermal one. Repeated pulsing can redissolve carbide precipitates completely in austenite, while on the other hand its content is decreased in bainite. Instrumented hardness testing shows a decrease in elastic modulus as a result of the weakening of the bonds caused by the passage of electric current. Easy shearing promotes diffusionless transformations like bainite and martensite because of reduction in elastic modulus.

Air-cooling of high carbon low alloy steel sample results in tetragonal martensite, retained austenite and fine carbides. Electropulsing applied to air-cooled steel containing martensite and RA undergo decomposition to cementite in martensite phase and induces bainite and martensite in RA phase. Instead of softening, application of EP effectively increases the hardness of the steel and it is more in case of low current density where temperature effect is less.

8.2 Suggestions for Future Work

The following suggestions are made for future work based on the present investigations:

- Investigation into the impact of electropulsing on ECAP samples with varying levels of imposed strain, both low and high, to be carried out analyze the microstructural modifications and the changes in mechanical properties
- Electropulsing of ECAP sample in between one pulse and five pulses can be carried out to get more insight into the grain modification mechanism.
- Formulation of an empirical model to predict bainite plate thickness, taking into account the influence of dynamic nature of dislocation density and austenite grain size.
- Evaluation of the strain hardening behavior of nanostructured bainitic steel through interrupted tensile testing, coupled with thorough microstructural characterization.
- Performing confirmatory tests on electropulsed steel containing retained austenite to accurately quantify the extent of bainite or martensitic transformation.

- Carrying out an assessment of the mechanical properties of electropulsed nanostructured bainitic steels.