Chapter – 8

Conclusions and Suggestions for Future Work

8.1 Conclusions of the present work

Equal-channel angular pressing can be adopted to refine coarse grained low carbon steel to ultrafine-grained level. Rate of microstructural refinement with respect to imposed equivalent strain is strongly dependent on amount of strain. Refinement rate is maximum at early stage of imposed strain at this stage increase in defect density is maximum. Beyond a critical value of imposed strain refine decreases due to recovery of dislocations and lesser dislocation activity due to reduction in grain size. Coarse-grained low carbon steel can be refined to grain size of 0.2µm with average misorientation of ~40°, by imposing equivalent strain of 16.8 by equal-channel angular pressing.

At low strain, grain refinement proceeds with elongation of grains and its subdivision to bands. Bands get further splited in to cells by rearrangement of dislocations. In the intermediate strain level bands are thinned down and become ribbons at high strain level. At large strain ribbons are broken and take semi equiaxed shape.

In the low carbon steel pearlitic cementite starts dissolving at equivalent strain low as 6 and the lamellae are partially broken. The dissolution of cementite continues with strain but complete dissolution could not be achieved within the equivalent strain of 16.8.

The material is strongly textured upon ECAP with imposed strain. New components are developed at different strain levels. At low to intermediate strain level

F_θ, J_θ, $\overline{J}_{\theta}$, $D_{1\theta}$, and F_θ texture components typical of pure shear are formed. At high strain level new component E_θ is formed. The positions of components are nevertheless deviated from their ideal position. The deviation decreases with the dissolution of cementite in to ferrite matrix.

Strength and hardness increase rapidly at early stage of deformation due to rapid rate of grain refinement and increase in defect density but the rate of strengthening and hardening decreases with strain as refinement rate and dislocation density decrease. An ultrahigh level of ultimate tensile strength greater than 1000 MPa is achieved at ε_{vm} = 16.8 but failure takes place by brittle fracture at high strain level ε_{vm}=16.8.

The ECAPed low carbon steel of ultrafine-grain structure has been further deformed to greater than 75% reduction in area by cold rolling or cryorolling and the material is refined to ~100 nm.

Bimodal grain size distribution consisting of ultrafine grains and micron-size grains of is obtained by post ECAP deformation and followed by optimized thermal treatment where ultrafine grains offers high resistance to deformation, i.e. high strength but micron sized grains adds ductility for the material by changing the nature of failure from brittle to the ductile fracture of the ferrite phase.

8.2 Suggestions for Future Work

It is worth exploring the formability of the ECAPed material as the selected steel is extensively used for sheet metal applications. Microstructure and texture development should be correlated to formability.

Methods may be derived to isolate contribution of various factors i.e., microstructural components, defect density towards strength and ductility.

Deformed material may be annealed for different periods of time to know the sequential orientation changes during short annealing.

Orders of magnitude enhancement in strength and hardness will affect wear resistance of the material. It is worth studying the effect of microstructural development and mechanical properties of the ECAPed and post ECAP-processed steel on wear resistance of the material.

Back pressure may be applied during ECAP processing so that much higher strain can be imposed on the sample and its effect on misorientation can be explored.