Synopsis

Magnesium is the lightest metal that can be used for structural applications. For the reasons of weight saving, there has been an increasing demand for magnesium from the automotive industry. However, poor formability at room temperature, due to a limited number of slip systems available owing to its hexagonal close packed crystal structure, imposes severe limitations on the application of Mg and its alloys in the wrought form. One possibility for improving formability is to form the components superplastically. For this, it is necessary to refine the grain structure. A fine-grained material is also stronger than its coarse grain counterpart because of grain size strengthening. Moreover, fine-grained magnesium alloys have better ductility as well as a low ductile to brittle transition temperature, thus their formability at room temperature could be improved. In addition to grain refinement, the issues pertaining to poor formability or limited ductility of Mg alloys can be addressed by controlling the crystallographic texture. Recently, it has been shown that warm equal channel angular extrusion (ECAE) of magnesium led to reduction in average grain size and shear texture formation, by virtue of which subsequent room temperature rolling was possible. Based on the literature, it was also certain that, in order to make magnesium alloys amenable for processing, grain refinement needs to be carried out and the role of shear texture needs to be explored. Since processing at higher temperature would lead to relatively coarser grain size, large strain deformation at lower temperatures is desirable.

The present thesis is an attempt to address these issues. The thesis has been divided in to eight chapters. The chapters 1 and 2 are dedicated to introduction and literature review on the subject that provides the foundation and motivation to the present work. Subsequet chapters deal with the research methodology, experimental and simulation results, discussion, summary and conclusion.

In the present investigation, two single phase alloys were chosen, the commercially pure magnesium and the magnesium alloy AM30. These materials were subjected to suitable processing techniques, detailed posteriori. A systematic analysis of microstructure and texture for each of the as-processed materials was performed by electron backscattered diffraction (EBSD) using a field emission gun scanning electron microscope (FEG-SEM). Bulk texture measurement by X-ray diffraction, neutron diffraction and local texture measurement by synchrotron X-rays were also carried out. In addition, dislocation density was measured using X-Ray diffraction line profile analysis (XRDLPA). The experimental textures were validated by using Visco-Plastic Self Consistent (VPSC) simulation. The details of experimental as well simulation techniques used in the present investigation is decribed in chapter 3.

To understand the philosophy of large strain deformation by shear in magnesium and its alloy, free end torsion tests could provide a guide line. Based on the understanding developed from these tests, further processing strategy could be planned. Therefore, a rigorous study of deformation behaviour under torsion was carried out. In chapter 4, the results of free end torsion tests carried out at different temperatures, 250°C, 200°C and 150°C and strain rates, 0.01 $rad.s^{-1}$, 0.1 $rad.s^{-1}$, 1 $rad.s^{-1}$ are presented for both the alloys. In addition to the analysis of stress-strain behaviour, a thorough microstructural characterization including texture analyses pertaining to deformation and dynamic recrystallization was performed. Both pure Mg and the AM30 alloy exhibit similar ductility under the same deformation condition, while the strength of AM30 was more. The strain hardening rate decreased with temperature and increased with strain rate for both the materials. However, the strain hardening rate was always higher in case of the alloy AM30. Large amount of dynamic recrystallization (DRX) was observed for both the alloys.

The initial texture had an influence on the deformation behaviour under torsion and the resulting final texture. The initial non-axisymmetric texture of pure Mg samples led to non-axisymmetric deformation producing ear and faces along the axial direction, and the final texture was also non-axisymmetric. An examination of the texture heterogeneity was carried out in one of the pure Mg torsion tested samples by subjecting it to EBSD examination at different locations of the surface along the axial direction. The strain induced on the ear portion was maximum, and in the face was lower. This has been attributed to the orientation of basal planes in the two regions.

The axisymmetric initial texture in case of the alloy AM30 led to the formation of axisymmetric texture with no change in the shape of the material. Owing to this simplicity, the occurrence of dynamic recrystallization (DRX) was studied in more detail for this alloy. The mechanism of texture development due to deformation as well as dynamic recrystallization could be tracked at every stage of deformation. A typical shear texture was observed with respect to the strain in each case. Very low fraction of twins was observed for all the cases indicating slip dominated deformation, which was validated by VPSC simulation. It was found that with the increase in strain during torsion, the fraction of dynamically recrystallized grains increased. The recrystallization mechanism was classified as "continuous dynamic recovery and recrystallization" (CDRR) and is characterized by a rotation of the deformed grains by ~30° along c-axis.

After developing an understanding of large strain deformation behaviour of pure Mg and the alloy AM30 through torsion tests, the possibility of low temperature severe plastic deformation for both the materials by equal channel angular extrusion (ECAE) was explored. The outcome of this investigation has been presented in chapter 5. At first, ECAE of pure magnesium was conducted at 250°C up to 4 passes and then the temperature was reduced by 50°C in each subsequent pass. In this way, ECAE could be carried out successfully up to 8th pass with the last pass at room temperature. A grain size ~250 *nm* and characteristic ECAE texture with the fibres B and C_2 were achieved. The AM30 alloy subjected to similar processing schedule as pure Mg, however, could be deformed only up to 6th pass (T_{ECAE}=150°C) without fracture. An average grain size ~ 420 *nm* and a texture similar to ECAE processed pure Mg was observed for this alloy. The difference in the deformation behaviour of the two alloys has been explained on the basis of the anisotropy in the stacking fault energy (SFE) in the case of pure Mg.

Neutron diffraction was carried out to confirm and validate the microtexture results obtained from the EBSD data, while the local texture measurement by synchrotron radiation was carried out at different locations of the ECAE samples to give a proper account of the heterogeneity in texture.

The effect of grain refinement was examined, deconvoluting the effect of shear in improving the strength and ductility using another severe plastic deformation technique, namely multi axial forging (MAF). In this process, the material was plastically deformed by a combination of uniaxial compression and plane strain compression subsequently along all the three axes. The details of this investigation has been presented in chapter 6. By this method, the alloy AM30 could be deformed without fracture up to a minimum temperature of 150°C leading to ultra-fine grain size (~400 *nm*) with very weak texture. A room temperature ductility ~55% was observed for this material.

Finally, a comparison of room temperature mechanical properties of the alloy AM30 was carried out for the ECAE and MAF processed conditions having similar grain size in order to observe the effect of texture formed during both the processes. A similar strength and ductility for both the cases was attributed to the orientation obtained from both the ECAE and MAF, which is away from the ideal end orientation for tensile tests. The final outcomes of the thesis has been summarized in chapter 7.