Chapter 5

CONCLUSION

From above research work on *processing and characterization of in-situ aluminium matrix composite by stir casting method* in different THREE phases, following conclusions can be drawn:

1. **Phase I: Optimization of magnesium content into the commercially pure aluminium (CPA)**

   (a) Both, density and ductility results were decreased in the Al-Mg system throughout the variation of magnesium content. Since the density of magnesium is lower than the aluminium, it made the overall system lighter. However, due to some brittle phases and its stress raising effect, the ductility of the system dropped.

   (b) The hardness results (BHN) of Al-Mg system were found increasing continuously as magnesium concentration increased because of formation and accumulation of the phases such as $MgSiO_3$ and Al_2Mg_3 at the grain boundaries while synthesis.

   (c) Ultimate tensile strength was found maximum at 3 wt % Mg. For higher magnesium concentrations, due to limited solubility of magnesium in aluminium, unreacted magnesium formed which was accumulated at the grain boundaries. This results in weakening of the grain boundaries.

   (d) The generated phases were found uniformly distributed at grain boundaries in the microstructures up to 3 wt % Mg. Unreacted magnesium along with other phases were present after 3 wt % Mg, which adversely affected various properties of Al-Mg system.

   (e) Al - 3 wt % Mg system was found to be optimum because of the good combination of various properties like microstructure, ultimate tensile strength, specific strength and hardness with low density. Hence, Al-3 wt % Mg system is quite good for manufacturing of the low cost Al-Mg alloy with highest possible metallurgical and mechanical properties.

2. **Phase II: Effect of variation of MnO_2 content by changing its addition sequence into the commercially pure aluminium (CPA)**

   (a) The $Al - MnO_2$ composite systems were synthesised by stir casting method. The different amount of MnO_2 powder was added into the commercially pure aluminium in two different sequences A and B. In sequence B, when MnO_2 powder was added into solid commercially pure aluminium in the beginning of the experiments (before melting of commercially pure aluminium), due to sufficient time involved in decomposition of MnO_2, various favourable chemical reactions were possible. Hence in sequence B, metallurgically sound structure was obtained which is giving highest value of hardness and ultimate tensile strength in $Al-2.5wt\%MnO_2$ system.

   (b) The MnO_2 particles were decomposed and formed in-situ phases and complex carbide of Al and Mn. Various in-situ generated phases into the final composite materials which were confirmed by the XRD analysis are $FeSiO_3$, $MnAl_2O_3$, Al_2O_3 and Mn_3AlC .

   (c) It is observed that the ductility, hardness and ultimate tensile strength results were increased when MnO_2 particles were added into commercially pure aluminium *before* its melting (Sequence B) compared to the results when MnO_2 particles were added into commercially pure aluminium *after* its melting (Sequence A). Hence sequence B is more promising as far as metallurgical and mechanical properties are concerned.

3. **Phase III: Effect of variation of MnO_2 by changing its addition sequence into the commercially pure aluminium (CPA) along with optimised magnesium metal from phase I**

   (a) In this analysis, the optimization of MnO_2 was studied using the commercially pure aluminium and optimized 3 wt % magnesium (from phase I study) matrix system. The amount of MnO_2 particles and the sequence of its addition were changed like in phase II analysis. The results of both, density and ductility were decreased whereas the hardness values were increased in present Al - 3 wt % Mg - MnO_2 system in both A and B sequences. The results of tensile strength in sequence B were observed marginally improved compared to sequence A experiments.

(b) Various in-situ phases and complex carbides were generated in present Al - 3 wt % Mg - MnO_2 system such as $MgFeSiO_3$, Al_3Mg_2, Mn_3AlC and Al_2O_3 in sequence A whereas $MgFeSiO_3$, Al_2Mg_3, Mn_3AlC, $MnAl_6$ and Al_2O_3 in sequence B analysis. The distribution of these in-situ generated phases were found maximum in Al - 3 wt % Mg - 2.5 wt % MnO_2 system of sequence B experiments as observed from microstructures.

(c) Microstructures of Al - 3 wt % Mg - MnO_2 in-situ composites showed effective dispersion of various above mentioned in-situ generated phases and compounds. Analysis of some regions were confirmed the recoveries of manganese which were higher in sequence B experiments as compared to sequence A experiments. Such in-situ phases were found accumulated at the grain boundaries while grain growth.

4. **OVERALL Conclusions:**

The following final conclusions can be made from all above phases are:

(a) *In phase I study*, Al - 3 wt % Mg system giving highest values of mechanical properties for present commercially pure Al metal.

(b) *In phase II study*, the sequence B for MnO_2 addition is found more promising, i.e. when MnO_2 added in commercially pure aluminium *before* its melting as far as mechanical properties are concerned. The result trend lines in graphs are steeper in sequence B compared to sequence A. In sequence B, the microstructures are much more refined and average value of Mn recovery is improved.

(c) *In phase III study*, magnesium amount was kept fixed 3 wt % as optimized in phase I, the best sequence of addition of MnO_2 was sequence B i.e. MnO_2 addition in commercially pure aluminium *before* its melting because the micromechanical results are more favourable then sequence A. Average recovered Mg and Mn both are higher in sequence B as compared to A. It promotes the formation various in-situ phases as indicated in XRD analysis which strengthen the matrix.

Using above approach, the manufacturing of light weight Aluminium Metal Matrix Composites (AMMCs) can be promoted to achieve good micromechanical properties at lower cost as compared to the conventional materials and method of manufacturing.