CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 SUMMARY

Magnesium and its alloys have attracted great attention in industry application and academic research due to their properties such as light weight, high specific strength, stiffness, machinability and recyclability. However, the development of new alloy types, manufacturing techniques such as welding play an important role in exploiting the new fields of application. In this investigation an attempt was made to study the effect of friction stir welding process parameters on mechanical and metallurgical properties of AZ61A magnesium alloy joints and the results are compared with pulsed current gas tungsten arc welded (PCGTAW) AZ61A magnesium alloys joints.

The extruded plates of AZ61A magnesium alloy were machined to the required dimensions (300 mm x 150 mm x 6 mm). Square butt joint configuration, was prepared to fabricate the FSW and PCGTAW joints. The smooth (unnotched) tensile specimens were prepared to evaluate yield strength, tensile strength, elongation and reduction in cross sectional area. Notched tensile specimens were prepared to evaluate notch tensile strength and notch strength ratio. Microstructural examination was carried out using an optical microscope (OM). The precipitated phase constitutions of the welded joints were identified using X-ray diffraction (XRD). The fractured surfaces of the tensile specimens were analysed using SEM.
8.2 CONCLUSIONS

i) From this investigation, it is understood that FSW joints are prone to defects like pin hole, tunnel defect, piping defect, kissing bond, cracks etc, due to improper flow of metal and insufficient consolidation of metal in the FSW region, even though they are free from solidification cracks.

ii) The threaded pin profile tool made of high carbon steel with shoulder diameter of 18 mm (D/d = 3.0) and pin diameter of 6 mm was used to join AZ61A magnesium alloy successfully by friction stir welding process without any macro level defects.

iii) The joint fabricated with a tool rotational speed of 1200 rpm, welding speed of 90 mm / min and axial force of 5 kN exhibited a maximum tensile strength of 224 MPa (84% of base material). The formation of defect free stir zone and finer grains at the stir zone under these welding conditions are responsible for higher hardness and higher tensile strength.

iv) Empirical relationships was developed using statistical tools such as design of experiments, regression analysis and analysis of variance to predict the tensile strength of FSW and PCGTAW joints of AZ61A magnesium alloy at 95% confidence level.

v) The average grain diameter of the stir zone is lower than the base metal (starting material), irrespective of the tool pin profiles used. However, the joint fabricated by cylindrical threaded pin profiled tool produced finer grains than other tools.
vi) The hardness of stir zone is higher than the base metal, irrespective of the tool pin profiles used. However, the joint fabricated by cylindrical threaded tool profiled tool showed higher hardness than other joints.

vii) The threaded cylindrical pin profile, a tool rotational speed of 1194 rpm, a welding speed 92.19 mm/min and axial force of 5.05 kN were found to be optimum friction stir welding condition for AZ61A magnesium alloy to attain the maximum strength of 224.7 MPa. (Joint efficiency = 84%).

viii) The optimum welding parameters of, a peak current of 165.6 A, a base current 83 A, pulse frequency 6.24 Hz and pulse on time of 46.2 % were found to be optimum pulsed current gas tungsten arc welding condition for AZ61A magnesium alloy to attain the maximum strength of 199.5 MPa.

ix) The joint fabricated by FSW process exhibited superior tensile properties compared to PCGTAW joints. The enhancement in tensile strength is approximately 12% compared to PCGTAW joints.

x) The formation of relatively finer grains (9 μm) in the weld region, higher stir zone hardness (84.7 Hv), the considerably smaller heat affected zone, the presence of uniformly distributed finer intermetallics in the weld region are the main reasons for superior tensile properties of FSW joints compared to PCGTAW joints.
8.3 SUGGESTIONS FOR FURTHER RESEARCH

The present investigation on friction stir welding of AZ61A magnesium alloy alloys has given some important information related to the effect of tool profiles, tool shoulder diameter (tool parameters) and welding parameters on mechanical and metallurgical properties of the joints. However, there are few other aspects need to be investigated to understand the process effectively. In this regard, following suggestions are to be considered for further research on this topic.

(i) Friction stir welding windows are to be developed by incorporating welding parameters and tool profiles for different grades of magnesium alloys to select the feasible working range of the parameters to fabricate defect-free welds.

(ii) Post weld heat treatment of friction stir welded magnesium alloy joints are to be established.

(iii) The relationship between yield strength of base materials and friction stir welding process parameters is to be established for different tool profiles.

(iv) More importantly, the available literature on fatigue and fracture toughness behaviour of FSW joints is very few. Hence, the future research will be focused on the evaluation of fatigue and fracture toughness properties of FSW magnesium alloy joints.