Chapter 9

Summary and Conclusions

9.1 Summary

High strength aluminium alloys (Al-Zn-Mg-Cu alloys) have gathered wide acceptance in the wide range of structural applications requiring a high strength-to weight ratio, good fracture toughness and good corrosion resistance, such as aircraft structural components, military vehicle, earth moving equipments, bridges and other highly stressed defence applications. Generally this aluminium material is hard to weld using fusion welding processes. Weld fusion zones typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification. This often results in inferior weld mechanical properties and poor resistance to hot cracking. Further, in fusion welding of aluminium alloys, the defects such as porosity, slag inclusion, solidification cracks etc deteriorates the weld quality and joint properties. Usually, friction stir welded joints are free from these defects since there is no melting takes place during welding and the metals are joined in the solid state itself due to the heat generated by the friction and flow of metal by the stirring action. However, the solutionizing temperature generated during FSW at the stir zone dissolves the precipitates of the age hardenable aluminium alloys like AA7075. Since the presence of precipitates decides the strength of the weld joints, the as welded FSW joints exhibits poor mechanical properties. Hence in this investigation, an attempt was made to improve the mechanical and metallurgical properties of friction stir welded AA 7075 aluminium alloy by means of two different PWHT combinations.

The parent metal used in this investigation was rolled plates of 12 mm thick, high strength aluminium alloy of AA7075 T651 grade. Square butt joints were fabricated using friction stir welding (FSW) process. Post Weld Heat Treatment (PWHT) such as Artificial Aging (AA) and Solution Treatment + Aging (STA) were employed to the joints. Characterisation of weldments were done by microstructure analysis (optical microscope), micro hardness measurement, analyzing the size, distribution and composition of precipitates (transmission electron microscope). Transverse tensile properties, fatigue behaviour, fatigue crack growth behaviour, and fracture toughness of the joints were evaluated and the results were analysed in detail with respect to the effect of PWHT. Very important conclusions obtained from this investigation are listed below.

9.2 Conclusions

(i) Of the two PWHT methods, the solution treatment followed by artificial aging (STA) treatment produced very fine and uniformly distributed precipitates in the weld metal region. Due to solution treatment, all the precipitates are completely dissolved in solid solution and there is no left out precipitates in the matrix. During aging, the precipitates are directly coming out from solid solution and hence they are very fine and uniformly distributed throughout the matrix.

(ii) Very low hardness was recorded in AA joint (90 HV) and the maximum hardness was recorded in STA joints (160 HV). STA treatment is found to be useful to improve the hardness level in TMAZ region of FSW AA7075 aluminium alloy. PWHT procedures are found to be useful to improve the hardness level of weld metal (WM) region of friction stir welded AA7075aluminium alloy.

(iii) Solution treated and aged (STA) joints exhibited very high joint efficiency of 79%; artificially aged (AA) joints showed joint efficiency of 56% and as welded (AW) joints yielded joint efficiency of 70%. The combined effect of fine and uniformly distributed precipitates in the weld region and higher hardness of weld region are responsible for superior tensile properties of STA joints.

(iv) The fatigue strength of STA joint was 100 MPa and the enhancement in fatigue strength value was approximately 14% compared to AW joints. Similarly artificially aged (AA) joints had shown 70 MPa which is 18% lower than AW joint. The superior tensile properties, higher hardness and uniformly distributed finer precipitates are the main reasons for superior fatigue properties of STA joints compared to AA joint and AW joints

(v) The fatigue crack growth exponent of STA joint was 3.10 and the reduction in fatigue crack growth exponent value is approximately 18% compared to AW joints. Similarly artificially aged (AA) joints had shown 4.43 as fatigue crack growth exponent and the decrement is merely a 14.6 % compared to AW joints. (lower the fatigue crack growth exponent and higher will be the fatigue life).

(vi) The fracture toughness value of the STA joint was 26 MPa√m which is 8% higher compared to FSW joints and 23% higher compared to AA joints The superior tensile properties, higher hardness and uniformly distributed finer precipitates are the main reasons for higher fracture toughness value of STA joints compared to AA joint and FSW joints.

9.3 Suggestion for Further Research

The present investigation on friction stir welding of age hardenable aluminium alloy AA7075 has given some important information related to the effect of post weld heat treatment on mechanical and microstructure 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) The fatigue crack growth and fracture toughness to be evaluated for TMAZ and HAZ of the joints by placing the notch in the respective regions.

(ii) The proposed frame work of the present investigation can be further refined, modified and applied to sub-zero heat treatment methods.

(iii) The properties of the FSW joints can be improved by techniques such as under water FSW, and the present investigation scheme may be applied.