CHAPTER 7

CONCLUSIONS

7.1 INTRODUCTION

This chapter presents the major conclusions arrived at from the present research work which involved the fabrication of AA6061/ZrB$_2$ MMC using in-situ method and application of relatively new welding process, FSW to join the same. The scope for future work to expand the present work is also provided at the end of the chapter.

7.2 THESIS CONTRIBUTIONS

AA6061 alloy reinforced with ZrB$_2$ metal matrix composites were successfully fabricated by in-situ reaction of K$_2$ZrF$_6$ and KBF$_4$. Optical and SEM micrographs and XRD patterns clearly revealed the presence of ZrB$_2$ particles. No intermediate phases were formed due to proper selection of stoichiometric ratio of inorganic salts. ZrB$_2$ particles were found to have uniform distribution in the matrix, spherical in shape, good bonding and clear interface. The maximum content of ZrB$_2$ was limited to 10 wt.% due to the formation of excessive slag. Increased content of ZrB$_2$ particles in matrix alloy resulted in higher hardness and ultimate tensile strength of the composites. Addition of 10 wt.% ZrB$_2$ particles increased the hardness from 45 VHN to 65 VHN and UTS from 190 MPa to 253 MPa respectively. ZrB$_2$ reduced the elongation and corrosion resistance of the matrix alloy. Addition of 10 wt.% ZrB$_2$ particles reduced the elongation from 8.5 % to 5.2 % and increased corrosion rate from 0.02 mm/year to 0.18 mm/year respectively.

The dry sliding wear behavior of AA6061/ZrB$_2$ MMC was evaluated using a Pin-on-disc apparatus. A mathematical model was developed to predict the wear
rate of AA6061/ZrB\textsubscript{2} MMC. The in-situ formed ZrB\textsubscript{2} particles improved the wear resistance of the composite. The wear rate of AA6061/10 wt.% ZrB\textsubscript{2} MMC and AA6061 were 335\times10^{-5} \text{mm}^3/\text{m} and 720\times10^{-5} \text{mm}^3/\text{m} respectively. The dry sliding wear behavior of AA6061/ZrB\textsubscript{2} MMC was found to be non linear. The wear parameters sliding velocity, sliding distance and normal load were proportional to the wear rate. The worn surfaces revealed an increase in number of cracks when sliding velocity, sliding distance and normal load were increased. The worn surface of AA6061/ZrB\textsubscript{2} MMC showed that the wear mode was abrasive.

Friction stir welding was successfully applied to join AA6061/ZrB\textsubscript{2} MMC composite. The FSW window for obtaining sound weldment was observed to be narrow. Mathematical models were developed to predict the tensile and dry sliding wear behavior of butt joints. Mathematical models were optimized using generalized reduced gradient method. Each process parameter independently and significantly influenced the tensile and dry sliding wear behavior of butt joints. The joint fabricated using the optimized FSW parameters (rotational speed of 1155 rpm, welding speed of 49 mm/min, axial force of 6 kN and zirconium boride of 10 wt.%) exhibited highest UTS.

Friction stir welded AA6061/ZrB\textsubscript{2} MMC joint exhibited the presence of different zones such as weld zone, thermo mechanically affected zone and heat affected zone. The transition zone was limited to TMAZ. The width of the transition zone reduced with increased content of ZrB\textsubscript{2} particles. The weld zone was characterized with a homogeneous distribution of ZrB\textsubscript{2} particles. ZrB\textsubscript{2} particles were fragmented subsequent to FSW due to the stirring action of the tool. FSW increased the hardness of weld zone than that of the parent composite due to particle fragmentation. The welded joints showed reduced ductile behavior and the wear mode changed from adhesive to abrasive with increased content of ZrB\textsubscript{2} particles. PWHT improved the hardness across the welded joint and enhanced the joint strength from 253 MPa to 310 MPa.

7.3 **SCOPE FOR FUTURE WORK**
• The in-situ reaction can be explored to sufficient depth to control the excessive formation of slag so that the content of ZrB₂ particles can be increased above 10 wt.%.

• The effect of in-situ parameters such reaction temperature, reaction rate, holding time and cooling rate on particle size can be studied.

• The effect of stoichiometric ratio of organic salts on the formation of intermetallic compounds can be studied.

• Different coatings can be identified to improve the corrosion resistance of the composites.

• Joint properties of FS welded AA6061/ZrB₂ MMC can be compared with similar joints made by other solid state and fusion welding processes.

• Research on other secondary processing such as cutting, forming and machining of AA6061/ZrB₂ MMC can be carried out.

• Dissimilar FSW of AA6061/ZrB₂ MMC and AA6061 can be carried out.