Conclusions

FSW is revolutionary solid state welding technique, progressing rapidly as a manufacturing and assembly process for joining aluminium alloys, hard materials such as steel and other important engineering alloys. This process is beginning to provide breakthrough reductions in the manufacturing cost of both aerospace and non-aerospace systems. The rapid implementation of FSW has been enabling by the ability to utilise processing equipment based on traditional machine tool technology and the capability to provide traditional metallurgical joint with “parent” metal soundness. For the successful implementation of FSW, there is much room for improvement particularly in the area of metallurgical understanding of process which results in various microstructural features and corrosion behaviour. This thesis presents experimental investigation of friction stir welding of similar and dissimilar aluminium alloys AA6082 and AA6061. The mechanical and metallurgical characterization for friction stir welded AA6082 and AA6061 were presented for different combinations of rotational speeds, welding speeds pin profiles and axial force. The correlation of mechanical properties and microstructure with the process parameters for the optimization of process is a unique approach which has been the main motivation behind this project. From the present experimental investigation the following conclusions are derived:

- Base metal AA 6082-T6 was found to exhibit the best characteristics for Friction Stir Welding.
- Tool material found to withstand for 6082-T6 and 60661-T6 base metal without tool breakage and it is also found that this tool material is amenable for friction stir welding with different tool pin profiles.
- It is found that tapered threaded screw pin profile facilitates the stirring action from the tip to the collar and avoid the turbulence compared to three flutes pin profile, there by this tool profile is effective for getting defect free welds in AA6082-O.
- For the given set of parameters, the optimum parameters were found to be tool rotation speed as 1230 rpm, welding speed as 390mm/min and axial force as 8kN.
- The tool rotation speed is the dominant parameter for tensile strength followed by the welding speed. Increase in rotational speed has resulted in increase of tensile
strength, % elongation and welded joint efficiency. Primary reason is that higher the speed, higher will be the deformation and heat generation in the weld. This will result in finer grain structures, because of which tensile strength is increases. The interaction between tool rotation speed and welding speed has more influence comparing with other interactions on tensile strength of welded joints.

- With the increase in welding speed above critical value, tensile strength and % elongation decreases due to low heat input at constant downward pressure and tool rotation speed.
- Axial force shows negligible effect on tensile strength compared to other process parameters. It has been observed that axial force is a quality indicator for friction stir welds. An insufficient axial force indicates a lack of shoulder pressure and can indicate a lack of containment of the surface flash and/or voids
- The effect of tool pin profile and process parameters on the appearance of the weld is presented. The results indicate that the shape of the pin has a significant effect on the joint structure and the mechanical properties.
- It is also found that amount of heat input plays an important role on the elongation properties of the welded samples. Increased heat input results in higher percentage of elongation of the friction stir welded samples. The sample welded with a tool rotation speed of 1650 rpm, welding speed of 50 mm/min and an axial force of 12KN exhibits the maximum elongation, while the sample welded with 1650 rpm, 60mm/min and 12KN yielded minimum elongation.
- As $E_{corr}$ value decreases, the corrosion resistance of sample decreases. With the increase in $E_{corr}$ value corrosion resistance increases. All sample show passivation after longer time of exposure to corrosion media. In few FSW sample corrosion rate is low, so grain boundaries are observed due to etching effect. For the same welding speed the hexagonal pin profile shows good corrosion resistance than triangular pin profile.
- The microhardness (HV) appears uniform for the plates joined using hexagonal pin profile.
- The fractography observations of the tensile-tested specimens revealed that the failure is in all cases governed by coalescence of microvoids.
The friction stir welds made on 6082-T6 aluminium alloy of 5mm thickness were found to have adequate ductility under optimized weld conditions with hexagonal pin tool profile.

It is suggested that the hexagonal pin profiled tool with plate to plate, pipe to pipe and shell joints with either longitudinal or circumferential type could effectively be used in industrial applications for 6082-T6 aluminium alloy.

**Suggestions for Future Work**

The present research work has provided a fundamental understanding of FSW process & feasibility of incorporating this technology with existing resources to weld aluminium alloys in the abutting configuration and characterized mechanically & metallurgically, which covered tensile testing and microstructural development, as well as corrosion behaviour in aluminium alloys 6xxx welds. Future work is still required to quantify the FSW process with variable weld process parameters that would concentrate on the following aspects:

- To study the effects of temperature distribution on the mechanical and metallurgical properties AA 6082T6 / AA6061T6 joints
- Other important developments that need attention will be to weld at higher feed-rates.
- To make the process to be operated at lower Z-Forces and without any backing plates it will make many other weld configurations possible.
- Improvement in tool design will always be an advantage since it plays an important role during weld quality. A new tool that can weld at lower forces, achieve better surface finishes and improve the tensile strength of the joint, are to be considered.
- Analyze the residual stress distribution for various welding parameters in order to determine how residual stresses change with welding parameters.
- Further investigations on the forces generated during single and multiple passes for different alloys at different conditions and for different process parameters might be very beneficial.
- Further studies may be done, considering most of the welding parameters, on a wider range of values on materials like Copper, Titanium, and Magnesium by using friction stir welding is another area of interest.