1.1 General Introduction

Modern aerospace concepts demand reductions in both the weight as well as cost of production of materials. Under such conditions, welding processes have proven most attractive, and programs have been set up to study their potential [1]. Car manufacturers and shipyards are also evaluating new production methods. Increasing operating expenses are driving manufacturers to reduce weight in many manufacturing applications, particularly in aerospace sector. The goal is to reduce the costs associated with manufacturing techniques to result in considerable cost and weight savings by reducing riveted / fastened joints and part count. One way of achieving this goal is by utilising a novel welding technology known as Friction Stir Welding (FSW). Friction stir welding is a solid-state joining process developed and patented by the The Welding Institute (TWI) in 1991 by Thomas et al and it is emerged as a welding technique to be used in high strength alloys (2xxx, 6xxx, 7xxx and 8xxx series) for aerospace, automotive and marine applications that were difficult to join with conventional techniques[2,3]. This technique is attractive for joining high strength aluminium alloys since there is far lower heat input during the process compared with conventional welding methods such as TIG or MIG. This solid state process leads to low distortion in long welds, excellent mechanical properties in the weld and heat-affected zone, no fumes or spatters, low shrinkage, as well as being energy efficient. Furthermore, other cost reductions are realized in that the process uses a non-consumable welding tool. The process was developed initially for aluminium alloys, but since then FSW was found suitable for joining a large number of materials.

In FSW a non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. The tool serves two primary functions: (a) heating of work piece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the work piece and plastic deformation of work piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in ‘solid state’. During FSW process, the material undergoes
intense plastic deformation at elevated temperature, resulting in generation of fine and equiaxed recrystallized grains. The fine microstructure in friction stir welds produces good mechanical properties.

The aluminium alloys are using in the aero-spatial industry from the beginning of the last century. In aerospace industry the basic aluminium alloys are 2xxx and 7xxx but, presently, the 6xxx aluminium alloys present a particular interest not only for researchers but also for the experts from industries. The 6xxx alloys have many advantages such as medium resistance, plasticity, good welding characteristics, corrosion resistance and a low cost. Besides, applying thermal treatments, the 6xxx aluminium alloys are used in many applications (the exterior of the planes fuselages, panels and even in automotive shock absorbers), in the detriment of the 2xxx and 7xxx alloys [4]. In present research work an attempt is made to study the effect of various FSW process parameters on the quality of the FSW joint of 6xxx aluminium alloys.

1.2. Research Aim and Objectives
The aim of this research work was to acquire first hand technical competency and fundamental technology know how of this technique. The study investigates the feasibility of incorporating this technology with existing resources to weld aluminium alloys in the abutting configuration and characterise the optimum operating parameters while establishing sound mechanical integrity of the welded joint with a special focus on 6xxx series aluminium alloys with minimum thickness of 5mm. The objective of this research was to characterize the mechanical properties of friction stir welded joints and study the microstructure of the parent metal and the weld nugget evolved during the friction stir welding of similar and dissimilar alloys of aluminum. Aluminum alloys AA6082 and AA6061 were considered for present investigation. The mechanical properties such as ultimate tensile strength, yield strength and ductility and also weld joint efficiency have been measured and an effort made to find out a relation between the process variables and properties of the weld. The tensile fractured surfaces were analyzed by using scanning electron microscopy. To have an insight into the mechanical properties, microhardness of FSW samples were taken. Optical microscopy has been carried out in order to investigate the microstructures of the friction stir welded material and base alloys. In heat treatable alloys, the precipitates only impart strength to the alloy. Dissolution of these strengthening precipitates impairs the mechanical
properties. The corrosion behaviour of base alloy and welded joints were carried out in 3.5% NaCl solution. Corrosion current and corrosion potential were determined using potentiostatic polarization measurements.

1.3 Chapter Abstracts
The present research work has been divided into 8 chapters. The literature review with respect to present work is summarized from chapter 2 to 5. The research methodology, result and discussion and conclusions are discussed in chapter 6 to 8.

Chapter 2 describes the historical background and innovation of Friction Stir Welding process and the process steps involved in creating a solid state joint. Firstly the material flow and process requirements are explained, this includes details of the complex flow of plasticised material around the FSW tool, machine variables and considerations for the materials to be joined. Next the applications of FSW in different geometries, in aluminum alloys and other materials and in industries are discussed. Finally the advantages and limitation of the process are listed followed by some examples of different FSW tool setups and comparison with fusion welding.

Chapter 3 presents the details of tool technology of the Friction Stir Welding and its fundamental role in producing the sound welded joint. Some different aspects of the tool and its design are described and their functionality in terms of the resulting welds is also included. The weld variables are explained with tool material, weld depth and weld material.

Chapter 4 summarizes the microstructural development due of Friction Stir Welding. Information has given about the key processes and mechanisms at work within the material during and after the FSW process has taken place. The evolution and final resulting microstructures of FSW welds in aluminium alloys are explained along with their differing material properties.

Chapter 5 deals with corrosion of aluminium, corrosion mechanism in aluminium, influence of alloying element on corrosion resistance and corrosion behavior of friction stir welded aluminium alloys.

Chapter 6 discusses the experimental research methodology used. It gives the detailed description of the experimental work carried out that includes from fabrication of FSW joints to the mechanical and metallurgical analysis.
Chapter 7 illustrates the results and discussions. Detailed mechanical & metallurgical characterization of friction stir welded aluminium alloys AA6082 & AA6061 is presented.

Chapter 8 summarizes the conclusions of this work and outlines possible for future work. The appendix contains the peer-reviewed papers that were published to date as a result of this work.