MATERIAL TRANSPORT DURING FRICTION STIR WELDING

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Dedicated to my parents who

gave me all their love and support throughout my college education.

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by

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ABSTRACT

Friction Stir Welding (FSW), an innovative and relatively new technique for joining metals, has caught the attention of the aerospace and automotive industry. The Welding Institute in England invented this joining technique in 1991, and in spite of a conservative welding community, this technique has been put into use rather quickly. The main attraction in this process is the ability to join metals similar or dissimilar without reaching a melting temperature. This is an advantage since all weld defects arising from melting and solidification are eliminated. Also since no melting is required, using this technique requires less heat input compared to many other welding techniques. Many studies in friction stir welding have been developed to study the mechanical properties, microstructure, and corrosion properties of these welds. But only a few have been devoted to the study of material flow phenomena occurring in this process. This work will consist of studying the metal flow phenomena and relate it to the properties as well as to the quality of welds when welding dissimilar aluminum alloys.

Material flow characterization was studied by placing a thin 99.99% pure copper strip (0.0045 in. thick, 0.25 in. high) in between two 0.25 in. thick 6061-T6 aluminum alloy plates and friction stir welding them together. Also aluminum alloys 2195-T6 and 6061-T6 were friction stir welded together. Weld samples were then cut into various sections and analyzed using light metallography (LM), Vickers microhardness testing, and by means of energy dispersive spectroscopy (EDS) scans.

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Chapter 1

INTRODUCTION

Most of the widely used welding techniques to join metals involve the creation of chemical bonds in the molten state in order to achieve actual mass transport by interdifussion across an interface. Mass transport is achieved by applying a certain temperature and pressure in order for the metal to melt and flow across a joint. Fusion welding is an example of the many techniques, which use melting as the driving force to join two pieces of metal together.

Although these techniques are widely used, there are many disadvantages due to melting and solidification. Problems arising from melting and solidification can deteriorate the mechanical properties of a joint, such as fatigue strength, tensile strength and ductility. These problems include microsegregation, gas inclusions or porosity, hot cracking, oxidation, formation of intermetallic compounds, and other microstructural changes, such as subgrain structure refinement due to fast quenching rates, which can be faster than in most castings. Another disadvantage in fusion welding is the high heat input, which can be a problem in welding dissimilar metals due to the difference in thermal expansion, and thermal conductivity between a given dissimilar metal system to be welded.

On the other hand, friction stir welding (FSW) is a solid state joining process where melting and solidification do not occur. Because melting and solidification does not occur, this technique eliminates problems arising in fusion welding where melting is involved. This welding process was invented in 1991 by The Welding Institute [4], and

has been exploited by the aerospace, automotive, and ship building industries ever since. This process has captivated the attention of industry, specially the aerospace industry for its ability to join alloys that are difficult to weld, such as the new generation of lightweight aluminum-copper-lithium alloys. In addition to this, FSW is a cheaper process due to the relatively low heat input, and the mechanical properties of the joint at the weld zone are far superior to those welded by conventional means. Table 1.1 shows a list of the advantages and disadvantages in FSW. This table shows how the disadvantages in FSW are minimal in comparison to the advantages. Intensive research is being conducted to further minimize these disadvantages in friction stir welding. An example, in which a disadvantage was erased from this list, is the elimination of the keyhole or crater at the end of each weld, which forced the FSW process to have additional equipment and material. This problem was eliminated by the development of a retractable pin-tool (RPT). The development of this RPT was initiated at NASA Marshall Space Flight Center (NMSF) in 1993 and it was patented under US Patent Number 5,893,507 [3]. This RPT varies its length automatically and eliminates the keyhole by slowly retracting completely in an area in which the tool has already welded material. The ability to automatically change its length also allows easy FSW of tapered thickness weld joints.

The main emphasis in this work will be the study of material transport during this solid state joining process. In chapter two the main mechanisms accommodating the FSW process will be discussed in addition to recent research work done in material transport phenomena. In chapter 3 the experimental procedures will explain how material transport analysis was approached in this particular research. Chapter four will give results and discussions, which clarify the flow of metal by using a faying surface tracer

Table 1.1 Table showing the advantages and disadvantages in friction stir welding.

ADVANTAGES OF FRICTION STIR WELDING
➢ Non-consumable tool ➢ One tool can weld up to 1000m of weld length in aluminum ➢ alloys. ➢ Low distortion ➢ No fumes ➢ No porosity ➢ Energy efficient ➢ No welder certification ➢ No gas shielding ➢ No filler wire ➢ Low Shrinkage ➢ Can operate in all positions ➢ Excellent mechanical properties ➢ No surface preparation ➢ Ability to weld dissimilar alloys and metals
DISSADVANTAGES OF FRICTION STIR WELDING
➢ Welding speeds are currently slow ➢ Work pieces must be rigidly clamped ➢ A backing anvil plate is usually required

and a frozen nib in place during welding. This will show that material is transported by two processes. Finally chapter five will summarize and conclude this study.