Study of Al Alloys Weldability for Higher Strength and Low Heat Affected Zone Using Fusion Welding and Friction Stir Welding

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Abstract

The welding joints formed from the method of advance welding technologies shows higher mechanical and thermal strength as compared to conventional welding technology. This review article discuss the basic principles of advance welding techniques like friction stir welding and laser submerged arc welding with solid state lasers and their advantages over the conventional welding technology. The basic study includes the terminology, process of conduction, thermal, mechanical strength and defects generated. Aluminum is taken as the base material because of its utilization in many industries like aerospace and shipping industry .The comparison has been done on the basis of strength of joints formed, thermal conditions, defects and their effect on environment. The applications of advance welding technology are also taken into consideration for the comparison. It provides us the view of modern practices done in the field of advance welding technology and also explains the future research area and modification.

Keywords: **Thermal, Convectional Welding, Advanced Welding, Friction stir welding.**

Introduction

Welding is defined as the metallurgical joining of two metal pieces together to produce essentially a single piece of metal. It is extensively used in the fabrication work in which metal plates, rolled steel sections, casting of ferrous materials are joined together. Today the application of advance welding technology is seen in many sectors including aerospace automotive, railways, ship industry, heat exchangers etc. Friction stir welding is one of the major advanced technologies used which grasp the attention of many industries. The joints formed by advance welding technology are stronger and free from defects as compared to joints formed from conventional process.

Friction stir welding process was invented by TWI in 1991. Since its invention the process has received worldwide attention. It is an effective process for welding Al alloys, brass, copper and low melting temperature materials. The study has been done in three phases. First phase included the practical welding technique of 6000 series of Al. Second phase examined the 2000 and 5000 series for aerospace and ship Al alloys. Third phase includes the data for further industrialization and research.

Friction Stir Welding

In FSW, a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the weld joint between two pieces of sheet or plate material that are to be welded together. The parts must be clamped from being forced apart or in any other way moved out of position. Frictional heat is generated between the wear resistant welding tool and the material of the work pieces. This heat causes the work pieces to soften without reaching the melting point and allows the tool to traverse along the weld line. The resultant plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged together by the intimate contact of the tool shoulder and the pin profile. This leaves a solid-phase bond between the two pieces. The process can be regarded as a solid- phase keyhole welding technique since a hole to accommodate the probe is generated, then moved along the weld during the welding sequence.

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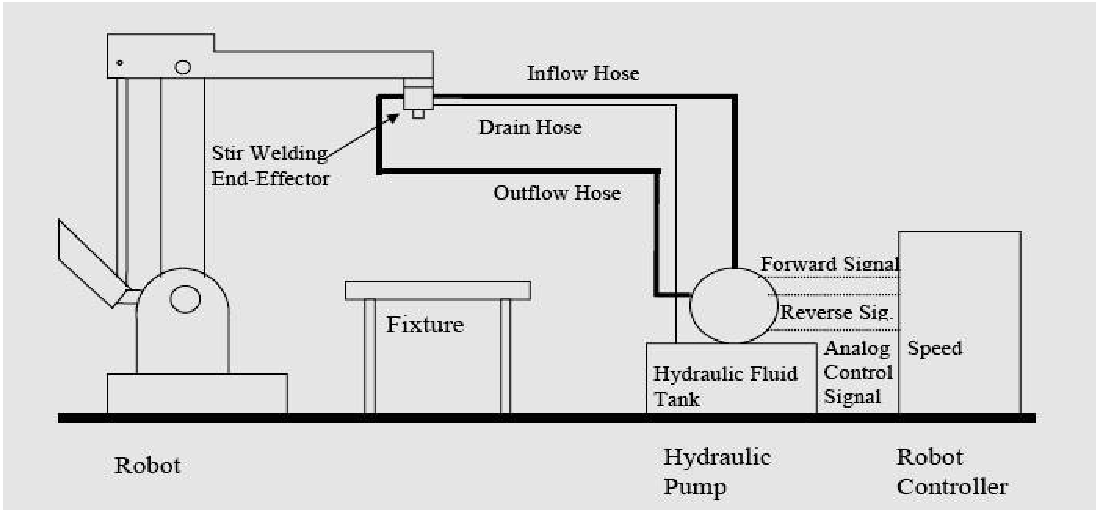

Figure 1.Friction Stir welding robotics setup for automobile industry

The process originally was limited to low melting temperature materials because initial tool materials could not hold up to the stress of stirring. This problem was solved recently with the introduction of new tool material technologies such as polycrystalline cubic boron nitride (PCBN), tungsten rhenium, and ceramics.

The use of a liquid cooled tool holder and telemetry system has further refined the process and capability. Tool materials required for FSW of high melting temperature materials need high hot hardness for abrasion resistance, along with chemical stability and adequate toughness at high temperature. Material developments are advancing rapidly in different tool materials, each material offering specific advantages for different applications.

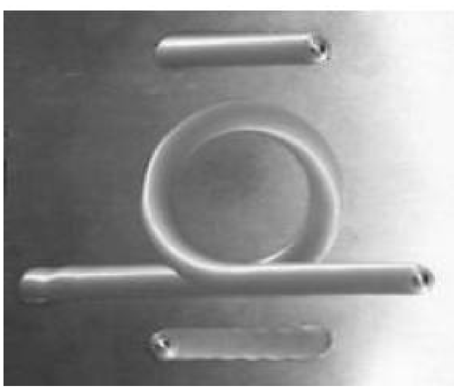

Figure 2.2 D and 3 D robotics FSW

Aluminum Alloys

The main scope of this article is study of Al alloys welding. So classification of Al alloys is important. The International Alloy Designation System is the most widely accepted naming scheme for wrought alloys. Each alloy is given a four- digit number, where the first digit indicates the major alloying elements.

S.N.	Al Series	Application
1	1000	Pure aluminum with minimum 99% aluminum content by weight and can be work hardened.
2	2000	Alloyed with copper, higher strengths comparable to steel. Formerly referred to as duralumin, Most common aerospace alloys, but were susceptible to stress corrosion cracking and are increasingly replaced by 7000 series in new designs.
3	3000	Alloyed with manganese, and can be work hardened.
4	4000	Alloyed with silicon. They are also known as silumin.
5	5000	Alloyed with magnesium.
6	6000	Alloyed with magnesium and silicon, are easy to machine, and can be precipitation hardened, but not to the high strengths that 2000 and 7000 can reach.
7	7000	Alloyed with zinc, and can be precipitation hardened to the highest strengths of any aluminum alloy.
8	8000	Aluminum- lithium alloys

Table 1.Al alloys classification

Welding of Al alloys using Fusion Welding (Conventional Technique)

The basic purpose of fusion welding is to provide a means to joint two pieces by raising the temperature to the fusion point so that they form a pool of molten metal at the ends to be joined and if needed filler material is used which nearly has the same composition as that of the parent pieces. Then the molten pool is allowed to solidify and it forms the weld. Welding of aluminum is done through many fusion welding processes like shielded metal arc welding (SMAW), Gas metal arc welding (GMAW) and Gas tungsten arc welding (GTAW). Amount of heat input plays important role in the strength of the joints. The mechanical properties were highly affected by the zones find in the structure of welded aluminum.

Different heat zones found during the welding of aluminum are-

Fusion zone: Melting of material is done and if possible filler material is also introduced. Solidification of the molten pool started.

Transition zone: In this zone, diffusion of alloying elements along the grain boundaries started.

Heat effected zone: Thermally controlled solid state processes (segregation effects, precipitation processes, recovery and recrystallization processes)

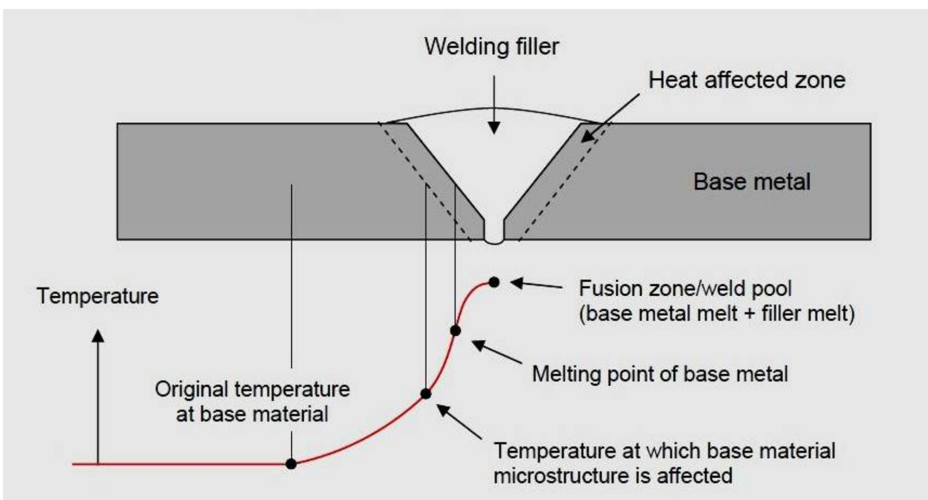

Figure 3.Formation of Heat Affected Zones

In fusion welding process HAZ is one of the prime concerns of welding. As the area of HAZ increases, the strength of welded joint decreases. In fusion welding process the material is subjected to heating cycle. In one complete cycle of heating the heating and cooling takes place. In this thermal process of heat transfer the material is subjected to tensile and compressive stresses. Due to this stresses variation the overall shear strength property of material decreases. So to fulfill the present requirement advanced welding technology is required.

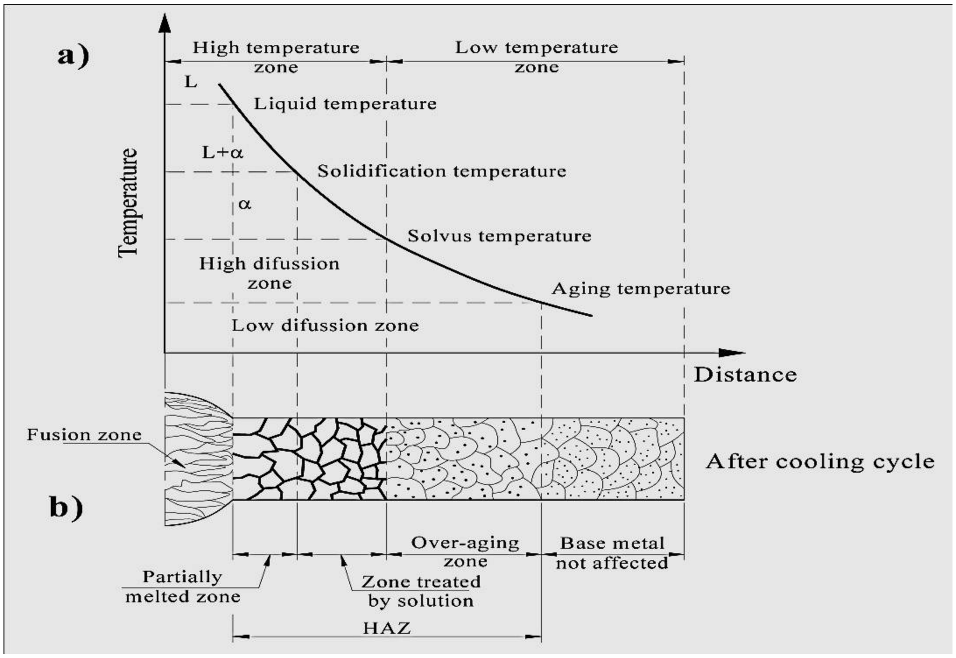

Figure 4.HAZ and Temperature variation

Advanced Welding Technology for Al Alloys

Conventional process of welding includes many disadvantages which reduces the strength of welded joints. With the increasing demand of the complex structures used in various industry it is very difficult to prepare the stronger welded joints with the help of conventional welding process. To overcome from the problems of conventional process advance welding techniques are used. Welds with the highest strength can be achieved by FSW .The crushing, stirring and forging action of the FSW tool produces the weld with the finer microstructure than the parent material. The benefits include joining of materials which are difficult for fusion welding (2000 and 7000 aluminum alloys).

Welding of Al Alloys Using FSW

Friction stir welding is a viable process for joining aluminum alloys that are difficult to fusion weld. During welding, the metals to be joined and the tool are moved relative to each other such that the tool tracks the weld interface. The rotating tool provides a continual hot working action, plasticizing metal within a narrow zone while transporting metal from the leading face of the pin to the trailing edge. Friction stir welding (FSW) is a solid- state joining process with the weld completed without creation of liquid metal.

A moving column of stirred hot metal consumes the weld interface, disrupting and dispersing aluminum surface oxides. The weld cools, not solidifies, as the tool passes, forming a defect- free weld. The process not only generates a heat affected zone (HAZ), but within this HAZ near the weld nugget a thermo mechanically affected zone (TMAZ) is also produced, illustrated schematically in fig. 5.

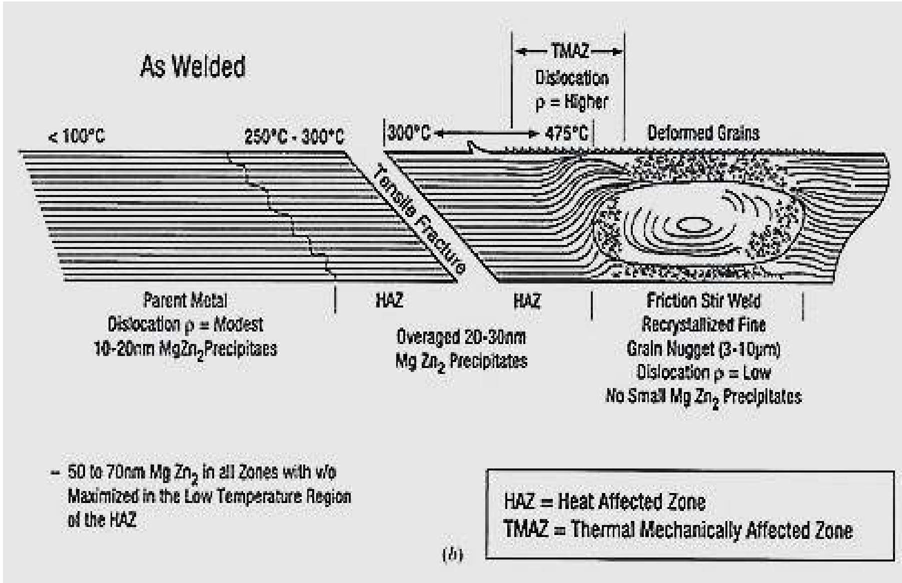

Figure 5.Heat affected zone in FSW process for Al alloys

The weld nugget corresponds to the tool probe that penetrates through the sheet thickness, whereas the broader surface deformation and subsequent surface recrystallization are associated with the rotating tool shoulder. All regions are considered part of the weld microstructure; however, the surface deformation caused by the tool shoulder is relatively shallow in depth. Being a solid- state process, friction stir welding has the potential to avoid significant changes in microstructure and mechanical properties that usually accompany fusion welds. The alloy 7075-T65l Al plate with nominal composition in wtpct 5.6Zn-2.5Mg-1.6Cu-0.23Cr-bal Al that was butt welded using the friction stir technique. All welds were full penetration with the rotating tool probe sufficiently close to the bottom of the plate to include the entire butt joint within the worked and recrystallized microstructure.

Conclusion

The FSW process offers significant advantages as compared with fusion joining processes for aluminum, several of which are particularly important to the automotive industry. These advantages include improved joint efficiency (tensile strength), improved fatigue life, no need for consumables, and improved process robustness. The invention of FSW process has revolutionized the entire welding industry. Its innumerable advantages over the conventional fusion welding technology offer tremendous opportunities for its future industrial applications in many sectors. Moreover there is lot of scope for carrying out further R&D on this promising technology. Since, the properties of the FSW weld depends significantly on the FSW process parameters, so it is very important to select their values with the utmost care and further work is recommended to be done for optimizing these parameters for various combinations of materials to be joined. From the literature it is learnt that after the successful implementation of the FSW process to the low density materials such as precipitation hardened aluminum alloys and magnesium alloy, FSW of high strength structural materials such as steel and titanium has attracted the research interests of the researchers worldwide. Selection of the suitable tool material, reduction of load on the FSW machine, reduction of tool wear and improvements in the strength of the FSW joint represents some of the major challenges in this current research field.

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