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RESEARCHARTICLE

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IMPACT ON EXTRUDED CAST 5251 Al-B_4C SURFACE COMPOSITE FABRICATED USING FSP

GURDEEP SINGH
Asstt. Professor, Mechanical Engineering Department, CGC Landran

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ABSTRACT

Friction stir processing is the emerging metal working technique. It is the special process for fabrication, processing and synthesis of work material. This joining technique is energy efficient, environment friendly and flexible. FSP has been studied and applied to reduce grain size for super plastic behaviour in Al alloys. Aluminium 5251 alloys have light weight, excellent resistance to corrosion and high strength to weight ratio. But its low hardness and strength makes it less acceptable in industries. By using FSP Al 5251 alloys matrix composites reinforced with ceramic material such as BrC of proper composition, its microstructure, hardness and strength will be improved. The strength of Al alloys can further be improved by varying the feed and speed of tool in FSP for various future applications.

Keywords— Al 5251 alloy, FSP, Super plasticity in Al

I. INTRODUCTION

1.1 Introduction to FSP

Friction stir processing is the emerging metal working technique. It is based on the principle of friction stir welding (a solid state welding process) for localized modification, improved mechanical properties and homogenization. In this, a non-consumable high speed rotating tool with shoulder and tool pin comes in contact with work material. With the help of axial force, a frictional heat is induced and plastic deformation on the surface of work material has to be modified. The parameters microstructure and mechanical properties on working zone can be controlled with the optimization of tool design and FSP parameters. FSP is the special process for fabrication, processing and synthesis of work material.

FSP has been studied and applied to reduce grain size for superplastic behaviour in aluminium alloys. In this process, which is clear from figure, a non consumable tool has been used to perform the operation. It is primarily two stage process.

I. Plunge welding stage
II. Linear welding stage

In plunge welding stage, the rotating tool penetrates the plate to be welded.

In linear welding stage the tool move along the joint line.

The high speed rotating tool produce energy due to friction between tool and workpiece and plastic deformation in the surface of workpiece which has to be modified. These both energies heat the plates, enabling their joining at temperature lower than the melting point of the workpiece. Hence due to stirring action of tool pin, pressure and tool shoulder a defect free, recrystallized, fine grained microstructure has produced

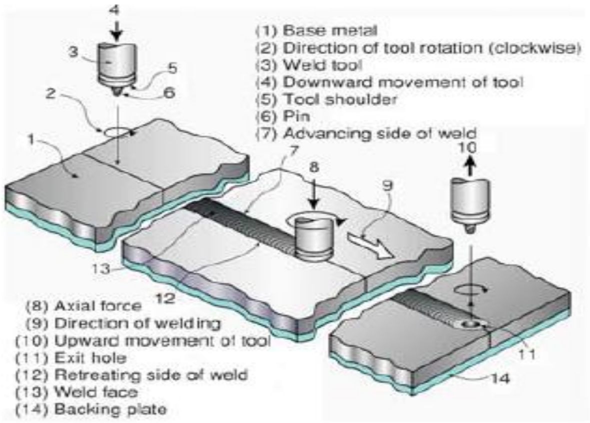


Fig. 1.1Process of FSP

Source: D.M. Veljic, "Heat Generation during Plunge Stage in Friction Stir Welding"

1.2 Heat Zones

There are four zones:

- Affected Material
- Heat Affected Zone (HAZ)
- Thermo Mechanically Affected Zone (TMAZ)
- Stir Zone

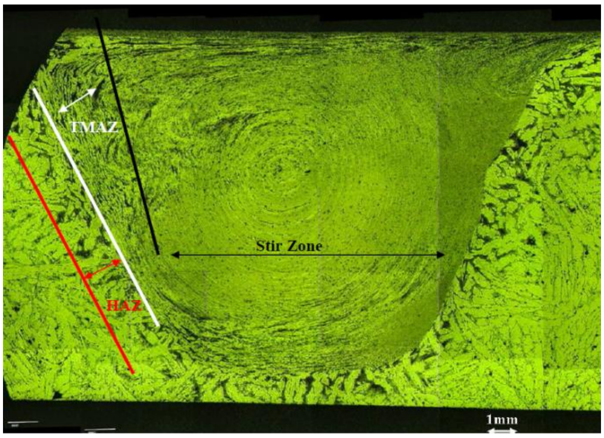


Fig. 1.2Different zones of FSP

Source: R A Williams, "A Microstructural And Mechanical Property Correlation Of Friction Stir Processed Nickel Aluminum Bronze"

Affected Material or Parent Metal is material remote from the weld that has not been deformed and that, although it may have experienced a thermal cycle from the weld, is not affected by the heat in terms of microstructures or mechanical properties.

HAZ lies closer to weld- center; the material has experienced a thermal cycle that has modified the microstructure and mechanical properties. However, there is no plastic deformation occurring in this area.

TMAZ region the tool has plastically deformed the material, and the heat from the process will have exerted some influence of material.

Stir Zone previously occupied by the tool pin. In this zone large volumes of material are processed.

1.3 Various Tool Materials

In FSP tool steel is commonly used as a tool material. The reason for this is that aluminium alloys are easily friction stirred with tool steels. The other advantages of tool steel are:

Easy availability, machinability, low cost and established material characteristics.

1.4 Other Tool Materials

- H13 tool steel
- Pure tungsten
- Sintered TiC:Ni:W (2:1:1)
- Hipped TiC:Ni:Mo (3:2:1) etc

1.5 Applications of FSP

- To fabricate surface composites
- To refine microstructure of cast light alloys
- To produce fine-grain microstructure, which exhibits superplasticity

1.6 Advantages of FSP

- Improved mechanical property (tensile and fatigue)
- Improved process robustness
- Less health and environmental issues
- Operating cost advantages

1.7.1 MATERIAL

Aluminium 5251 alloy will be used on FSP because of the following reasons:

- Corrosion resistant: 5251 Aluminium sheets are excellent corrosion resistant. It can be easily used in normal, industrial and marine environment conditions without any problem.

- Anodising: Grade 5251 has very good anodising properties for both decorative and technical equirements.
- Good surface finishing
- Good welding quality. Ideal for welding fabrication.
- Excellent aesthetic look of the product.

Nominal Composition Percentage

Si = 0.40, Fe = 0.50, Cu = 0.15, Mn = 0.10 to 0.50, Mg = 1.70 to 2.40, Cr = 0.15, Zn = 0.15, Ti = 0.15, Al = rest.

Reinforced Particles

Various reinforcing particles are used to improve the properties of the materials. These are Al_2O_3, TiB, ZrB, TiC, B_4C, SiC etc.

Boron carbide has many attractive properties such as high hardness [Vicker hardness (38GPa)], low specific gravity, high elastic modules, value (460 GPa) and neutron absorption. Boron carbide improve both strength and wear resistance of the composite.

II. RELATED STUDY

In the past few years, various experiments have been conducted on AA6061 Al alloy. K. Elangovan experimented on five different tool pin profiles. The different tool pin profiles used are straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square. These pin profiles are used to fabricate the joints at three axial forces – 6 kN, 7 kN and 8 kN. He concluded that the combination of 7 kN axial force on square pin profile tool is the best. It produces defect free good quality FSP region.

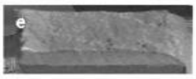
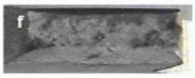
Axial Force (kN)	Fracture surface	Location of fracture	Fracture surface appearance	Orientation of defects
6		In between FSP and HAZ of the advancing side	Uneven surface with dull grey, fibrous appearance	No defect
7		In between FSP and HAZ of the retreating side	Perfectly flat surface with very bright, fine granular appearance	No defect
8		In between FSP and HAZ of the advancing side	Flat surface with bright, coarse granular appearance	No defect

Fig. 1.3 Experimentation results concluded by K. Elangovan on AA6061 Al alloy

Various experiments have been performed by reinforcing other particles into the Al. One such experiment is done by Adem Kurt. He performed FSP on pure Al. After FSP, mechanical properties of pure Al were found not suitable for industrial purpose. Then he added SiC particles on the surface layer of Al. Then he performed FSP on it. He concluded that the hardness of Al+SiC is improved by three times as compared to pure Al. Moreover, increasing the travelling speed also increases the microhardness of the Al. Also, upon increasing the rotation speed, the hardness of the reinforced material increases significantly.

After performing various experiments on Al alloys it has been analysed that FSP are successfully used for producing ultra fine grain structures in Al as well as in Mg, W alloys and steel. F.C. Liu et al performed an operation on Al – Zn – Mg – Cu alloy and found that superplasticity will be at low temperature of 350 – 540 % will be achieved at 200 – 350 ^{0}C. With the increase of temperature, there will be increased optimum strain rate for maximum elongation. At temperature of 350 ^{0}C, there will be shifting of optimum strain rate to high strain rate of 1 X 10^{-2} s^{-1}. A strain rate sensitivity will be 0.33 – 0.42observed for maximum superplasticity at different temperatures.

For improving the tribological properties of Al alloys, various reinforcement particles (SiC, Gr and Al_2O_3) are uniformly dispersed in the stir zone. DevarajuAruri et al. used 6061 – 76 Al alloy and fabricate with reinforced particles and note down the effect on the wear and mechanical properties with the influence of tool rotation speed. It has been noted that with increase of rotational speed, the microhardness of the material will be decreased

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because of production of high heat that cause matrix softening. By this, wear rate will be increased also. Moreover, microhardness will depend upon the proper and uniform distribution of SiC and Al_2O_3 particles. But these particles will reduce the tensile properties of the material as compared to the base material.

Other experiments are also performed on Al alloys using SiC reinforced particles. M. Puviyaresen et al. used AA6063 Al alloy and disperse micro – size (2µm) SiC particles into it. He noticed that the variation in the groove width of stir zone will also pay an effect on microhardness. With the addition of SiC particles, there is an increase in microhardness about 30% as compared to the base material. Also the SiC particles can flow beyond the thermal mechanical affected zone (TMAZ) under the shoulder.

Other reinforced particles are also used to increase the hardness of the Al alloy as compared to base metal. A Thangarasu et al used the TiC particles. He fabricate the TiC particulate (2 µm) reinforcing Al matrix composite using FSP. After performing the various experiments he concluded that TiC particles are more effective as compared to SiC particles. TiC reinforcing particle increase the hardness of AMC by 45% higher as compared to the matrix alloy.

As it hs been studied that Al alloys have various advantages but it has low hardness and strength. To improve its weakness, various experiments are performed on Al alloy with reinforced particles in the last few years. Dharampal Deepak et al. used the 5083 Al matrix reinforced with SiC particles. Using FSP, SiC particles having homogeneous distribution will lead to increase the hardness of the surface. The wear resistance will also be improved.

Feed rate also has an effect on the micro structure and mechanical properties of the Al alloys. L. KerthiKiyan et al. take the different feed rate viz. 10, 12 and 15 mm/min.

After performing the various experiments, it has been observed that with the increase of feed speed, the impact strength of the material will also be increased. With the increase of hardness and ductility valves, the tensile and yield strength will also be increased.

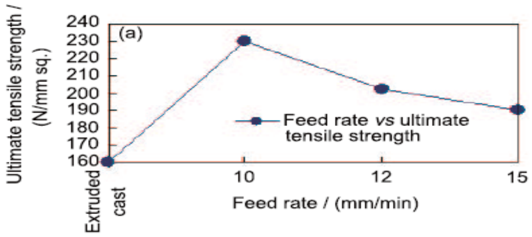

Fig. 1.3

Relationship between feed rate and tensile strength

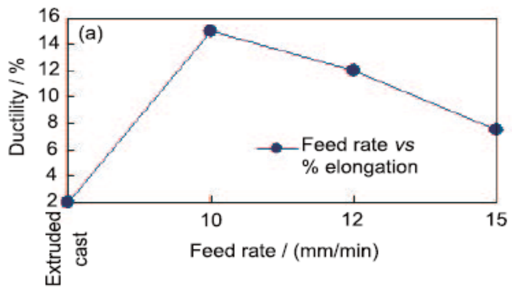

Fig. 1.4

Relationship between feed rate and elongation

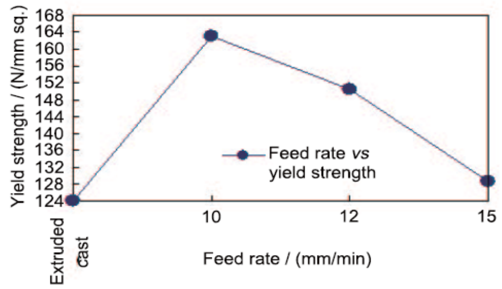

Fig. 1.5

Relationship between feed rate and yield strength

III. CONCLUSION

It has been observed from literature survey that most of the research papers are based on Al alloy because of its low cost and easy availability. But Al 5251 alloy is less used because of low hardness and strength. But it can be improved by FSP. Moreover, there is less work on Al 5251 alloy using FSP. It has various advantages like light weight, high strength to weight ratio and excellent resistance to corrosion so that used in aerospace and automobile industries. Thus, following points are concluded from the literature survey.

- The defect present in cast aluminium alloys are eliminated on processing the alloy by FSP process.
- Homogeneous distribution of reinforced particle in the FSP zone will increase the micro hardness of FSW zone by 30-55% higher as compared to matrix alloy.
- Reinforced particles decreased the tensile properties as compared to the base material.
- Square pin profiled tool produced defect free and good quality FSP region with axial force of 7 kN.
- With the increase of rotational speed of tool, microhardness decreases and wear rate increases.
- By FSP treatment, the materials are used for superplastic applications. Low temperature superplasticity of 350 – 540 % may be achieved at 200 – 350 ^{0}C.

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