MICROSTRUCTURAL ANALYSIS OF 1100 Al CLAD 5083 Al BY FRICTION STIR PROCESSING

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ABSTRACT

Friction stir processing is a unique surface modification process for non-ferrous metals. Especially for aluminum and its alloys. In this present work, Al 1100 commercially pure aluminium alloy was clad over Al 5083 aluminium alloy friction stir processing. Tool rotational speed and travel speed are process parameters. Effect of the process parameters on microstructure of Al clad composites are investigated

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INTRODUCTION

Friction stir process is worked on the basic principles of friction stir welding process (FSW) created in view of the essential standards of friction blend welding (FSW), a strong state Joining process initially produced for aluminum amalgams (alloys), is a rising metal working system that can give limited alteration and control of microstructures in close surface layers of hand led metallic segments. The FSP causes extreme plastic deformation, material mixing, and thermal exposure, bringing about huge microstructural refinement, densification, and homogeneity of the prepared zone. The FSP procedure has been effectively utilized for creating the fine-grained structure and surface composite, altering the microstructure of materials, and combining the composite and intermetallic compound in situ. FSW.

Chen et al. [1] investigated the effect of stirred intermetallics Al-Fe-Si particles by friction stir processing on structure and corrosion resistance of MAO coated Al6061 aluminium alloy. The results revealed that the coarse and congregated Al-Fe-Si particles lead to large microvoids at the interface of the MAO and substrate. The corrosion properties of the MAO coating have been improved after FSP due to refining and uniform distribution of Al-Fe-Si particles in the coating.

Din et al. [2] investigated the corrosion behaviors of steam based conversion coating containing TiO₂ particles on Al-Mg-Si grade aluminium alloy. The results showed that the presence of TiO₂ enhanced the corrosion resistance of coating.

Hu et al. [3] tried cerium tartrate as new pigment in epoxy coating on aluminium alloys. The result showed that the cerium tartrate was an effective pigment for improving the barrier effect of epoxy coating on aluminium alloys.

Wojciechowski et al. [4] anodized aluminium in oxalic and sulphuric acid solutions. Silane coating also applied over them. The results revealed that the silane coated aluminium showed improved corrosion resistance. The best anti-corrosive coating was reported with unsealed pores samples.

Surca et al. [5] investigated the protective behavior of bis-(3-(3-(3-triethoxysilyl)propyl)thioureido)propyl terminated polydimethylsiloxane (PDMSTU) pre-treatment coatings on AA 2024 aluminium alloy. The electrochemical experiments showed that the presence of BTESPT and TS-iOc7-POSS molecules improves the protective behaviour of the silane coating, while Raman imaging was used to determine their distribution in coatings.

Plagemann et al. [6] attempted zinc-magnesium-pigment rich coating on aluminium alloys. In the presented investigations corrosion protection coatings based on intermetallic zinc–magnesium pigments were tested. This approach was based on the idea to combine the cathodic protection of magnesium pigments with the better handling and application properties of zinc, due to its lower reactivity. Salt spray tests showed a superior protection behavior for the tested pigments with zinc contents of less than 80 wt% in comparison to pure zinc and magnesium references. The pigment composition of 74 wt% zinc proved to be especially advantageous. Present work investigates the effect of process parameters like tool travel speed and tool rotational speed on the microstructure of the Al 1100 clad Al 5083 aluminium structures.

EXPERIMENTAL PROCEDURE

The commercially pure Al 1100 aluminium alloy was selected as clad material and Al 5083 aluminium alloy was selected as substrate. Both aluminium alloys were machined to 50 x 50 mm² plate. Substrate material was kept as 5 mm thick plate and clad as 1 mm thickness. A FSP tool of 18 mm shoulder diameter and 5 mm diameter pin. Pin length was kept as 5 mm. Tool material was High Chromium High Carbon alloy (HCHCr). Al 1100 strip was inserted into the machined groove in Al 5083 and the assembly was fixed to the FSP machine table using suitable fixtures. The FSP tool was fixed to the spindle and tightened. The FSP machine was programmed with preset process parameter values and activated. The rotating FSP tool plunges at Al 1100 region and passes through Al 5083 region. This resulted in bonding of Al 1100 with Al 5083 alloy. The tool took an offset of radius of its shoulder diameter and plunged again into the materials and performed friction stir cladding technique. Likewise four parallel passes were conducted. The same procedure was followed for other process parameter sets. The process parameters are shown in Table 1.

Samples were cross sectioned and prepared for microstructural analysis. Samples were etched with Keller reagent. Optical microscopy was adopted to analyse the microstructure.

Table 1: FSP Process Parameters

Tool Rotational Speed (RPM)	Tool Travel Speed (mm/min)
700, 800, 900	15, 30

RESULTS AND DISCUSSIONS

Microstructure of Al 1100 clad Al 5083 aluminium alloy

Figure 1: Microstructure of Al Clad Sample 700 rpm and 15 mm/min.

Fig.1a: Shows the bottom parent metal microstructure with parallel grain flow along the direction of rolling. The fine grains of Mg_2Si in primary aluminium phase in the same direction.

Fig.1b: Shows the heat-affected zone with thermo mechanical transformation leading to increased plasticity and flow in direction of the tool near the nugget zone.

Fig. 1c: Shows the nugget zone with insoluble inter metallic probably $Al_6(Fe, Mn)$ in fragmented grains of AA1100 and with AA 5083.

Fig 1d: Shows the bottom interface zone between the 1100 & 5083. The zone to the width of the nugget zone shown complete fusion and the exchange of constituents of 1100 & 5083.

Fig. 1e: Shows the shoulder zone at the 1100 side with fragmented grains and insoluble inter metallics.

Figure 2: Microstructure of Al Clad Sample 700 rpm and 30 mm/min.

Fig.2a: Shows the bottom parent metal microstructure with parallel grain flow along the direction of rolling. The fine grains of Mg_2Si in primary aluminium phase in the same direction.

Fig.2b: Shows the heat affected zone with thermo mechanical transformation leading to increased plasticity and flow in direction of the tool near the nugget zone.

Fig. 2c: Shows the nugget zone with insoluble inter metallic probably $Al_6(Fe, Mn)$ in fragmented grains of AA1100 and with AA 5083.

Fig.2d: Shows the bottom interface zone between the 1100 & 5083. The zone to the width of the nugget zone shown complete fusion and the exchange of constituents of 1100 & 5083,

Fig.2e: Shows the shoulder zone at the 1100 side with fragmented grains and insoluble inter metallics.

Fig.3a: Shows the parent metal 1100 at top of the cladding with only primary phase with secondary as impurity.

Fig.3b: Shows the bottom AA 5083 with grain orientation along the direction of forming with Mg_2Si in primary aluminium matrix. Shows the heat affected zone with thermo mechanical transformation leading to increased plasticity and flow in direction of the tool near the nugget zone.

Fig.3c : Shows the shoulder zone at the 1100 side with fragmented grains and insoluble inter metallics.

Fig.3d: Shows the nugget zone with insoluble inter metallic probably $Al_6(Fe, Mn)$ in fragmented grains of AA1100 and with AA 5083. The matrix has both the constituents of AA 1100 & AA 5083.

Fig.3e: Shows the bottom interface zone between the 1100 & 5083. The zone to the width of the nugget zone shown complete fusion and the exchange of constituents of 1100 & 5083,

Figure 3: Microstructure of Al Clad Sample 800 rpm and 15 mm/min.

Fig.4a: Shows the bottom AA 5083 with grain orientation along the direction of forming with Mg_2Si in primary aluminium matrix.

Fig.4b: Shows the shoulder zone at the 1100 side with fragmented grains and insoluble intermetallics. The matrix is dominantly with constituents of AA 1100.

Fig.4c: Shows the shoulder zone at the 1100 side with fragmented grains and insoluble intermetallics.

Fig.4d: Shows the nugget zone with insoluble intermetallic probably $Al_6(Fe, Mn)$ in fragmented grains of AA 1100 and with AA 5083. The matrix has both the constituents of AA 1100 & AA 5083.

Fig.4e: Shows the right side parent metal with dominant microstructure of AA 5083.

Figure 4: Microstructure of Al Clad Sample 800 rpm and 30 mm/min.

Fig1: Shows the parent metal AA 5083 left side with microstructure identical of parent AA 5083.

Fig2: Shows the first interface zone of the clad AA 1100 & 5083. Left is 5083 & right is AA 1100.

Fig3: Shows the shoulder zone at the 1100 side with fragmented grains and insoluble intermetallics.

Fig4: Shows the heat affected zone of 5083 near the cladding zone with insolubles and Mg_2Si particles. This zone is at the left side.

Fig5: Shows the heat affected zone of 5083 near the cladding zone with insolubles and Mg_2Si particles. This zone is at the right side.

Fig6: Shows the clad AA 1100 & AA 5083 at the interface zone. The fusion zone does not show any discontinuity and is effective and very thin at the interface.

Figure 5: Microstructure of Al Clad Sample 800 rpm and 30 mm/min.

Figure 6: Microstructure of Al Clad Sample 900 rpm and 15 mm/min.

Fig.6a: Shows the parent metal AA 5083 leftsidewith microstructure identical of parent AA 5083.

Fig.6b: Shows the first interface zone of the clad AA 1100 & 5083. Leftis 5083 & right is AA 1100.

Fig.6c: Shows the shoulder zone at the 1100 sidewithfragmented grains and insoluble inter metallics.

Fig.6d: Shows the heataffected zone of 5083 near the cladding zone with insolubles and Mg₂Si particles. This zone is at the leftside

Fig.6e: Shows the heataffected zone of 5083 near the cladding zone with insolubles and Mg₂Si particles. This zone is at the right side.

Fig.6f: Shows the clad AA1100 & AA 5083 at the interface zone. The fusion zone does not show anydiscontinuity and effective and verythin at the interface.

Figure 7: Microstructure of Al Clad Sample 900 rpm and 30 mm/min.

Fig.7a: Shows the parent metal AA 5083 left side with microstructure identical of parent AA 5083.

Fig.7b: Shows the heat-affected zone of 5083 near the nugget zone/cladding zone.

Fig.7c: Shows the shoulder zone at the 1100 side with fragmented grains and insoluble intermetallics.

Fig.7d: Shows the nugget zone of the AA 1100 with fragmented grains primarily with Aluminium alpha phase.

Fig.7e: Shows the heat-affected zone of 5083 near the cladding zone with insolubles and Mg₂Si particles. This zone is at the right side.

Fig.7f: Shows the cladded AA1100 & AA 5083 at the interface zone. The fusion zone does not show any discontinuity and effective and very thin at the interface.

CONCLUSIONS

In this work, the commercially pure Al 1100 aluminium alloy was clad over Al 5083 aluminium alloy by friction stir processing. Effect of process parameters like tool travel speed and tool rotational speed on the microstructure was investigated. Following conclusions are drawn from this investigation.

- In both 700 rpm 15 mm/min and 30 mm/min samples, bottom parent metal microstructure shows parallel grain flow along the direction of rolling. The fine grains of Mg₂Si in primary aluminium phase in the same direction.
- In both 700 rpm 15 mm/min and 30 mm/min samples, the nugget zone contains insoluble intermetallic probably Al₆(Fe, Mn) in fragmented grains of AA1100 and with AA 5083.
- In both 800 rpm 15 mm/min and 30 mm/min samples, microstructure shows the shoulder zone at the 1100 side with fragmented grains and insoluble intermetallics.
- In 800 rpm samples, the heat-affected zone of 5083 near the cladding zone contains insolubles and Mg₂Si particles.
- Samples clad at 900 rpm does not show any discontinuity and effective and very thin at the interface.

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