International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 8, August 2015.
www.ijiset.com
ISSN 2348 – 7968

An investigation of heat affected zone in tailor welded AA 5052 and AA 6061 alloy blank materials

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ABSTRACT
This work has been focused on prediction of heat affected zone in a 5xxx and 6xxx series of aluminum tailor welded blank using finite element technique and experimental methods. To carry out above objective suitable blank materials namely AA 5052 & AA 6061 were selected. The tailor welded blank of selected materials were prepared using micro tungsten inert gas welding process. The tailor welded blank was modeled using two dimensional thermal solid elements in ANSYS. The model was simulated to obtain the temperature distribution in the region of weldment. Further the detailed analysis of heat affected zone has been carried out by scanning electron microscope and micro hardness test was conducted to investigate the variation of mechanical properties in heat affected region and base metals. The heat affected zone of aluminum tailor welded blank was investigated by thermo simulation test, microstructure analysis and micro hardness test.
Key Words: TIG welding; Tailor welded blank; Heat affected zone; Finite element analysis

1.0 INTRODUCTION

In recent years, the use of tailor welded blanks (TWBs) has increased in practice not only in the automotive industry but also in other manufacturing industries such as electrical goods, electronic packaging and construction markets [1]. TWBs are comprised of two or more sheets of metal with dissimilar material and different thickness or similar material with different thickness or dissimilar material with equal thickness [2]. Moreover, a TWB contains a heat affected zone (HAZ) which has quite different mechanical properties and microstructure from base materials [3].

The thermal diffusivity of the base material plays a large role if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small [4]. Alternatively, a low diffusivity leads to slower cooling and a larger HAZ. The amount of heat inputted by the welding process plays an important role as well, as processes like oxyfuel welding use high heat input and increase the size of the HAZ. Processes like laser beam welding and electron beam welding give a highly concentrated, limited amount of heat, resulting in a small HAZ [5]. Arc welding falls between these two extremes, with the individual processes varying somewhat in heat input. To calculate the heat input for arc welding procedures, the following formula is used.

$$Q = \left(\frac{v \times I \times 60}{S \times 100} \right) \times Efficiency \qquad (1)$$

Q= heat input (kJ/mm), V = voltage (V), I = current (A), S = welding speed (mm/min).

In view of the above shortcomings, this paper is intended to present an experimental method of analysis to determine the Heat affected zone of weldment from the Aluminium TWBs with equal thickness. The TWB is prepared by micro tungsten inert gas (TIG) welding process. The calculated heat generation values during TIG welding were employed for the simulation of TWB forming using a general-purpose finite element package, ANSYS. Further the scanning electron microscopic image and micro hardness test was conducted. Finally the predicted region of HAZ in simulation compared with test results and found to be satisfactory.

1.1 Base material and welding process

Micro TIG welding is the process we use for small intricate weld that cannot be used traditional manual TIG welding. Because this TIG welding technique uses limited heat it welds with minimal distortion. This welding process can weld intricate assemblies down to 0.1mm thick. This process uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used. TIG Welding is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The chemical composition of AA 5052 alloy used in study was 0.6 Si-0.7Fe-0.275Cu-0.15 Mn-1Mg-0.195 Cr-0.25Zn-0.15Ti-96.68Al. The chemical composition of AA 6061 alloy was 0.04 Si-0.29 Fe-0.10 Cu-0.027 Mn-2.7 Mg-0.15Cr-0.08Zn-0.005Ti-

96.508Al. The mechanical and thermal properties of AA 5052 and AA 6061 alloys were shown in Table 1 and Table 2. The synthesis and characterization of AA 6061 aluminum nanocomposites with various reinforcements prepared by high energy ball milling and its mechanical properties were reported in our previous studies [6-9].

Table 1 Mechanical properties of AA 5052 and AA 6061 alloys

Grade	Vickers hardness	Poisson ratio	Shear strength MPa	Ultimate tensile strength MPa	Tensile strength MPa	Modulus of elasticity MPa
AA 5052	95	140	0.33	230	195	70
AA 6061	90	83	0.33	115	88	80

Table 2. Thermal Properties of AA 5052 and AA 6061 alloys

Grade	Thermal Conductivity W/mK	Specific heat Capacity KJ/Kg K	Melting Temperature °C	Density Kg/Cm^3
AA 5052	180	0.91	660	2700
AA 6061	170	0.92	650	2800

Filler metal is either matched directly to the parent metal or chosen based on its hardness and final application. For example, some die makers texture a mold, giving it a design or pattern, once it has been repaired. Filler metal hardness in this case should be at or just below the hardness of the parent material to make texturing possible [4]. It is recommended that consulting with end user to understand the final application and what hardness is desired from the finished weld.

For micro TIG welding, 100 percent argon for shielding gas for most applications. The only time strays from 5052 grades aluminum. It's a trick picked up along the way that allows him to forgo preheating. It cautions anyone using straight helium to be wary of the fact that it creates a hotter arc than argon and can cause unnecessary stress and warping on the part for those with less experience. The specifications of micro TIG welding, 100 V and 60 A were used and its welding speed 0.2 mm/sec. The TIG tailor welded blank was shown in Fig. 1.

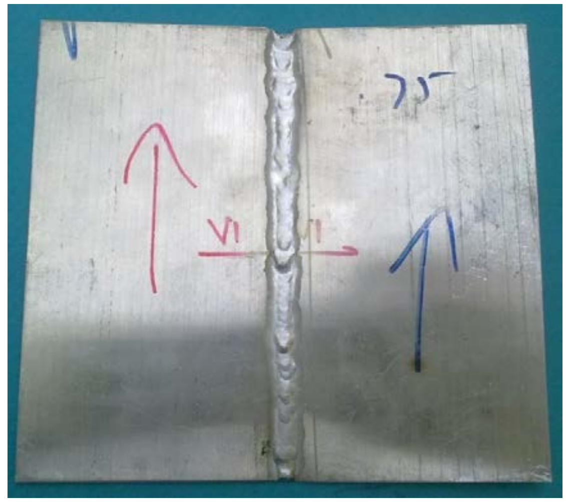

Fig. 1 The TIG Welded Aluminum TWB

3. Result and Discussion

3.1 Finite Element Modeling and simulation of TWB

All modeling were performed using the Ansys 13. The parent material model was comprised of plane 55 which is available in Ansys 13. For the models excluding weld properties and geometry, nodal rigid bodies were used to connect adjacent nodes of the thin and thick parent materials. Fig. 2 shows the modeling of TWB.

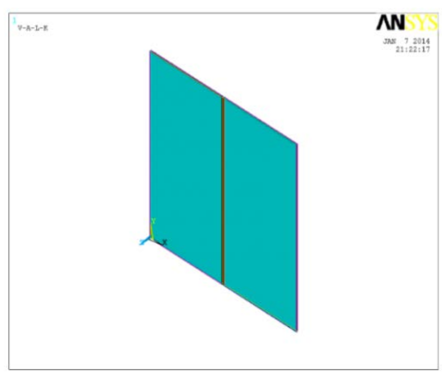

Fig. 2 Modeling of TWB.

International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 8, August 2015.
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ISSN 2348 – 7968

For the ASTM test specimen, an additional model will developed in which the mesh is as described above for the models including weld properties. However, the material properties assigned to the thermal elements are identical to the material properties for the shell elements that define the parent material. The purpose of this model is to assess the effects of mesh and element type on the results, independent of the material properties. For the remainder of this document, prior to finalizing the finite element models, a sensitivity study was performed on element dimensions, formulations and the number of integration points required. The results of these sensitivity studies formed the basis for the finite element models. The simulation is done by transient heat analysis. The heat input is calculated using equation 1 as 0.840 KJ/mm. This value is given as input to the transient heat analysis with density and heat conductivity. Based on the calculated value the simulation results found were mentioned in Figs.3-5. Similar results were obtained with other materials in the previous studies [10-11].

3.2 Microstructural study of the Weld surface

SEM analysis of the specimen welded by the TIG process shows that in this case there also occurs incipient fusion in the area of primary carbide parts on the hot side of heat affected zone (HAZ). Micro structure and micro chemical changes in the area of primary carbides in HAZ are the same as the changes in both AA 5052 and AA 6061 alloys.

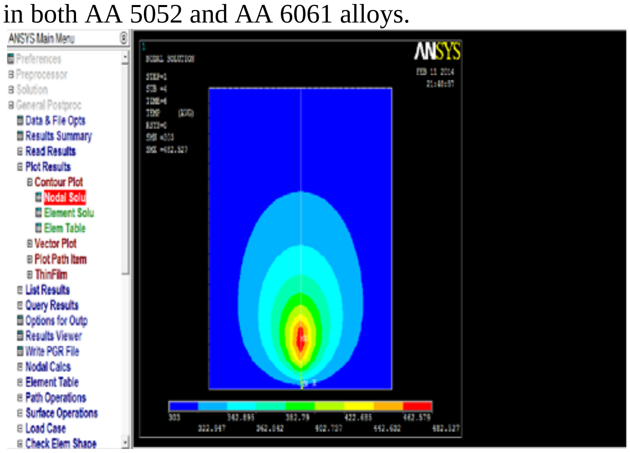

Fig. 3 Simulation result of TWB at t=3 sec

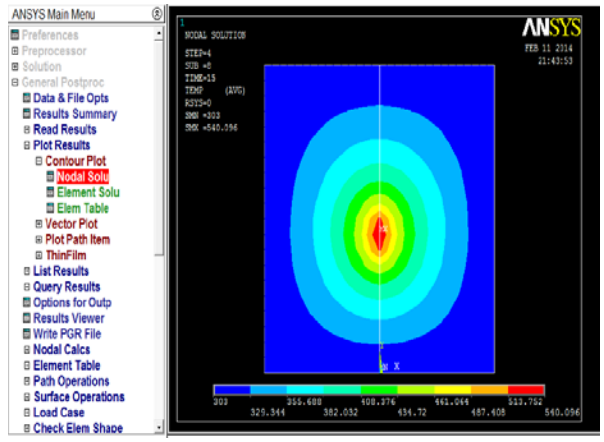

Fig. 4. Simulation result of TWB at t=15 sec

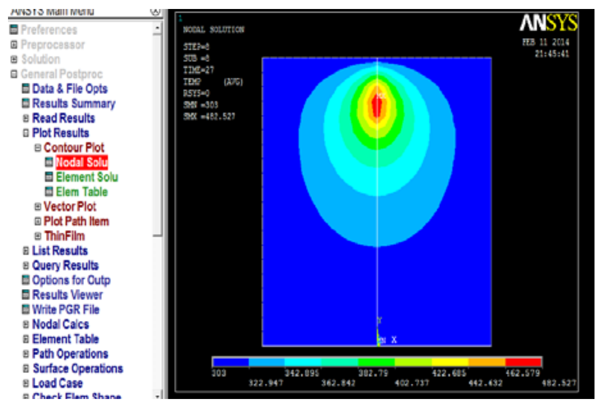

Fig. 5. Simulation result of TWB at t=27 sec

Fig. 6 shows the microstructure at the cross-point from the base material into the HAZ of AA 5052 alloy, while Fig. 7 shows the cross-point into the hot part of HAZ of AA 6061 alloy. Distribution of elements in the area of partly dissolved primary carbide is the same as the distribution in Figs. 6-7.

ISSN 2348 – 7968

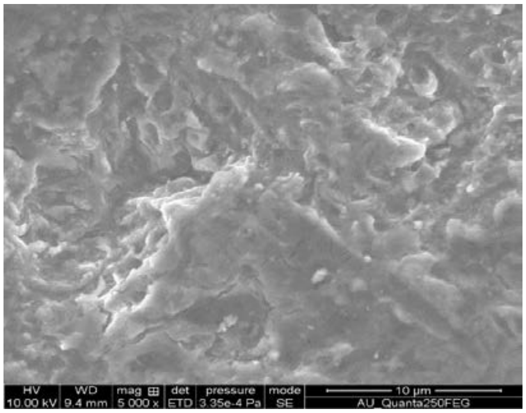

Fig. 6. Microstructure analysis of AA 5052 alloy

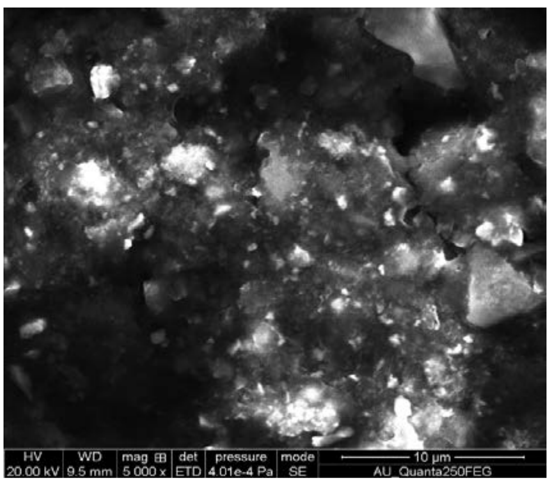

Fig. 7. Microstructure analysis of AA 6061 alloy

4. Conclusions

With the process of surfacing by TIG of heterogeneous blank we have been made the analysis of HAZ, welds on the AA 5052 and AA 6061 alloy tools with all the elements that were characteristic of welding procedures: weld, heat affected zone and base material. HAZ was narrower at the AA 5052 alloy welding than at the AA 6061 alloy; while the hardness in HAZ at TIG process was lower than AA 6061alloy. The border between the welds and HAZ fusion line was normally evenly joined in the weld in such a way that HAZ doesn't cross that line into the weld and also the weld doesn't cross over into the HAZ. In this case the border was undefined as there were some independent or connected spots of melt around the big primary carbides in the hot part of HAZ. Because of the high temperatures in the hot part of HAZ next to the weld, primary carbides dissolved fast in the aluminum which was enriched with chromium and carbon to the point of Al composition whose melting point was below the actual temperature in that part of HAZ. The occurrence of the melt speeds up the melting process so the level of the melt was increased. Heat affected zone of all process was depended on the available amount of heat, conduction and cooling action.

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