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Evaluation of Mechanical Properties of Dissimilar Metals by Friction Welding

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Abstract:

Aim of the research work is to join the dissimilar metals using solid state welding process and to evaluation the mechanical properties. Now a day's Friction welding is most commonly welding technique in automobile engineering and heavy industry. An attempt was made to join dissimilar metals like mild steel to pure Al using friction welding technique.Tests were conducted with different welding process parameters. The results were analyzed by means of tensile test and Vickers micro hardness test and founded that there is improvement in mechanical properties of the welded joint.

Keywords:

Friction welding, mild steel, Pure Aluminum, tensile strength

I. Introduction:

Welding is a manufacturing process of creating a permanent joint obtained by the fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler material. The materials to be joined may be similar or dissimilar to each other [1]. Various methods are available to join various materials together, including fusion welding, solid state bonding, brazing, mechanical joining and adhesive bonding. However efficient welding of dissimilar metals has posed a major challenge due to difference in thermo-mechanical and chemical properties of the materials to be joined under a common welding condition. This causes a steep gradient of the thermo-mechanical properties along the weld[2]. A variety of problems come up in dissimilar welding like cracking, large weld residual stresses, migration of atoms during welding causing stress concentration on one side of the weld, compressive and tensile thermal stresses, stress corrosion cracking, etc [3].

Over the years a lot of research has been done in the area of dissimilar welding and many interesting results have been brought up with regards to the problems encountered in dissimilar welding. With dissimilar welding finding its use in nuclear, petrochemical, electronics and several other industrial domains, this section brings into account the work of the predecessors in this field [4].

Researchers made an attempt to weld dissimilar metals and are explained here:

Ch, Muralimohan et al [5] studied the friction welding of Al to copper. The tensile strength of the joint was 3.8% higher than the base metal Al. The microstructure reveals that there is formation of intermetallics of Al and copper and the microhardness value constantly increased towards the weld interface due to strain hardening effect. Chengwu et al. [6] studied the microstructure and mechanical properties of copper-steel dissimilar welding Experimental results showed that for the welded joint with high dilution ratio of copper, there was a transition zone with numerous filler particles near the interface. The welded joint with lower dilution ratio of copper in the fusion zone exhibited higher tensile strength. A.K. Lakshminarayanan et al.[7] showed that the properties of friction welded magnesium–titanium dissimilar joint no discernible regions were observed in the titanium side, as it had not undergone any significant plastic deformation. Phase analysis indicated that the aluminium from the magnesium side diffused toward the weld interface and formed a thin continuous intermetallic layer by reacting with the titanium. Kush P. Mehta et al. [8] studied the friction stir welding was carried out on dissimilar copper to aluminum materials by nine different tool designs. The results revealed that, the copper particles detached from base material were large and irregular in case of polygonal pin designs.

Maximum irregular and large copper particles were reported in welds made by triangular pin profiles. Furthermore, defects were decreased as the polygonal edges increases. Defect free macro joint was reported for cylindrical tool pin profile.

Khan et al. [9] studied laser beam welding of dissimilar stainless steels in a fillet joint configuration and during the study metallurgical analysis of the weld interface was done. Fusion zone microstructures contained a variety of complex austenite ferrite structures. Local micro-hardness of fusion zone was greater than that of both base metals. Mai and Spowage [10] did their work on characterisation of dissimilar joints of steel-kovar, copper-steel and aluminium-copper. It was stated in their work that joining of dissimilar materials is one of the challenging tasks facing modern manufacturers. Lundin [11] did his research on dissimilar welds with its emphasis on carbon migration, stress/strain state of welds and transition joint failure mechanism. The study stated that the majority of failures have been associated with austenitic stainless steel filler metal joints, and it is considered that the failure mode exhibited by the nickel-based filler metals is fundamentally different than that with the austenitic stainless fillers. From this it confirms that it is very difficult to get good properties at the weld zone.

2. Welding Theory and Dissimilar welds:

A schematic diagram of a dissimilar metal weld is shown in figure 1. When welding dissimilar metal welds the choice of filler metal plays an important role and usually has a composition differing from both of the parent metals. The composition of the weld metal will therefore be a mix of the parent metals and the filler metal at some specific ratio [12].

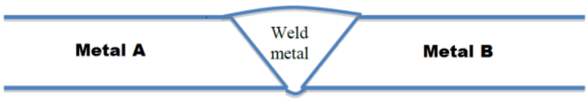

Figure 1. Schematic diagram of dissimilar metals

Welding dissimilar metal welds faces many characteristic problems caused by structural changes and several constitutional changes can occur during welding. Changes in the dilution ratio of the parent metals are possible and affected by the welding conditions.

2.1 Welding process of dissimilar metals:

The weld metal composition is usually not uniform throughout the weld, especially in multipass welds. A composition gradient is likely to arise in the weld metal between the two parent metals. The solidification procedure of the weld metal is influenced by the dilution and the composition gradients, this is important with respect to hot cracking. When designing a dissimilar metal weld final weld metal and the mechanical properties must be considered. [13] The factors that usually are responsible for failure of dissimilar metal welds are alloying problems and formation of brittle phase and limited mutual solubility of the two metals, differing melting points, and differences in thermal expansion coefficients and differences in thermal conductivity.[14]

2.2 The Heat-affected zone:

The HAZ can be divided into four different zones as shown in figure 2. The width of the different zones in the HAZ depends on the preheating level or interpass temperature and the specific heat input of a particular welding procedure. It also depend on forced cooling or the a lack of forced cooling, the size of workpiece, thickness and so on. [15]

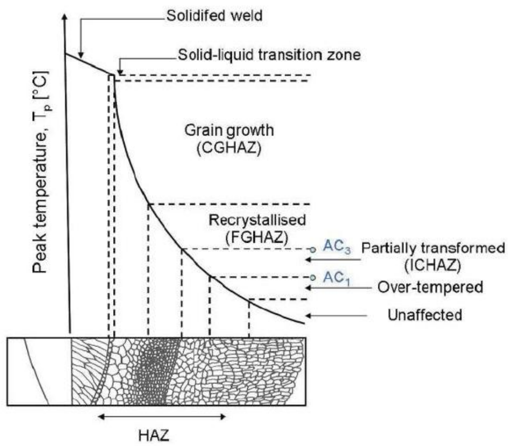

Figure 2. Schematic diagram of HAZ

Weldability is the capacity of a material to be welded under the fabrication condition imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service. Weldability encompasses the metallurgical compatibility of a metal or alloy withspecific welding process and the ability of the metal or alloy to be welded with mechanical soundness. Increases or decrease in hardness in HAZ depends on the alloying elements present in weld zone.

To control the effect of alloying elements in HAZ it is expressed in terms of carbon equivalent (CE) [16].

$$CE = \%C + \frac{\%Mn}{4} + \frac{\%Ni}{20} + \frac{\%Cr}{10} + \frac{\%Cu}{40} - \frac{\%Mo}{50} - \frac{\%V}{10}$$

For Stainless steel, the nickel and chromium equivalents are calculated based on Schaeffler diagram and is shown below. [17]

$$Ni_{eq} = \%Ni + 30.\%C + 0.5.\%\,Mn$$

$$Cr_{eq} = \%Cr + \%\,Mo\ + 1.5.\%Si + 0.5.\%\,Nb + 2.\%\,Ti$$

In this present work, Mild steel and Pure Al metal have been joined by continuous drive friction welding process and the results were analyzed and presented. The tensile tests and Vickers micro hardness test were performed to define welding parameters and analyze the resistance of the weld.

3. Experimental Procedure:

In the experiment, Mild Steel and Pure aluminum materials were used for welding. The chemical composition obtained by chemical analysis of Mild steel is given in Table1. The specimens were machined from materials according to the required dimensions. Mild steel bars of length 150mm, outer diameter of 20mm and inner extruded part diameter of 18mm, and Pure Al alloy bars of length 150mm, outer diameter of 18mm and inner extruded part diameter of 15mm respectively.

Table 2: The Chemical Composition of Mild steel

Element	%
Carbon	0.16
Silicon	0.40
Manganese	0.80
Sulphur	0.04
Fe	Remaining

Setup of friction welding equipment:

In figure 3 the friction welding equipment is shown which has a drive motor capacity of 6 kw and max speed of 1600 rpm. It is connected to computer to take the readings.

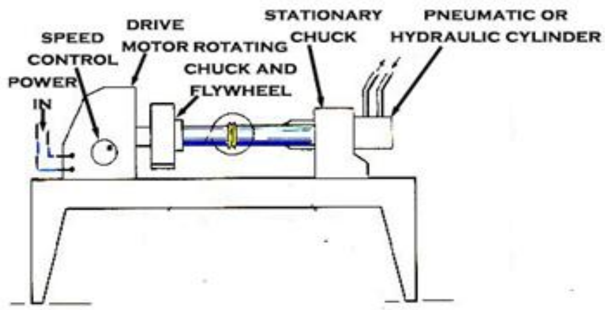

Figure 3: Friction welding setup

The main parameters used to perform the set up are: Friction pressure (fp) and friction time (ft) - heating phase; Upset pressure (Up) and upset time (Ut)-forging phase, and rotational speed per minute (RPM).Different parameters selected for the present work were given in Table3.

4. Results and Discussions:

After welding was performed, tensile tests were carried out to evaluate the tensile strength of joints. The welded specimens were machined and subjected to tensile tests on a machine with a load cell capacity of 100 KN at room temperature. The effects of friction time and friction pressure on the strength of joint were measured while keeping the upset time as constant. Table 4 shows the values of tensile test values. From table 4 we can see that as the s friction time and friction pressure for the joints are increased, tensile strength of the joints increases and when the friction pressure and friction time further increased, the tensile strength is decreased. Thus the friction time and friction pressure as direct effect on the tensile properties of the weld.

Table 3: Parameter for the present study

Experiments	Friction pressure (MPa)	Friction time (s)	Upset Pressure (MPa)	Upset Time (s)	Speed (rpm)
1	60	4	195	8	1600
2	80	6	195	8	1600
3	100	8	195	8	1600
4	120	10	195	8	1600
5	140	12	195	8	1600

Table 4: The effect of friction pressure and friction time on tensile strength

Experiments	Friction pressure (MPa)	Friction time (s)	Tensile strength (MPa)
1	60	4	108
2	80	6	110
3	100	8	135
4	120	10	120
5	140	12	115

Micro hardness was conducted at the interface of the weld and in the regions near both the mild steel side and the Pure Al side isshown in Table 5. From the table 5 the values of welded interface are in the range between the micro hardness values of mild steel and pure Al.

Table 5: Microhardness values of Welded interface.

Experiments	Friction pressure (MPa)	Friction time (s)	Microhardness values (VHN)
1	60	4	135
2	80	6	122
3	100	8	167
4	120	10	136
5	140	12	125

5. Conclusion:

In this study the friction welding of mild steel to pure Al has been successfully employed. After the welding process the tensile strength and micro hardness studies were carried out. From the following results were summarized below:

- The friction welding parameter should be selected such that the good friction weld joint is formed.
- The tensile strength of the weld joint is good.
- Hardness of both materials in the vicinity of the weld interface was higher than that of the base metals.

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