Fluidity and Microstructural features of Al-alloy Weld Beads

Abstract: This paper highlights the effects of fluidity and joint design on the weld bead characteristics of Al-alloy.

Dr. A. Chennakesava Reddy
Associate Professor
Department of Mechanical Engineering
Vasavi College of Engineering
Ibrahim Bagh
Hyderabad – 500 031

The fluidity was largely affected by the both type of the alloy and joint design. The mechanical properties were greatly influenced by the type of the alloy and moderately by the joint design. The microstructure is finer in the HAZ than that in the center of the weld bead.

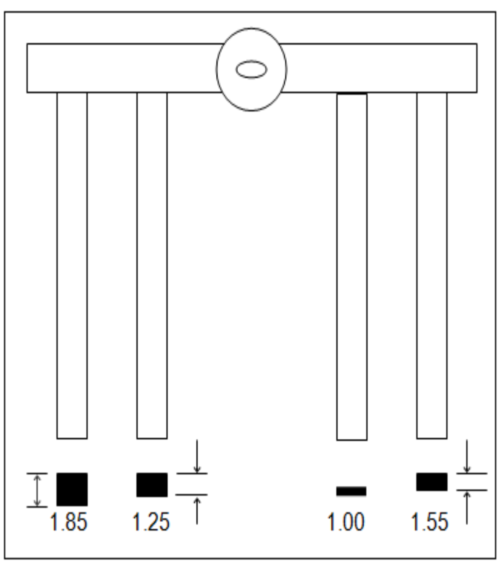

Fig.1 Strip fluidity test mould. All dimensions are in mm.

Introduction

The intensive demand for Al and its alloys arises chiefly from their attractive physical, mechanical and chemical properties. Al and its alloys have certain welding characteristics, which need some special attention during welding when compared to other metals and alloys. The first and the foremost consideration is the effect of the thin film of oxide which is always present on the surface of Al. this film contains moisture which may react during fusion welding, with the liquid metal in the weld pool, to form oxide and to liberate hydrogen which can cause porosity. Al being a very good conductor of heat dissipates heat at a very fast rate from the joint being welded to the adjacent base metal. Fast heat removal rate affects the fluidity characteristics particularly in the narrow joints. Al has got high coefficient of linear expansion. Unless some precautions are taken, the welding heat causes distortion and bulking.

Table -1: The compositions of the alloys

Alloy	%Cu	%Si	%Mg	%Ni	%Al
Alloy-1	3.5	6.0	---	---	rest
Alloy-2	10.0	4.0	0.3	---	rest
Alloy-3	4.0	2.0	1.5	1.0	rest

In case of Al-alloys, at the solidus, both strength and ductility are low, so that when welded under restraint the metal is likely to crack. Cracks may develop either in the weld metal due to its low strength around the solidus of the freezing pool or in the overhead zone of the parent metal due to fusion of low melting point constituents.

Joint filling capability and metallurgical behavior are therefore, essential as they not only help in the selection of appropriate welding procedure, but also minimize weld rejections. An investigation has been carried out to study the effect of alloy composition and joint design on the fluidity, mechanical and microstructural characteristics of weld beads made by the MIG welding.

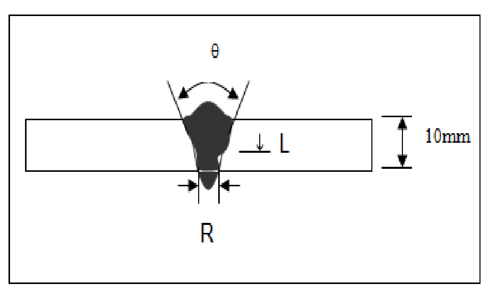

Fig. 2 Weld bead

Experimental Procedure

The compositions of Al-alloys used in the present investigation are given in the Table-1. A strip fluidity testing mould of cast iron whose design and dimensions are shown in fig.1 was used for determining the fluidity of Al-alloys. The strip fluidity test measures the ability of alloy to fill a joint of different cross sections and thus provide wider specifications of actual welding conditions.

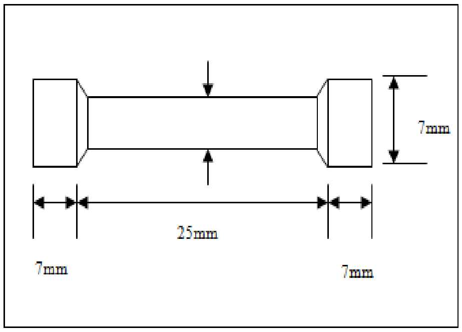

Fig.3 Tensile specimen

The butt-welded joints of Al-alloys were prepared using MIG welding process. An electric arc was struck between Al=alloy continuously fed electrode (+) pulled from a spool by a wire-feeding mechanism and the job (-). A shielding gas of 100% argon was used to protect the weld pool.

Fig.2 and Table-2 give the details of the design of joints. 1.6mm dia electrode with a composition given in Table-3 was employed. The machine settings are given in Table-4. The welding gun was brought to within about 25mm of the work, with the electrode protruding about 13mm beyond the cup. The trigger was then pulled to close the power supply contacts and energies the wire and open the shielding and water solenoids. The arc was struck by scratching the electrode against the work.

After the arc struck, the end of the gas cup was held approximately 19mm from the work. A 10^0 forehand angle of the electrode relative to the work was maintained during welding.

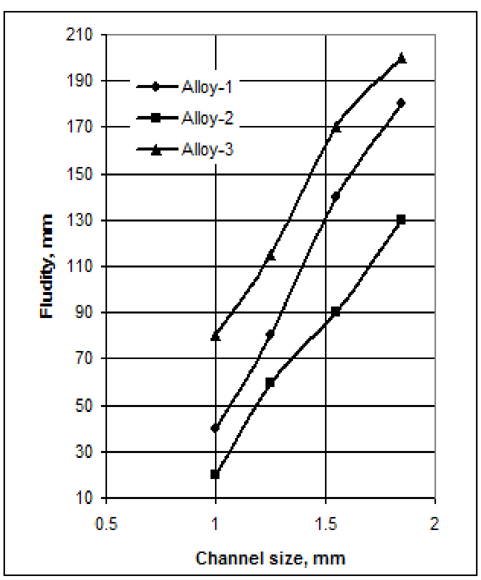

Fig.4 Effect of channel size on the fluidity

Tensile specimens of 5mm dia and 39mm length (fig.3) were prepared from the weld beads. The mechanical properties (viz., tensile strength, hardness, and %elongation) and microstructures of weld beads were studied using standard procedures.

Table-2: Design of joints

Joint	R, mm	L, mm	θ, Degrees
Joint-1	0.5	4.0	60
Joint-2	0.5	2.0	45
Joint-3	1.0	4.0	60
Joint-4	1.0	2.0	45
Joint-5	2.0	4.0	60
Joint-6	2.0	2.0	45

Results and Discussion

Each experiment was repeated twice to avoid inconsistency or errors in the results. The average of the readings are plotted and analyzed against the controlling parameters (viz., joint design, channel size, type of alloy).

Fluidity Characteristics

Flow capabilities of liquid metals in various channels of strip fluidity testing mould are shown in fig.4. The alloy-3 gives good flow characteristics. The reason could be addition of Ni, which reinforces the streams of liquid metal and subsequently decreases the turbulence in the flow.

The other reason could also be the enhancing of sustainable and prolonged liquidity characteristic of metal. These lead to the long run of metal even in narrow channels. An interesting observation is seen between the flowing characteristics of alloy-1 and –2. Alloy-2 is restricted to the short distances of liquid flow in various channels. The argument is justified by the following reaction:

Mg (molten) + H_2O (vapor) = MgO (dross) + 2H (dissolved in melt)

Table-3: The chemical composition of electrode							
%Cu	%Si	%Mg	%Fe	%Ti	%Mn	%Zn	%Al
0.30	4.50	0.05	0.80	0.20	0.05	0.10	rest

Table-4: Machine settings			
Current (DCRP), Amp	Voltage	Argon flow rate, lpm	Welding speed, cm/min
250	28	25	50

Two harmful effects accompany this reaction: oxide inclusions may be entrapped in the channels, and hydrogen gas defects causing vaporized turbulence. Therefore, retracted flow is the result.

The resultant effect is increasing trend of fluidity with opening capillary mode in the channels (i.e., the fluidity is directly proportional to the channel size). This is ----ensued during the progressive solidification of liquid metal while flowing through the channel. Of course friction is applied with fluid and geometry interactive consequence.

Mechanical Properties

-%elongation) are illustrated in fig. 5,6 and 7. The tensile strength of weld bead with input variables of alloy-3 and joint-5 is greater than that of any other weld bead. This is supported by the fluidity characteristics in relevant to the joint design in addition to the resistance to tearing during solidification process and the resistance to plasticity fracture by Ni constituent. The alloy-2 is impressed with low strength due to pinhole porosity resulted from the evolution of hydrogen gas. The alloy-1 is with lower and upper limits of alloy-2 and alloy-3respectively.

The heat affected zone (HAZ) hardness is found to be high in joint-1 and-2 (fig.6). There is clear contribution of Ni constituent towards the hardness value. The role of Mg in the form of metallic compound Mg_2Si is to promote hardening effect of the alloy. The fanatic growth of hardness in alloy-2 is owing to copper content. It is not surprise that the mechanical properties of hardness and strength can be expected to increase as copper content increases while the ductility decreases. But there is not much influence of the joint design over the surface hardness except in joint-2 the hardness values of alloy-1 and-2 are same (the reason is unknown).

The ductility characteristic measured in terms of %elongation is viewed in fig.7. Alloy-3 once again dictates its supremacy in the ductility. It is all due to the role of Ni. The alloy-2 gives low ductility due to the hardening effect of Mg_2Si.

3.3 Microstructural characteristics

The microstructures of weld bead obtained from joint-5 and alloy-3 is shown in fig.8. Two locations namely center and HAZ of the weld bead were chosen for the study. The structure is fine in the heat-affected zone (HAZ) whereas it is coarse in the center of the weld bead.

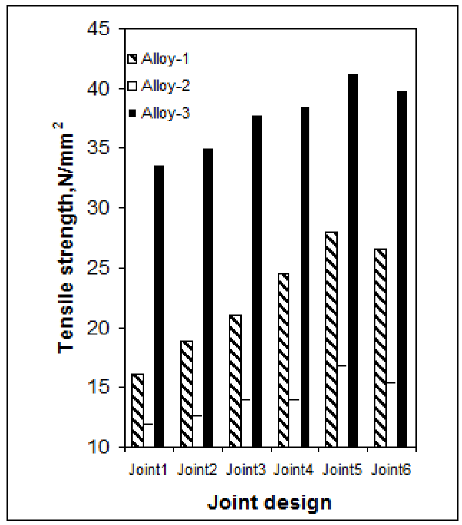

Fig.5 Effect of joint design on the tensile strength of weld bead

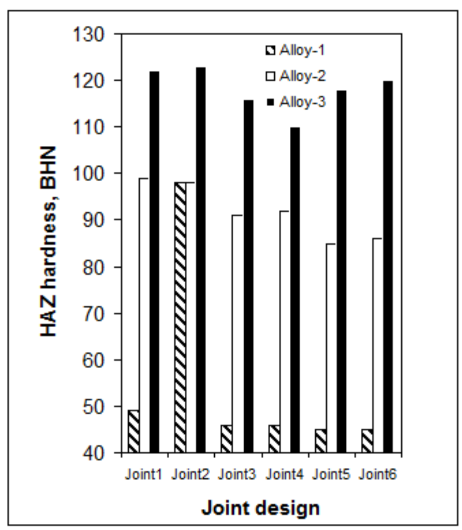

Fig.6 Effect of joint design on the HAZ hardness of weld bead

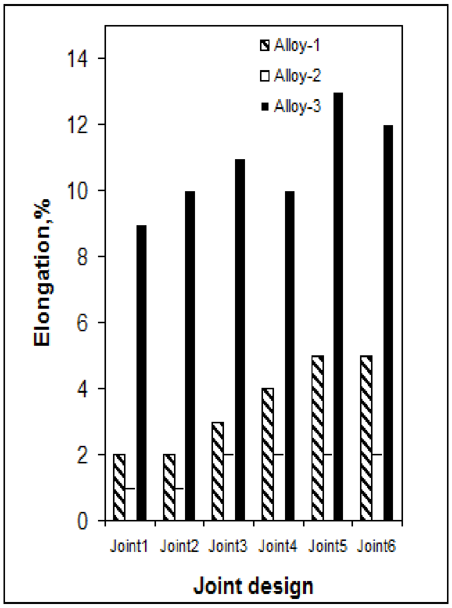

Fig.7 Effect of joint design on the ductility of weld bead

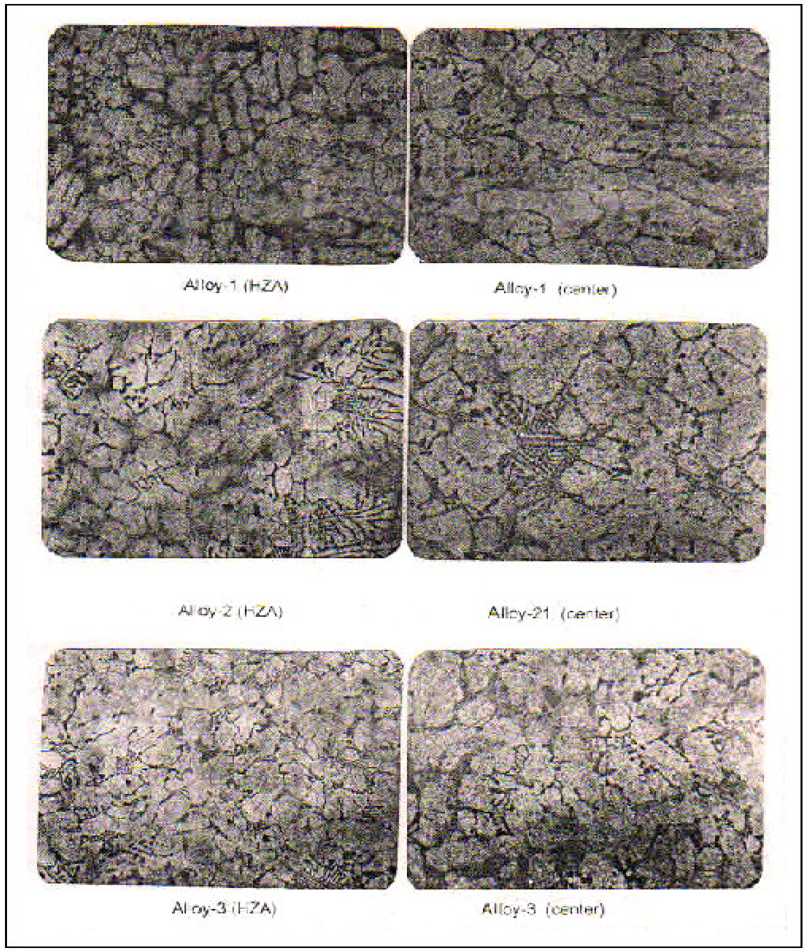

Fig. 8 Microstructure of weld beads produced from joint-5, 200X

This is particularly owing to the heat transfer process. The cooling is rapid in the heat-affected zone. In the center of the weld bead the cooling is slow due to the heat removal is decayed by the center-to-surface distance. The microstructure is almost invariant with change in joint design. More precisely it is 2% increase in grain size from joint-1 to joint-6 with one step of joint change.

Conclusions

The fluidity of the liquid metal depends on the joint design and type of the alloy. The fluidity is increased by the addition of Ni and decreased by the inclusion of Mg. There is turbulence due to the evolution of hydrogen gas. The turbulence and the additional viscosity owing to the solidification process reduce the fluidity. The mechanical are largely influenced by the type of alloy and moderately by the joint design. The microstructure of weld beads is finer in the heat-affected zone and coarser in the center of the weld bead.

References

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