Penetration Enhancing Activated Flux for TIG Welding of Stainless Steels

■ EXECUTIVE SUMMARY

Specific activated flux has been developed for enhancing the penetration performance of the TIG welding process for welding of type 304 LN and type 316LN stainless steels. A significant increase in penetration of over 300% has been observed in single pass TIG welding. The significant improvement in penetration was attributed to constriction of the arc and the reversal of Marangoni flow. The use of flux has been found to overcome the variable weld penetration observed during autogenous TIG welding of austenitic stainless steel with less than 50 ppm silver. There was no degradation in the microstructure and mechanical properties of welds produced by A-TIG welding compared to that of conventional TIG welding process.

■ OUTLINE

The major limitations of TIG welding of austenitic stainless steels are due to the limited thickness of material which can be welded in a single pass, poor tolerance to cast to cast variations and the low productivity. The thickness of austenitic stainless steel that can be welded in single pass is normally restricted to 3 mm with argon as shielding gas. Therefore, improvements in weld penetration have long been sought in austenitic stainless steel welds produced by TIG welding process because TIG welding result in high quality welds besides providing for precise control of heat input and low cost of the equipment. A novel variant of the TIG welding process called A-TIG is known to overcome the limitations. This process involves applying a thin coating of the activated flux on the joint prior to welding. The flux is patent protected and is not reported in literature.

The specific activated flux has been developed in the present work for enhancing the penetration during autogenous TIG welding of type 304LN and type 316LN stainless steels. The use of activated flux produced a significant increase in penetration of 10 – 12 mm in single pass TIG welding of 304LN and 316LN stainless steels. The significant improvement in penetration achieved using the activated flux developed in the present work was attributed to the constriction of the arc as well as reversal of Marangoni flow in the molten weld pool. The constriction of the arc during A-TIG welding could be seen clearly from the IR thermal images of the arc column and was also evident from the decrease in weld bead width by half compared to that of conventional TIG welding. So, combined operation of the above two mechanisms only lead to increased penetration by as much as 300% in 304LN and 316LN stainless steels produced by A-TIG welding. Figures 1 and 2 show the effect of flux on depth of penetration and weld bead width for type 304LN and type 316LN stainless steels. The use of activated flux has been found to overcome the variable weld penetration observed in 316LN stainless steel with less than 50 ppm of sulphur as shown in Fig. 2. Fig. 3 shows the weld cross sections of the A-TIG and multipass welds on 316LN stainless steel. The A-TIG weld was made in single pass while the multipass weld was made with 11 passes. The A-TIG welds produced in the present work were sound and passed radiographic examination and bend tests without any indications. There was residual fused flux layer produced on the face of the A-TIG welds that had to remove using wire brush. The use of activated flux was found not to cause any significant change in the chemical composition of the weld metals compared to that of the base metals. The transverse strength properties of the 304LN and 316LN stainless steel welds produced by A-TIG welding exceeded the minimum specified strength values of the base metals. Improvement in toughness values were observed in 316LN stainless steel produced by A-TIG welding due to some refinement in the weld microstructure in the region close to the weld centre. There was no degradation in the microstructure and mechanical properties of the A-TIG welds compared to that of the welds produced by conventional TIG welding. So activated flux developed in the present work has greater potential for use during the welding of structural components made of 304LN and 316LN stainless steels.

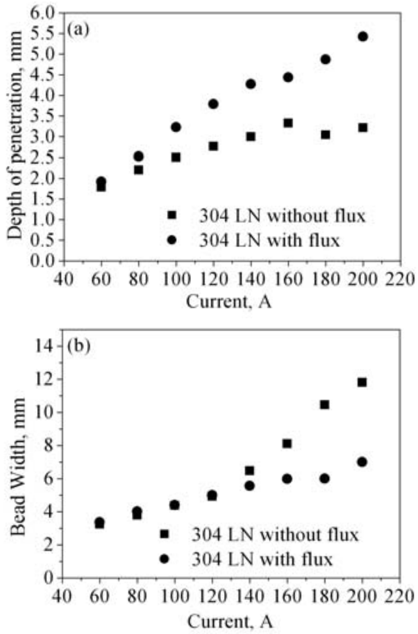

Fig. 1: Effect of activated flux on depth of penetration and weld bead width for 304LN stainless steels

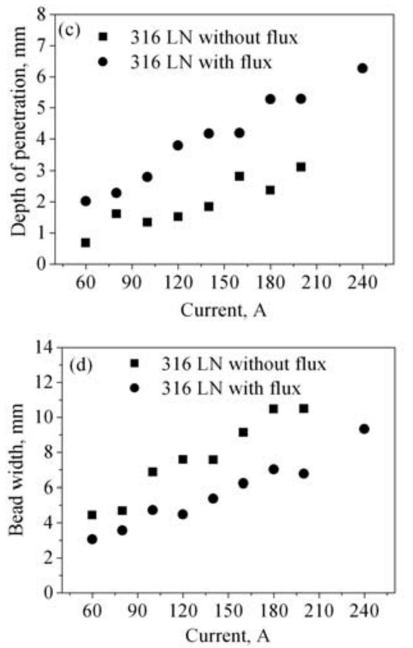

Fig. 2: Effect of activated flux on depth of penetration and weld bead width for 316LN stainless steels

SIGNIFICANCE OF A-TIG WELDING PROCESS

The implementation of the A-TIG welding process would result in a significant increase in weld penetration in austenitic stainless steels and overcomes penetration variability as a result of chemical composition differences between heats of material. It would also result in reduced heat input reduction in distortion, reduction in cost, improved productivity and overall improved quality. Use of activated flux has also been found to improve the mechanical properties of the welds compared to conventional TIG welds.

GENERAL EXPLANATION RELATED TO THE DESCRIPTION

The flux in the form of powders is made into a paste by mixing with acetone and the paste is applied on the surface to be welded by means of a brush. The acetone evaporates within seconds leaving a layer of flux on the surface.

The A-TIG process is suitable for any position welding. By employing A-TIG process, overall welding costs can be reduced upto 50%. These economics in fabrication costs can be achieved through:

a. Reduction in bevel preparation requirements
b. Decrease in number of weld passes
c. Shortening of welding times
d. Reduced consumption of welding filler wire
e. Elimination of back gouging and grindin
f. Reduced distortion

Typical applications include pipes and tubes in nuclear industry, Fabrication of pressure vessels and tube to tube sheets in heat exchangers in the power and chemical industries, hydraulic cylinders and undercarriage legs in aerospace industry.

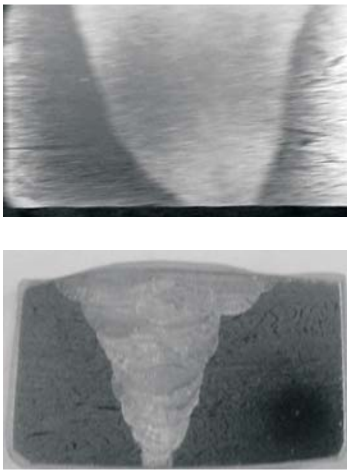

Fig. 3: Cross section of the 316 LN Stainless steel weld (12 mm thick) produced by (a) ATIG welding (b)Multi-pass TIG welding (11 passes)

BRIEF DESCRIPTION OF THEORETICAL BACKGROUND

The activated flux which gets vaporized during welding will constrict the arc by capturing electrons in the outer regions of the arc. Electron attachment can take place in the cooler peripheral regions where the electrons have low energy in a weak electric field. Towards the centre of the arc where there is a strong electric field, high temperatures and very high energy electrons and ionization will dominate. Thus restricting current flow to the central region of the arc will increase the current density in the plasma and at the anode resulting in a narrower arc and a deeper weld pool. A reversal in the Marangoni flow caused by the change in the coefficient of surface tension from negative to a positive value due to an increase in the dissolved oxygen content creates a narrow and deep weld pool. Combined operation of the above two mechanisms only lead to increased penetration by 300% in A-TIG welding.

ACHIEVEMENT

The use of activated flux has produced a significant increase in penetration of 10 – 12 mm in single pass TIG welding of type 304 LN and 316 LN stainless steels. The use of flux also has been found to overcome the variable weld penetration observed in austenitic stainless steels with less than 50 ppm of sulphur. The use of flux has caused no degradation in the microstructure and mechanical properties of welds compared to that produced conventional TIG welding. The use of flux therefore would result in significant cost reduction as there is no requirement for edge preparation and filler metal addition. This in-house developed Activated flux has been successfully field-tested and demonstrated for all its claimed advantages for welding of dummy core subassemblies made of 304L SS.

PUBLICATIONS ARISING OUT OF THIS STUDY AND RELATED WORK

1. An international patent "Tungsten Inert Gas Welding Flux for enhancing Penetration in Single Pass for austenitic stainless steels" has been filed for the development of activated flux for TIG welding of austenitic stainless steels (patent no. PCT/IN06/00442/dt. 8/11/06)
2. M. Vasudevan, A.K. Bhaduri, and Baldev Raj, Microstructure and Mechanical Properties of Austenitic Stainless Steels, International Welding Congress, February 16 – 19, 2005 Mumbai.

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