Commercialization and Promotion of Welding Flux for Precipitation Hardening Stainless Steel

I. Title of Research: Commercialization and Promotion of Welding Flux for Precipitation Hardening Stainless Steel

II. Research Team Members

Department	Name	Position
Materials Engineering	Kuang-Hung Tseng	Professor

III. Development Idea

The precipitation hardening (PH) stainless steel with excellent mechanical strength, better wear resistance, and good atmospheric corrosion resistance can be formed by adding additional elements such as copper, aluminum, titanium, niobium, and molybdenum to the iron-chromium-nickel stainless steel, followed by a solution treatment and an aging treatment. The PH stainless steel can be widely used in golf club heads, gas turbine blades, oil pipeline valves and nuclear energy reaction components, etc.

Tungsten inert gas (TIG) welding is one of the main arc welding processes, in which the necessary heat for welding is generated by maintaining an arc between a refractory tungsten electrode and the base metal to be welded. The electrode, the arc, and the area surrounding the molten metal are protected from atmospheric contamination by an envelope of inert gas during heating and subsequent cooling. It is most used to weld thin sections of stainless steel, aluminum alloy, magnesium alloy, and titanium alloy. The primary limitation of TIG welding is low productivity because of its low deposition rate, shallow penetration depth, and low travel speed. The inability for TIG welding to produce deep penetration welds limits the thickness of workpieces that can be reliably joined to less than approximately 3 mm. The low efficiency and productivity of TIG welding can be traced to the greater number of passes required to fill the groove joint for thick plates or heavy wall pipes, causing additional filler metals to be needed. Additional costs and a substantially longer welding time are incurred through edge preparation.

This variant of TIG welding called activated TIG welding was proposed by the E.O. Paton Electric Welding Institute of the National Academy of Sciences of Ukraine. TIG welding that uses activated flux to overcome the limitations by increasing joint penetration using a single-pass operation without any edge preparation. A key factor in activated TIG welding is the composition of an activated flux. The flux is a mixture of activated compounds suspended in a carrier solvent. Furthermore, the required flux powders depend on the physical, chemical, and mechanical properties of the various base metals to be welded.

This project primarily focuses on developing a precipitation hardening stainless steel flux and promoting its commercialization. The welding flux for PH stainless steel with the specific weight percentages of SiO_2, MoO_3, Cr_2O_3, Ni_2O_3, Al_2O_3, AlN, NiO and CuO is applied to join two workpieces of PH stainless steel, a weld formed between the two joined workpieces has a higher weld D/W ratio. Therefore, risk of problems such as thermal deformation and residual stress can be reduced. Moreover, when the welding flux for PH stainless steel is applied to join the workpieces of PH stainless steel with thickness greater than or equal to 3 mm, the formation of the bevel faces of the two workpieces of PH stainless steel before the welding procedure can also be omitted, solving the problems of decrease of mechanical strength, as well as large heat-affected zone (HAZ). In addition, omitting the formation of the bevel faces of the two workpieces of PH stainless steel can also reduce welding time and manufacturing costs.

IV. Technological Competition and Industrial Application

Activated TIG welding technology can be widely used in the industry fields of the machinery, power, construction, shipbuilding, and petrochemical manufacture. Commercial activated flux ingredient of super-duplex stainless steel activated TIG welding has been successfully developed by the present study. The activated TIG welding of super-duplex stainless steel has positive effects on the engineering technology: 1. increasing the penetration depth of welded joint; 2. reducing the distortion and residual stress of weldment; 3. saving time of pre-operation work; 4. saving time of post-treatment work; 5. instead of multi-pass procedures; 6. avoiding the heat-to-heat variations in the geometry of the resultant weld.

V. Merchandise Statement of Achievement

Since the power density of the heat source used in the TIG welding procedure is not high enough, the formed molten pool is wide and shallow, resulting in a resultant weld with insufficient depth when the TIG welding procedure is applied to join the two workpieces of PH stainless steel with thickness greater than or equal to 3 mm. Referring to **Fig. 1**, to eliminate the problem of forming the wide, shallow molten pool, before joining two workpieces of PH stainless steel 91, 91’, a side 91 of a workpiece of PH stainless steel 9 and a side 91’ of another workpiece of PH stainless steel 9’ are first milled by a miller M to form bevel faces 92, 92’, respectively. Referring to **Fig. 2** and **3**, a groove is formed at the butt joint of the bevel faces 92, 92’ of the two workpieces of PH stainless steel 9, 9’ for carrying out the TIG welding procedure with the use of the conventional welding rod W, as well as the tungsten electrode E. A weld 93 is therefore formed after the TIG welding procedure. The formation of the bevel faces 92, 92’ increases the depth of the weld 93. However, the formation of the bevel faces 92, 92’ also increases the width of the weld 93 formed between the joined workpieces of PH stainless steel 9, 9’. Besides, a HAZ is formed at the joint of the two workpieces of PH stainless steel 9, 9’, resulting in a decrease of mechanical strength of the jointed workpieces of PH stainless steel 9, 9’. Moreover, the larger HAZ also causes the problems such as severe thermal deformation, residual stress and even the decrease of the corrosion resistance. In addition, the formation of the bevel faces 92, 92’ also extends welding time and increases manufacturing costs.

It is therefore an objective of the present project to provide a welding flux for PH stainless steel that can form a deep, narrow weld between two jointed workpieces, and thus, formation of a bevel faces of the two workpieces before the welding procedure can be omitted.

Referring to **Fig. 4**, before carrying out the TIG welding procedure, the respective sides 11, 11’ of two workpieces of PH stainless steel 1, 1’ can be abutted with each other, and the welding flux for PH stainless steel 2 can be applied by a brush B on the surface of the two workpieces of PH stainless steel 1, 1’. The TIG welding procedure can be carried out afterwards. The welding flux for PH stainless steel is melted by a welding heat source together with a tungsten electrode to form a molten pool between sides 11, 11’ of the two workpieces of PH stainless steel 1, 1’. The molten pool is then cooled to form a weld 12, obtaining the two jointed workpieces. A deep, narrow weld 12 with a higher weld D/W ratio is formed due to the use of the welding flux for PH stainless steel.

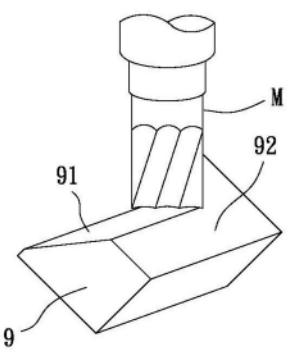

Fig. 1: Depicts pre-processing on a workpiece to be joined with another workpiece by TIG welding procedure

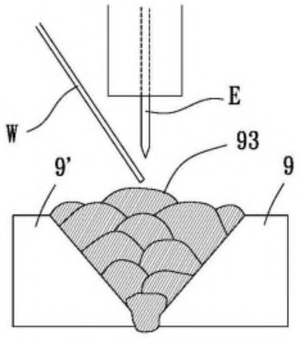

Fig. 2: Depicts a cross-sectional view of two workpieces being joined by TIG welding procedure.

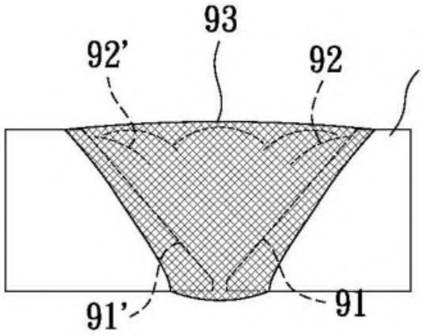

Fig. 3: Depicts a cross-sectional view of a weld formed between the two jointed workpieces.

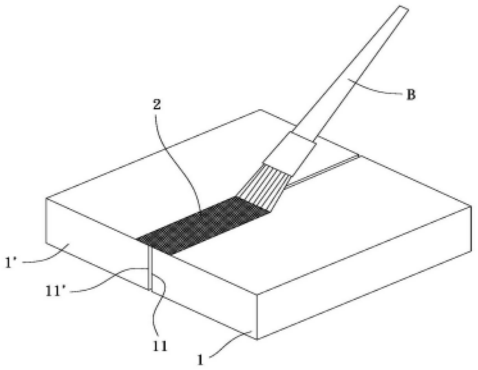

Fig. 4: Depicts a schematic diagram showing a welding flux for PH stainless steel spreading on surfaces of workpieces of PH stainless steel to be joined by TIG welding procedure.