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CONTENTS

ADEQUACY OF THERMOHYDRODYNAMIC MODEL OF THROUGH PENETRATION IN TIG AND A-TIG WELDING OF NIMONIC-75 NICKEL ALLOY*

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Results of experiments on weld formation in TIG and A-TIG welding of Nimonic-75 alloy, and results of computer simulation of the effect of convection on «sand glass» shape of weld are presented. The experiments were carried out with and without activating flux PATIG Nim-75-A on 3.15 mm thick plates. Adequacy of the model was evaluated by comparing the sizes of the real and simulated weld sections. The causes of recirculation flows were analyzed. Correlation of the experimental and computation data was revealed.

Keywords: *TIG and A-TIG welding, nickel alloy, penetration, mathematical model, adequacy of mathematical model*

Positive results connected with an abrupt increase of penetration depth at activating flux deposition on the surface of metal to be welded in TIG welding (A-TIG process) of titanium obtained at the E.O. Paton Electric Welding Institute [1, 2] stimulated investigations on arc column contraction in TIG welding of steels and other materials [3–5].

Study [6] marked the beginning of investigations of convection in welding. This work is devoted to the influence of surfactants on penetration depth. Work [7] provides experimental proof of the postulates of [6] on the key factor in penetration depth, namely, change of the sigh of temperature coefficient of surface tension $d\sigma/dT$ from negative to positive sign. Addition of surfactants lowers surface tension at melting temperature, and values of $d\sigma/dT$ coefficient become positive. However, at temperature increase up to 1900 °C, surface tension reaches values characteristic for pure metal with a maximum at critical temperature, and values of $d\sigma/dT$ coefficient again become negative, as for pure metal.

World's first two-dimensional model of weld pool convection [8], created in 1983, provided theoretical confirmation of the postulates of [6] and showed that Marangoni surface tension forces are predominating, and together with the Lorentz electromagnetic forces they are responsible for appearance of double eddy regions. Later it was established [9] that the sign of thermal concentration dependence of surface tension and its values determine the direction of convective heat transfer under the arc and number of vortices. Simulation of the role of electromagnetic forces in A-TIG welding is carried on, and the nature of the mechanism of this phenomenon still has not been determined. It is established that arc contraction does not affect austenitic steel penetration, but it should be taken into account as an auxiliary factor [10, 11]. It was proved here that electromagnetic convection promotes deep penetration [12] and the centrifugal component of the electromagnetic force is the dominating factor of penetration [13]. Published results are given only for the simplest axisymmetrical case of a stationary heat source of incomplete penetration on a stationary item from austenitic steel.

Technology of A-TIG welding of Nimonic-75 nickel alloy was tried out for the first time at PWI [14]. It is based on application of a short (1.5 mm) arc and activating salt-oxide flux PATIG Nim-75-A, containing metal fluorides and oxides. Fluorides promote arc contraction [5] and influence development of physical processes in it [15, 16]. Fluoride fluxes allow welding titanium sheets of up to 8 mm thickness [17, 18]. A team of scientists led by B.E. Paton [19] developed a theoretical model of arc contraction by fluoride fluxes. For sodium fluoride NaF at welding current I_w = 100 A value of anode spot radius $r_a \approx 1.5$ mm was obtained.

Another nickel alloy Nimonic-263 was welded over a layer of isolated titanium oxides and their mixtures, and the welding process was simulated using PHOENICS program [20]. Calculation results differed from experimental data.

Computer simulation has recently become the main method of scientific investigations. Program code developers and experimenters using such programs, face the following question: how the error of simulation results should be assessed? Computer simulation ends by prediction of the result of welding, and the most important characteristic of the prediction is the confidence level. According to [2] prediction error is a

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