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PECULIARITIES OF THERMAL AND HYDRODYNAMIC PROCESSES OCCURRING IN TIG AND A-TIG WELDING OF STAINLESS STEEL

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Analysis of distribution of temperature over the surface of the weld pool in TIG and A-TIG welding of stainless steel using the stationary and moving arc was carried out on the basis of calculation and experimental data. It is shown that in TIG and A-TIG welding the distribution of temperature over the weld pool surface above the boiling point has a characteristic plateau, the size of which is commensurable with size of the anode spot of the arc, the maximal temperature and size of this plateau being somewhat smaller in A-TIG welding. Problems of mathematical description and modelling of the Marangoni convection developing in A-TIG welding by the thermal-capillary and concentration-capillary mechanisms are discussed. Two circulation flows may form in the weld pool, their interaction causing a flow of the melt directed deep into the weld pool.

Keywords: TIG and A-TIG welding, stainless steel, stationary and moving arc, weld pool surface temperature, capillary Marangoni convection, force factors, penetration, experiment, mathematical modelling

The authors in their previous studies [1, 2] considered the phenomenological model of existence and interaction of the TIG/A-TIG arc-weld pool system, as well as the probability of existence of the quasi-keyhole in A-TIG welding. Peculiarities of the effect on formation of the weld pool and weld by thermal, mass exchange, electromagnetic, hydro- and gas-dynamic processes occurring in the arc column and weld pool in A-TIG welding using the stationary and moving arc were studied on the basis of analysis of experimental data and theoretical estimates. A substantial, fundamental difference in formation of the welds made by TIG and A-TIG welding with the moving and stationary arc was shown. This difference consists in the fact that in welding with the moving arc the processes of melting and solidification of the weld metal occur simultaneously, whereas in spot welding they are separated in time. Formation of the A-TIG spot weld is characterised by the presence of a specific deep crater with reinforcement on the weld periphery, which results from subsequent shrinkage phenomena. A fundamentally different formation of flows of the arc column plasma about the weld pool surface, directed from the periphery to centre, may take place in A-TIG welding, compared to TIG welding, this causing transfer of the overheated metal to the pool bottom and formation of the narrow and deep welds.

Study [3] offered a conjugate mathematical model of thermal, electromagnetic and hydrodynamic processes occurring in a weldment in stationary (spot) TIG welding. As established by modelling, parameters that determine the thermal state and hydrodynamics of the weld pool in arc welding are sizes of the anode (diameter of the current channel at anode) and heat

spots of the arc, R_a and R_h , respectively. The cardinal difference in penetrating capacity of the TIG and A-TIG welding methods is caused by a different proportion between sizes of the current and heat spots. Comparative analysis of the effect by three different force factors (Lorentz force, Marangoni effect, and Archimedes force) on the hydrodynamics and thermal state of the weld pool was carried out on the basis of results of experimental and calculation studies of the kinetics of penetration in TIG and A-TIG welding. At a small size of the anode spot (less than 4 mm), the dominant factor that determines depth and shape of the weld spot was shown to be a centripetal component of the Lorentz force.

Analysis of our results, as well as results of the studies performed by other authors, required additional experimental and theoretical investigations.

The purpose of this study was to conduct comparative analysis of experimental and calculation data on distribution of temperature over the weld pool surface, and consider peculiarities of capillary convection in TIG and A-TIG welding of stainless steel by using the stationary and moving arc.

Peculiarities of distribution of temperature over the weld pool surface. The calculations made by using the mathematical model [3] indicate to the probability of increase in density of the heat flow that exists at certain sizes of the anode and heat spots of the stationary TIG arc in welding of stainless steel 304, while this increase may lead to extra overheating of the weld pool surface to a temperature above boiling point T_b . This results in growth of heat losses for evaporation and decrease in assimilation of heat by the weldment. The temperature profile in overheating of the weld pool surface (in transverse direction) to a temperature above the boiling point has a characteristic plateau at $T > T_b$ (Figure 1).