Study and Analysis of Change in Characteristics at Rewelding on Different Alloy

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Abstract

Number of constructions, produced from eutectic silumins are continually increasing, therefore problem of their welding became very actual. Eutectic aluminium - silicon alloys are sensitive to changes of a welding thermal cycle. These cast aluminium alloys constructions after welding have large residual stresses, and mechanical properties of welded joint deteriorate. It is difficult to define welding regime in case of complex construction shape, especially near the component edges and other components with different wall thickness, using classical calculation methods. Most useful way to define heat input, optimal welding current and speed is simulating of welding process using finite elements method (FEM). The mentioned method enables to achieve lower size of the heat affected zone and better quality of welded joint.

Keywords: Cast aluminium alloy, Eutectic slumming, TIG welding, Thermal deformation, Finite elements method.

1. Introduction

Cast aluminium alloys constructions are used very widely. Complex constructions usually are joined using welding process. Sometimes the large components are mechanically damaged during exploitation. The change to new one is expensive, and sometimes it is cheaper to use repair welding or surfacing. During welding, local metal overheating takes place. Metal heating and cooling initiate different physical and chemical processes, structural transformations, volume changes, stresses, plastic deformation appearance. These variables influence on welding constructions quality. For more responsible constructions and elements affected by the hard load it is intolerable. All supplemental methods (bending, heat treatment) used to reduce the residual stresses and deformations just increase production costs sometimes without expected outcome. Therefore, usually it is necessary to improve welding technology, to optimise the welding regimes, depending on welding arc thermal influence on the metal near the seam, and reduce these negative effects. Object of modelling and experiments is eutectic cast aluminium - silicon alloy complicated shape construction. The cast aluminium - silicon alloys have good casting properties: fluidity, which ensures production of fine wall and complicated form castings, small linear shrinkage till 1 %, low melting temperature 863 °K, small cracking liability, good mechanical properties. Strength and corrosion resistance of aluminium - silicon alloys are increased using alloying, modification and heat treatment. For heavily loaded components the most suitable aluminium alloys are with improved mechanical properties. Designs from the given alloys after welding cannot be subjected to the subsequent post heat treatment or bending. Cast aluminium rims have complicated shape, different wall thickness in various places. During welding different heat transferring conditions in the rims relatively the weld axis can be found. This complicates the optimal welding regimes selection and residual deformations prediction, using classical calculation methods.

2. Experimental Method

The materials used in this study were aluminium alloys 2017A-T6 and 7075-T6 in the form of sheets of thickness of 6 mm.

The chemical composition of alloy 2017A was as follows: 3.9% Cu, 0.6% Mn, 0.6% Mg, 0.4% Si, and balance Al; whereas that of alloy 7075 was as follows: 1.63% Cu, 5.72% Zn, 2.49% Mg, and balance Al, both in wt%. Butt joints were made parallel to the rolling direction at the rotation speed of 450 rpm and a linear velocity of the tool of 4.7 mm/s.

The welding process was performed using a conventional tool: a threaded pin with a diameter of 8 mm, 4.6 mm length, and a shoulder with a diameter of 25 mm; the angle between the tool shoulder and the surface of the welded sheets was 1.5. The welding line was shifted 2 mm (¼ pin tool diameter) toward alloy 2017A. As a result, alloy 7075 was less stirred. The investigated sample (the joint) was artificially aged at 150 C for 8 h (post-welding heat treatment).

The microstructure investigations were conducted using an OLYMPUS GX51 optical microscope with Nomarski differential interference contrast and a Philips 525M scanning electron microscope (SEM). The optical microscopic observations were performed on the cross section and longitudinal sections layers (parallel to the face of the weld) that were ground and polished mechanically, and then etched with 2 mL HF, 4 mL HNO3, and 94 mL H2O solution.

Macrostructures were obtained as a composite of 32 images taken from the light microscope, which have been put together in ICE software, Microsoft. The ICE software application to create macrostructures is described by Wojcicka et al. (Ref 12). The SEM studies were conducted on fractures formed during rupture in a static tensile test. The tested samples were cut perpendicular to the line of welding.

The studies of the mechanical properties were carried out to determine the hardness profiles lHV0.2 at sections layers (mentioned above) located at a distance of 0.8, 1.6, 2.4, 3.2, 4.0, 4.9, and 5.5 mm from the surface (face of the weld) in the direction also perpendicular to the welding line.

3. Simulation Methodology

Welding specimen geometry and loading conditions are modelled, using the software “ANSYS”. To create a welded constructions volumetric model the “Solid70” 8-node brick finite elements was used. The process of welding was simulated with incremental steps, when welding arc movement process was divided into the suitable time intervals. In any cases of heat transfer process during welding, 3 models were used: heat source model, welded construction model and heat exchange conditions model.

Heat input model: For arc welding imitation model of a heat source, moving along the surface was used. The basic characteristic of a heat source at the fusion welding is the quantity of transmitted energy into the welded metal.

Heat input into welded joint is simulated by enter a thermal energy of a heat source. However, putting into practice, the given model for welding with concentrated heat sources usually it is difficult to achieve convergence of the solution. Therefore, in the present paper the surface model of heat source was used, considering the sizes of welding arc spot. The thermal efficiency of welding process depending on welding method and method of edges preparation are considered when calculation of the general capacity of heat source is carried out.

Transient thermal analysis: Temperature distribution of in a body, temperature changes during welding and sizes of heat-affected zone were established, using calculations based on the finite element’s method. The simulation of heat exchange processes in a welding pool and welded constructions slightly differs from the classical tasks of heat conduction. It is required to establish distribution of temperature in welded constructions, considering the dependence of material properties on temperature. The changes of material modular condition and phase transformations influence on the accuracy of results. In the case of simulation processes of heat exchange the greatest problems are related with heat transfer to the welding pool.

Heat energy transfer can take place in 3 ways: conduction, convection and radiation. In the solid heat is transferred due to conduction. From the metal surface heat is rejected due to convection and radiation. Heat transfer processes are important during welding: heat input during welding, dissipates in the atmosphere and solid due to cooling. Enthalpy of the material as a function of temperature was used in the thermal analysis with phase change problem. Using the software system TC-4A for thermochemical equilibrium calculation, melting point, phase changes and solidification temperatures of the aluminium - silicon alloy were established. The accepted conditional characters and definitions:

- Aluminium alloy is the isotropic material with properties being varied depending on temperature (thermal conductivity, effective emissivity, enthalpy).
- The thermal energy is transferred to in 3 ways: heat conduction, convection and radiation.

4. Effect of Welding Parameter

Recently many studies have been conducted to establish the optimum parameter for friction stir welding of dissimilar aluminium alloys and to identify their microstructures, mechanical properties and defect formation. It is important to note that for FSW of dissimilar material, addition parameters, such as material arrangement and position of tool plunge with respect to the weld centre line, need to be considered, as well as general parameter such as tool geometry, rotation speed and welding speed. Because material flows and thermal hysteresis differ between the advancing and retreating sides, so material arrangement and tool plunge position exert a significant effect on weld formation. In friction stir welding process, the welding parameter including tool rotation speed, traverse and axial force affect the friction heat generation and mixing process. Therefore, optimum welding parameter must be selected in order to produce the best joint strength. The efficiency of aluminium matrix composite weld joints is generally in the range of 60% to 97% of those of the base material. It is accepted that the ultimate tensile strength of friction stir welding joints of aluminium matrix composite increases by increasing the rotation speed until a specific limit. The highest hardness value occurs in the centre of the nugget zone followed by a gradual decrease across the thermo-mechanically affected zone (TMAZ) and Heat affected zone (HAZ) until reaching the hardness value of the base material as shown in Figure 9. This is attributed to more grain refinement in the nugget zone due to dynamic recrystallization and more uniform distribution of finer reinforcement particles in the weld zone due to friction stir welding action. It may also be concluded that lower heat input leads to the formation of coarse grains because of incomplete recrystallization and thus a reduction of the nugget zone micro hardness.

5. Conclusions

1. Using of the given heat source model and three–dimensional transient thermal analysis method for thermal cycles simulation gives a possibility to determine values of those parameters with high accuracy, especially for very complicated shape cast aluminium alloy welded components.
2. Comparisons of experimental and simulations results show that used calculation methodology gives the high correspondence of the results with the experimental. Values of temperatures received by finite elements method are very close to the real temperature distribution in the welded construction. Difference between experimental and simulation results do not exceed 5%.
3. Three–dimensional numerical simulation of TIG welding process by FEM is suitable for calculation of heat affected zone area in the welded joint. The calculated sizes of welded seam precisely reflect real geometry of welded seam. By changing the heat flow input estimated by calculations, it is possible to optimise welding regime and to reduce the size of heat affected zone. In this case the heat affected zone area decreased 1.5 times.

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