Abstract

Arc welding is the most common manufacturing process for the joining of structural elements for different applications. The high temperature developed by the application of heat causes significant metallurgical changes around the weld area, which decides the mechanical properties of the joint. Microstructure changes during welding are primary concern of welding industry. The other important consequences of welding are the residual stress and distortion. Non-uniform and changing temperature field during welding is primarily responsible for production of residual stresses and also distortion of the components. The knowledge of temperature field during welding is, thus, a very basic issue to be resolved. The close form solution of heat flow equation, first proposed by Rosenthal, gives very unreliable results in this high temperature range, particularly close to the weld pool. Also realistic joint configuration such as V-groove, U-groove welds cannot be analyzed with this method. Numerical solution using finite element method has been tried but application of standard unsteady state heat conduction formulation takes prohibitively large computation time.

Quasi-stationary state analysis has been used for mathematical formulation. Finite element analysis has been implemented to get the temperature distribution in the whole domain of plate. It includes all the non-linearities as well as other features of welding arc and weld pool in the analysis, so as to provide reliable solution of temperature field in welding, even for complex joint geometries. It offers the advantage of many times faster computation compared to transient heat flow analysis while retaining the accuracy of prediction. The most critical input data required for analysis of thermal cycle are the parameters necessary to describe accurately the heat input to the weld-pool from the arc. The size of heat source was obtained from the experimental measurement of crater (weld pool) size and the distribution of heat energy in the weld pool was assumed to be uniformly distributed.

Two experimental set-ups were used for the validation of numerical model. The first unit consisted of set-up for measuring arc length and diameter of arc at the top of plate consistent with welding current, welding speed and electrode. This set-up is also used to measure weld pool (crater) size. The second set-up consisted of manual metal arc welding (MMAW) machine and CCD camera to monitor the temperature distribution at the bottom of plate.

The results of the analysis are compared with those of experimental. In this study, bead-on-plate and v-groove configurations were investigated for different plate thicknesses. The experimental isothermal plots were compared with those of calculated results. Also temperature distributions along the center of travel of arc and at a distance away from it at the bottom of the workpiece have been given. The comparison of experimental and calculated results shows a good agreement. Additional numerical calculations, which depict heating as well as cooling cycle in the weld pool and heat affected zone, were performed for a wide range of welding process parameters.

***Keywords*:** Quasi-stationary state, Finite element method, Manual metal arc welding, Weld pool (crater), Image device, Temperature distribution