Numerical prediction of residual stresses and distortions in GMA welding of thin aluminium alloy plates

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ABSTRACT

The purpose of the present investigation is to numerically determine residual stresses and distortions in butt welded thin plates of aluminium alloy using finite element software Ansys workbenchv.15 during Gas Metal Arc Welding process. In the present investigation, two different welding conditions including backing plate and without backing plate were considered. A moving Goldak's double ellipsoidal volumetric heat flux model is employed to simulate the movement of weld heat source. For performing the numerical simulation, a coupled transient thermal-structural analysis based on thermo-elastic-plastic approach is adopted. Temperature-dependent thermal and mechanical properties of plates are also employed during numerical study. From the obtained results, it is found that less distortions and residual stresses were found in plates welded with backing plate arrangement.

1. INTRODUCTION

Aluminium- Magnesium alloys are non-heat treatable aluminium alloys. They are strain hardenable. They derive their strength from the hardening effect of alloying elements such as magnesium, silicon, iron etc. These alloys find their suitability in automotive industry, aerospace applications, various transport and marine applications. They possess excellent corrosion resistance, good weldability and have ability to maintain toughness at cryogenic temperatures.

Gas Metal Arc Welding (GMAW) is widely used process for joining aluminium alloys because it offers high welding speed, ability to join both thick and thin plates, higher heat input rate and narrow heat affected zone. However, residual stresses and distortions are inevitable in GMAW weldments. Residual stress is produced in the weld structure due to non uniform thermal expansion and contraction of material associated with localized transient heating and uneven temperature distribution caused by concentrated welding heat source during welding process. Consequently, incompatible strains are developed which led to the generation of self-equilibrating stresses that remains in the welded fabrications after it cools down to ambient temperature, thus producing the residual stresses (1). Residual stress results in uneven plastic deformations around the weld vicinity and surrounding areas. These stresses and distortions are undesirable in welded components as they affect fatigue performance, results in stress corrosion cracking, impair the buckling strength of components and causes deterioration of dimensional accuracy and aesthetic value of service components (2-5).

2. RESULTS & DISCUSSION

2.1 Thermal variations

Figure 1.2 illustrates the numerical results for transient temperature distribution in AA plates in case I and case II when advancing GMA welding heat source travels along the weld direction through different points at subsequent time steps of 10, 20 and 30 seconds. From figure 1.2 it can be perceived that very high temperature region exists in the weld zone and nearby heat affected zone (HAZ). As the heat source advances in weld direction, the temperature of the zone

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where initially heat source is located at $t = 0$ has decreased considerably to the range of 261–185 ˚C in both the cases. It should be noted that the highest temperatures obtained numerically in case I and case II shown in figure 1.2., i.e. 418 ˚C and 349 ˚C, is much lesser than the experimentally obtained values, i.e. 427 ˚C and 376 ˚C, respectively.

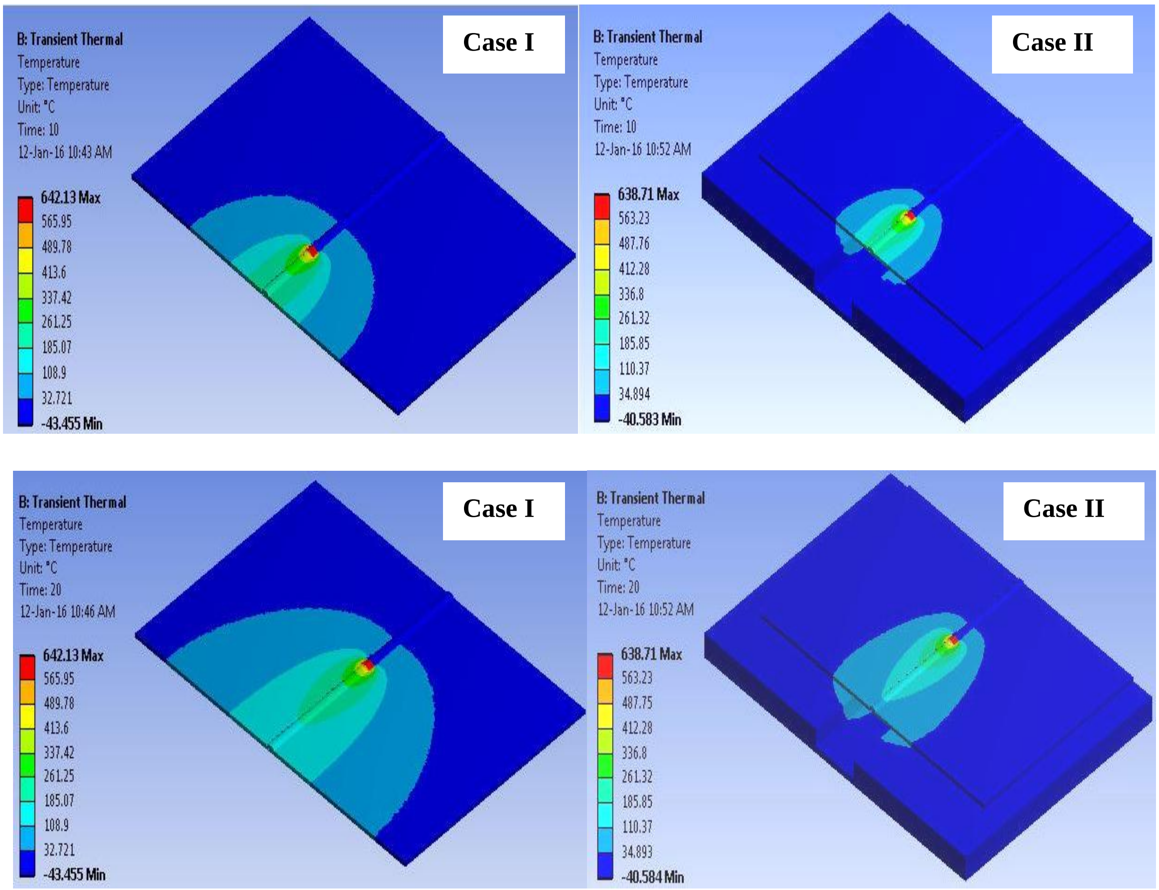

Figure 1. Numerical results for transient temperature in case I and case II at time steps of 10s and 20s in GMAW welding.

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