

## Article

# Metal-Cored Arc Welding of I-Profile Structure: Numerical Calculation and Experimental Measurement of Residual Stresses

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**Abstract:** In this study, numerical and experimental research of residual stresses was carried out on an I-profile structure model and welded by using the Metal-cored Arc Welding (MC-AW) technique. The numerical research was carried out by sequential simulation, using the birth and death element in the thermal analysis, while the same was omitted in the mechanical analysis in order to speed up the calculation process. The measurement of residual stresses was conducted on the outer surfaces of the model at a depth of 0.015 mm below the surface. It was determined that the longitudinal stresses in the weld and its immediate surroundings are tensile, while towards the ends of the model, they change to compressive. Transversal residual stresses exist mainly around the weld itself, and the immediate surroundings and decrease towards the ends of the model. A high agreement between the numerical and experimental results was found.

**Keywords:** MAG welding; metal-cored arc welding; MC-AW; X-ray diffraction technique; welding residual stresses; S355J2+N steel welding



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## 1. Introduction

When connecting various structural components in the field of energy, shipbuilding, automotive industry, pressure equipment, etc., a welding procedure is imposed as a logical and dominant choice of joining technology [1–4]. Among the many welding technologies used in industrial practice that are based on the addition of filler material depositions from molten metal wires, the Metal Active Gas (MAG) welding procedure occupies a prominent place due to its recognized quality, easy performance, low price and application simplicity [5,6]. Appreciating all the good sides of the material joining process by welding, it is impossible to avoid those bad ones that are reflected in the formation of residual stresses and deformations that arise from the rapid cooling and shrinking of the molten filler material and its close surroundings to the ambient temperature [7,8]. The harmful influence of residual stresses on the integrity and lifetime of welded structural components is especially visible in a combination of external tensile loads and tensile residual stresses in the presence of cracks. In this case, tensile residual stresses contribute to faster crack growth and reduction of the welded component service life, while, in contrast, compressive stresses in combination with tensile loads slow down crack growth [9,10]. In addition, rapid nonuniform cooling causes deformations and distortions of the welded component, which leads to deviations from the designed dimensions and creates problems when assembling the final product. The process of removing residual stresses and deformations by thermal and mechanical procedures [11,12] after welding is often long lasting and too expensive. Also, the large dimensions of the final assembly as well as work in the open space of a

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