Wire+arc additive manufacturing of Invar with pre-alloyed and in-situ mixed Fe and Ni wires

Romali Biswal, Goncalo R. Pardal*, Craig Coppen, Stewart Williams
Welding Engineering and Laser Processing Centre, Cranfield University, UK
*Corresponding author; Email address: r.biswal@cranfield.ac.uk; g.pardal@cranfield.ac.uk

Abstract

Due to exceptionally low thermal expansion coefficient, Invar alloys are widely used to manufacture moulds for precise composite structures in aerospace industry. Wire+arc additive manufacturing (WAAM) offers high deposition rates and is particularly attractive for depositing Invar which is a difficult material for machining. This study investigates (a) the deposition of pre-alloyed Invar for two commercially available compositions- one with and other without Nb, and (b) mixing of elemental Fe and Ni wires to deposit $Fe_{64}Ni_{36}$. The low thermal conductivity of Invar leads to a large melt pool length (30-32mm) and addition of Nb helps in reducing the melt pool size to 20-22mm. Nb addition led to significantly lower segregation of precipitates to the grain boundary and helped in mitigating grain boundary cracking which were observed in the composition lacking Nb. Tensile testing of pre-alloyed Invar (with Nb) performed in vertical (along the build direction) and horizontal orientation (perpendicular to the build direction) showed that the material shows weak anisotropy. The average yield stress and elongation to failure in vertical direction was 284.7 MPa, 34.2% and in horizontal direction was 296.5 MPa, 34.8% respectively. Digital image correlation imaging showed that the horizontal specimens undergo strain accumulation at the grain boundaries, thereby leading to a banded surface appearance. Fracture surface showed typical cup and cone failure, which agrees with the high values of ductility observed in the material. In-situ mixing was conducted for 5 compositions, and it was found that ratios close to 1:1 resulted in better mixing and a relatively more homogenous build.

Keywords: Invar additive manufacturing, tensile testing, fractography, digital image correlation, anisotropy