Application of GMAW to the welding of thick Super Duplex materials

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Background

- Super duplex stainless steel (SDSS) is highly sensitive to welding thermal cycles, where heat input, inter-pass temperature, and cumulative reheating in multi-pass thick-section joints directly increase the risk of sigma-phase precipitation and disruption of phase balance.
- Twin-wire GMAW welding offers attractive deposition rates for such applications; however, its arc stability on SDSS remains uncharacterised.

Aim and Objectives

Aim

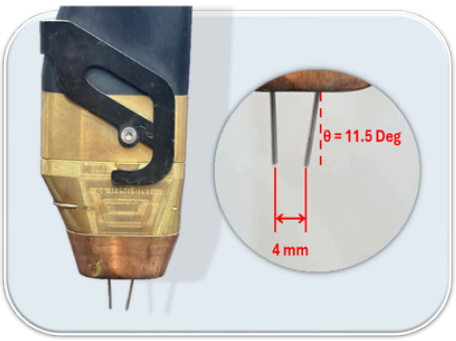
- To optimise the welding conditions for the best final microstructure and mechanical properties.

Objectives

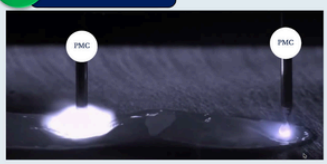
- To investigate twin-wire GMAW welding in different mode and gas combinations.
- To determine the weld quality of multi-pass SDSS piping by comparing the use of Ar + 30%He and Ar + 2.5%CO_2 shielding gases.

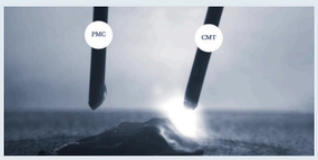
Methodology

1. Twin wire trials on bead on plate → PMC - PMC (Ar + 2.5%CO_2), PMC – CMT Ar + 2.5%CO_2), PMC – PMC (Ar + 30%He), PMC – CMT (Ar + 30%He) → Macro examinations → Compare the stability and bead profile of twin Vs single wire GMAW
2. Single wire GMAW-PMC trials on SDSS pipe → Macro & micro examinations → SEM and Hardness test on samples

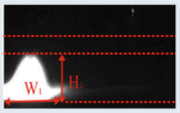


1 Results

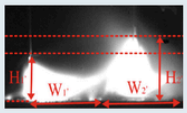




The twin wire welding on duplex exhibited a highly unstable arc, resulting in spatter and a convex weld bead shape, making it unsuitable for multipass welding

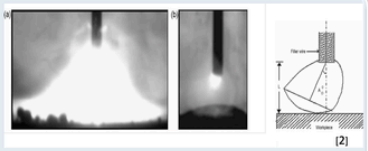


Leading wire Welding



Twin wire Welding [1]

- Electromagnetic forces cause arc attraction. Leading arc deflects towards the trailing arc resulting in reduced arc stiffness. Creates uneven thermal conditions.
  - Leading arc -> colder weld pool
  - Trailing arc -> hotter weld pool



- The low-current phase has reduced arc stiffness and pressure, making it prone to deflection.
- Arc deflection in this phase can initiate arc blow and instability.

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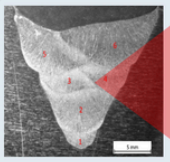
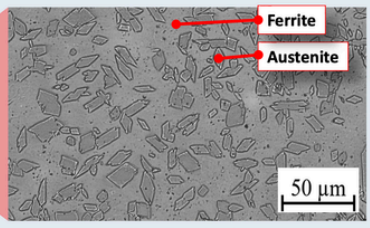
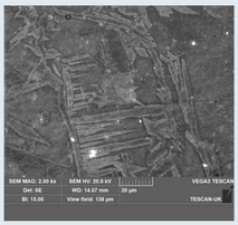


Macro Examination

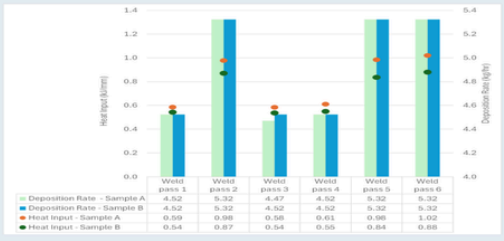


Micro Examination

Single-wire GMAW-PMC with both and Ar + 30%He(Sample A) and Ar + 2.5%CO_2(Sample B) shielding mixtures, at a heat-input range of 0.67–1.27 kJ/mm, provided acceptable phase balance in line with standards/recommendations.



SEM conducted on both samples; No intermetallic phases like sigma or chi is found.



In Sample A, the heat input is observed to be greater than in Sample B, even though the deposition rates and other parameters are nearly identical. Therefore, this increase can be attributed to the inclusion of helium in the shielding gas.

Conclusions & Future Works

Conclusion

- Twin wire GMAW produced arc instability across all process mode and gas combinations, suggesting the instability is intrinsic to the twin arc configuration on high-alloy duplex steel.
- Single-wire GMAW-PMC welding produced no sigma phase, porosity, or weld defects, and achieved good mechanical properties and phase balance when heat input and inter-pass temperature were properly controlled.
- No significant phase balance difference was observed between Ar + 30%He and Ar + 2.5%CO_2; however, Ar + 30%He produced higher heat input and a wider melt pool.

Future Works

- Investigate twin-wire GMAW with increased wire spacing to minimise arc interaction.
- Investigate higher heat input ranges for single-wire GMAW-PMC in SDSS to produce higher productivity.

References [1] Ye, D., Hua, X., Zhang, J., Wu, Y., Bai, Y., & Lv, Y. (2015). Analysis of arc interference and welding stability in twin wire GMA welding. International Journal of Advanced Manufacturing Technology, 81, 627–633. https://doi.org/10.1007/s00170-015-7225-

[2] Ghosh, P. K., Dorn, L., Kulkarni, S., & Hofmann, F. (2009). Arc characteristics and behaviour of metal transfer in pulsed current GMA welding of stainless steel. Journal of Materials Processing Technology, 209, 1262–1274. https://doi.org/10.1016/j.jmatprotec.2008.03.049