Title of the Thesis:

EXPERIMENTAL INVESTIGATIONS ON WELDABILITY OF AUSTENITIC STAINLESS STEELS USED IN INDUSTRIAL BOILERS USING GAS TUNGSTEN ARC WELDING

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ABSTRACT

This thesis presents an extensive investigation into the weldability and penetration behaviour of 8 mm-thick 304H austenitic stainless steel using the Gas Tungsten Arc Welding (GTAW) process through a sequence of systematically designed experimental studies. The research integrates advanced process optimization strategies, activating flux techniques, filler-assisted welding, mechanical characterization, microstructural evaluation and machine learning-based modelling to develop a comprehensive understanding of weld quality enhancement.

The study begins with autogenous TIG welding performed on single-sided butt joints, where a structured experimental design is formulated using Response Surface Methodology (RSM) in conjunction with a Central Composite Design (CCD). This approach allows controlled variation of major process parameters such as heat input, shielding gas flow rate and torch angle across three levels. The resulting dataset enables detailed examination of how these variables influence weld bead geometry, including penetration depth, reinforcement and bead width. The systematic modelling provided by RSM–CCD supports the development of statistically reliable relationships between input parameters and weld responses, highlighting critical parameter interactions affecting weld formation.

Building on the trends identified in the initial investigation, a second phase involves double-sided TIG welding conducted with optimised parameter combinations derived from the global preference matrix of the Analytic Hierarchy Process (AHP). This phase addresses penetration limitations observed earlier by applying a structured multi-criteria decision-making framework to refine parameter selection. Subsequently, a third phase introduces Activated TIG (A-TIG) welding using a TiO_2-based activating flux applied on the faying surfaces. The activating flux promotes arc constriction and enhances heat transfer through the reverse Marangoni effect, significantly improving penetration depth and weld morphology under the optimised conditions.

To further expand the scope of the study, a fourth experimental phase investigates non-autogenous TIG welding using 1.2 mm SS 304H filler wire. This phase is again designed using RSM–CCD to explore how heat input, root gap and shielding gas flow rate influence weld penetration, fusion characteristics and mechanical performance. Post-weld evaluations include tensile testing to determine ultimate tensile strength and percentage elongation, as well as hardness and micro-hardness measurements across the weld zone, heat-affected zone and base metal. Microstructural examinations using optical microscopy and scanning electron

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microscopy elucidate solidification modes, grain morphology and phase distribution, enabling correlation with the observed mechanical properties and weld quality.

The final component of the study employs standard machine learning algorithms to model and predict weld quality indicators—such as bead geometry parameters, tensile strength, elongation and hardness—based on input welding variables. The comparative performance of the models demonstrates the potential of data-driven approaches in enhancing understanding of welding behaviour and in forecasting outcomes for process design.

Together, the sequential experimental phases, advanced statistical design techniques, activating flux application, filler addition and machine learning-based predictions contribute to a holistic assessment of TIG welding performance in high-temperature austenitic stainless steels. This integrated methodology offers valuable insights into the factors governing weldability, penetration behaviour and joint strength in critical engineering applications.

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