Confidential

Abstract

Title: "*Advanced Robotic Welding for High-Integrity Small-Bore Tubing in Deepwater Projects.*"

Abstract:

Subsea oil and gas operations necessitate highly reliable and structurally sound connections to ensure safe and efficient hydrocarbon production and control. Among these, the interface end connections on Remotely Operated Vehicle (ROV)-installed bundled tube Steel Flying Leads (SFLs) serve as critical junctions within subsea hydraulic and chemical distribution networks. These assemblies facilitate the integration of hydraulic, electrical, and fiber-optic lines, and are predominantly constructed using small-bore tubing (≤1 inch) fabricated from corrosion-resistant and high-performance alloys such as super duplex stainless steels, nickel-based alloys, and austenitic stainless steels.

Historically, welding of these materials has relied on manual and limited orbital Gas Tungsten Arc Welding (GTAW) techniques. Manual welding introduces several challenges, including high complexity, prolonged cycle times (~1 hour per weld), low production throughput, and extensive welder qualification durations (~4 weeks). These factors have contributed to manufacturing bottlenecks, with weld quality metrics for critical joints often falling below 80%.

To address these limitations, a novel fully automated robotic GTAW system has been developed specifically for small-bore tubing in SFL applications—representing a first-of-its-kind solution globally. The system incorporates a Special Purpose Machine (SPM) equipped with robotic manipulators, Programmable Logic Controllers (PLCs), and a Supervisory Control and Data Acquisition (SCADA) framework to enable precision-controlled welding operations. Integrated safety and validation features—including area safety scanners, light curtains, laser-based monitoring, and SQL-driven data logging—ensure compliance with international safety and quality standards.

This automation initiative has resulted in a ~70% reduction in welding cycle time, improved weld consistency through precise parameter control, and eliminated operator-induced variability. The system has undergone comprehensive validation encompassing mechanical and metallurgical testing, dimensional inspections, and real-time SCADA-based monitoring, culminating in a fully traceable Manufacturing Record Book (MRB).

This paper details the design, system integration, and performance validation of the robotic welding solution, emphasizing its transformative impact on subsea fabrication workflows, quality assurance, and scalability. The successful deployment of this technology establishes a new benchmark for automated welding in high-specification subsea deepwater applications.

Keywords: Small-Bore Tubing Welding, Robotic GTAW Automation, Super Duplex Stainless Steels, Corrosion-Resistant Alloys, SCADA-Based Welding Control, Welding Cycle Optimization, Manufacturing Traceability, Special Purpose Welding Machines, Deepwater Hydraulic Distribution Systems