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Pitting Corrosion Restoration Solution for Thick Pipe by Additive Manufacturing

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INTRODUCTION & AIM

Recent advancements in the Directed Energy Deposition Wire Arc (DED-Arc) method for Additive Manufacturing have made it possible to restore damaged surfaces of pipes. Main focus is on pitting corrosion defect elimination because they are extremely detrimental when affecting large areas and may lead to safe operation impairment and subsequent decommissioning.

The chosen method is DED-Arc according to БДС EN ISO/ASTM 52900:2022 [1].

Aims

Pipeline restoration: Successfully eliminate pitting corrosion defects on heavily corroded 14MoV6-3 steel pipes using the DED-Arc method.

Equipment life extension: Provide a cost-effective alternative to decommissioning by restoring damaged industrial components.

Geometric preservation: Avoid post-weld heat treatment to prevent structural distortion of the outer pipe geometry.

Objectives

1. Material selection: Utilize a corrosion-resistant filler wire (Ni-Alloy 625) specialized for chloride-containing and acidic environments.
2. Process optimization: Apply a 50% pass overlap and the temper bead technique at a low heat input.
3. Non-destructive testing: Perform Visual Testing (VT) and Ultrasonic Testing (UT) to verify surface quality and ensure zero disbonding.
4. Microstructural characterization: Evaluate bond strength, porosity, microcracking and interface zones using microhardness and microstructural analysis.
5. Performance verification: Confirm satisfactory corrosion behavior and achieve high deposition rates for practical application.

METHOD

A pipe made of 14MoV6-3 (1.7715 according to EN 10027) material sustained pitting and was heavily corroded. For the DED-Arc, filler wire was selected with a minimum molybdenum content (Ni-Alloy 625), which is very resistant to generalized aqueous acidic corrosion, pitting and stress corrosion cracking (SCC) in chloride-containing environments. No post-weld heat treatment (PWHT) was allowed in order not to corrupt the pipe outer geometry. Extracted samples were tested with microhardness measurement: bond strength, microcracking detection, porosity, interface zones assessment as well as microstructural analysis. After the application, visual testing (VT) for the surface quality was performed followed by ultrasonic testing (UT) as a non-destructive evaluation of the restored areas with checking for disbonding and internal imperfections. Table 1 shows the parameters for the DED-Arc process.

Position	PA
Filler metal EN ISO 18274	S Ni 6625/ Ni-Alloy 625
Diameter	1,2 mm
Current	100-120 A
Volatage	28,7-30 V
Travel speed	140-155 cm/min
Heat imput EN 1011-1	0,4-0,7 KJ/mm
Wire speed feed rate	5-8 m/min
Distance from pipe	10-12 mm
Nozzle diameter	10-18 mm
Shielding gas EN ISO 14178 Z- ArHeHC	15-22 l/min

Figure 1 DED-Arc process parameters values

RESULTS & DISCUSSION

The DED-Arc method allows the restoration to be performed with 50 % overlapping of each successive pass and performing temper beat technique thus eliminating the need for PWHT. Strictly controlled parameters provide low dilution between material base and overlay with strong metallurgical bonding. The process has 0.4 to 0.7 KJ/mm heat input, no defects and the restored surface pass UT and VT. Pitting holes have been filled in. The deposition rate achieved is 5 kg/h. The corrosion behavior of the obtained cladded pipe proves satisfactory.

Visual examination of the pipe surface revealed extensive, deep pitting corrosion fields. These localized defects pose a catastrophic risk to operational safety by causing severe wall-thinning, which can lead to bursting or leakage if left untreated. On figure 1 is shown the overall view of the 14MoV6-3 steel pipe showing severe pitting corrosion defects and localized material loss prior to restoration.

Baseline - non-destructive testing has to be performed via ultrasound to precisely map the restored wall thickness and identify internal sub-surface imperfections caused by the corrosive environment. This data establishes the volumetric requirements for the subsequent additive repair effectiveness. Figure 2 is giving the ultrasonic testing (UT) profile of the calibration pipe sample strip, that is prepared for the DED-Arc cladding procedure evaluation.

Figure 1 Observed severe pitting in 14MoV6-3 pipe

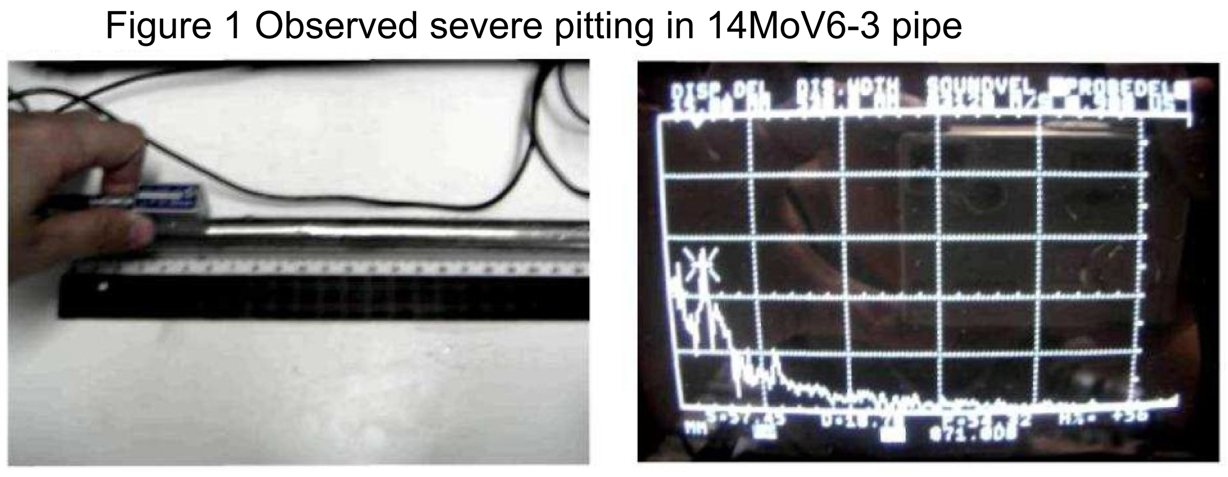

Figure 2 UT testing of sample for additive repair effectiveness

The restoration proposed can be executed using an automated DED-Arc system utilizing Ni-Alloy 625 filler wire. The process has to be precisely calibrated to achieve a high deposition rate of 5 kg/h while keeping the heat input low (0.4–0.7 kJ/mm) to prevent base metal distortion. Figure 3. Experimental setup of the DED-Arc system during the automated overlay cladding process.

Important for applying the overlay are 50% pass overlap and utilizing the temper bead technique, so as all pitting cavities to be completely filled. Post-repair visual (VT) and ultrasonic testing (UT) verify a defect-free surface with excellent metallurgical bonding, zero disbonding and no internal porosity. Figure 4 gives the visual appearance of the restored pipe surface, showing full defect elimination.

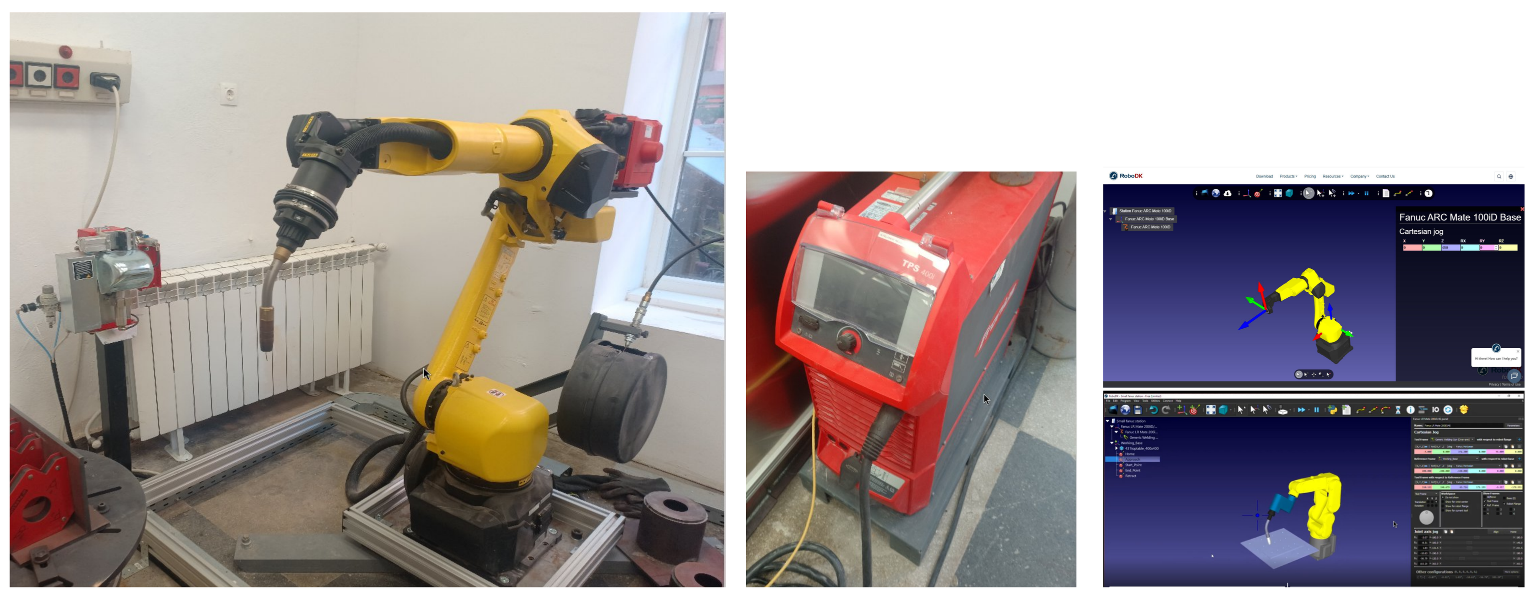

Figure 3 DED-arc application setup with software simulation

Figure 4 Restored surface of the pipe /without grinding/

CONCLUSIONS

Successful restoration & structural integrity: Successful restoration of corroded pipe has been performed by DED-Arc with improved rates of metal deposition and high quality which allows cost saving and extended equipment life.

Optimized process parameters: By strictly controlling the heat input within the low range of 0.4 to 0.7 kJ/mm and maintaining a 50% pass overlap, the dilution between the base metal and the overlay was kept to a minimum.

Elimination of PWHT & geometrical preservation: Implementation of the advanced temper bead technique effectively eliminates the need for PWHT. This successfully prevented any thermal distortion, fully preserving the geometry.

Complete defect elimination: All pitting corrosion holes and deep surface defects were completely filled in and eliminated. Non-destructive evaluation via Visual Testing (VT) and Ultrasonic Testing (UT) confirme a flawless, high-quality surface with zero internal imperfections, porosity or disbonding.

High efficiency & economic viability: The process achieves a high deposition rate of 5 kg/h with satisfactory long-term corrosion behavior. This proves that the method is a highly cost-effective alternative to decommissioning and replacement, significantly extending the service life of industrial equipment.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

References

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