Effect of 304L Stainless Steel Cladded Thickness with Q345R Steel on Mechanical Properties and Microstructure

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Introduction

Stainless steel clad (SCC) represents an innovative combination of two different steel into a singular form. This combination of steels provides superior durability and wear resistance. For example, the combination of 304L & Q345R is one of SCC steel plate that is widely used for pressure vessels, tanks and power plants, etc [1]. SSC is manufactured using metal deposition and hot rolling methods, exhibiting a flat and clean interface with a metallurgical bonding state at the interface. Diffusion of key elements C and Cr occurs at the interface, and the Vickers hardness in the transition zone of the SSC near the carbon steel side showed 545 HV 0.2 due to the martensite phase formed by the diffusion of these elements [2].

Results

1. Microstructure

- Primary solid solution constituents in Q345R steel, which encompass pearlite and ferrite, whereas 304L stainless steel predominantly comprises austenite.
- Examination of the interface between these materials reveals the presence of two prominent zones. The first is characterized as the carbonization area situated on the stainless steel (SS) side, while the second is identified as the decarbonization area residing within the Q345R steel.
- This dichotomy arises from the diffusion of C from the carbon steel to the stainless steel; the diffusion of Cr from the stainless steel into the interface and towards the

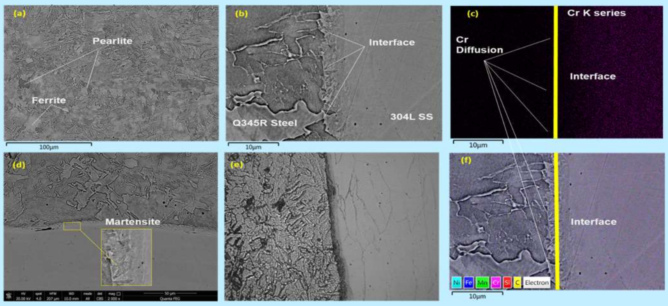


Fig.1: SEM Microstructure (a) Q345R Steel Microstructure, (b) SS interface cladding, (c-f) Cr diffusion, (d) Martensite phase, (e) Interface & 304L SS sufficient Etching

2. Tensile & Compression Behaviour

Fourteen tests, with seven in each orientation (rolling and normal direction), were conducted to investigate the impact of 304L SS cladding ratio on Q345R steel. Compressive stresses were measured, revealing that variations in cladding thickness had minimal effects. In the normal direction, compressive stresses ranged from 594 MPa (0.5 mm clad) to 637 MPa (1 mm clad). In the rolling direction, values varied from 582 MPa (2 mm clad) to 637 MPa (3 mm clad).

- σ_{uts} = 691 MPa for 304L SS, 654 MPa for cladded and 451 MPa for Q345R Steel.
- σ_y = 206 MPa for 304L SS, 510 MPa for cladded and 262 MPa for Q345R Steel.
- % elongation = 49% for 304L SS, 55.2% for cladded and 63.3% for Q345R Steel.

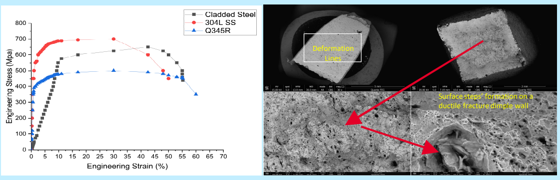


Fig.2: Stress Strain Curve with post tensile fractography

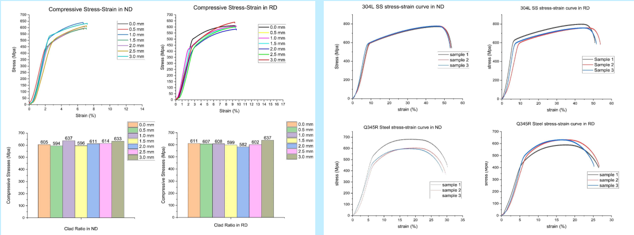
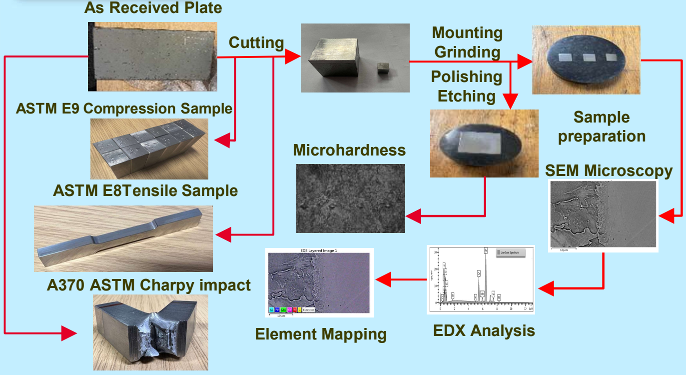


Fig.3: Effect of Cladded ratio and Orientation for 304L SS and Q345R in RD & ND

Flow Chart



As Received Plate
Cutting
Mounting
Grinding
Polishing
Etching
Sample preparation
ASTM E9 Compression Sample
ASTM E8Tensile Sample
A370 ASTM Charpy impact
Microhardness
SEM Microscopy
EDX Analysis
Element Mapping

3. Toughness Test

Forty-two Charpy toughness tests were conducted, with 21 tests in each orientation (rolling and normal direction), on 304L SS cladded with Q345R Steel. The cladding thickness varied incrementally by 0.5 mm for each sample. The tests were repeated three times for each cladding ratio, and the average mean values were calculated.

For samples without cladding, the average toughness in the rolling direction (RD) was the lowest at 148 J, while in the normal direction (ND), it was 195.6 J. The highest toughness values were observed in ND for the 0.5 mm cladding ratio (204 J) and in RD for the 1.5 mm cladding ratio (226 J). Notably, the toughness value for the 0.5 mm cladding ratio in RD was only 1% lower than that of the 1.5 mm cladding ratio, with a value of 224.6 J.

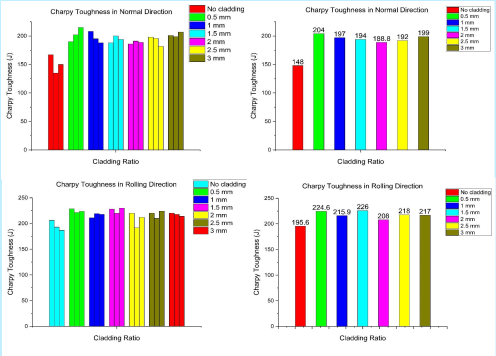


Fig.4: Effect of Cladded ratio and Orientation on Toughness

4. Microhardness

- The microhardness measurements were taken in different zones, including the stainless steel, Q345R steel, and the interface line. The average microhardness in the Q345R steel was around 200 0.5HV, whereas around 250 0.5HV on the stainless steel (SS) side. The highest hardness of 275 0.5HV was noticed in the interface line and the zones nearer.

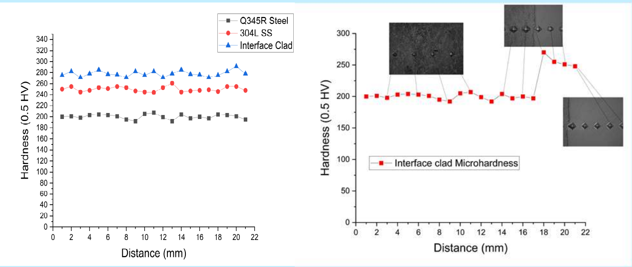


Fig.5: Microhardness distribution

Discussion

- The initial zone is characterized as the decarbonization area within the Q345R steel, while the carbonization area is observed on the stainless steel (SS) side. This phenomenon arises as a consequence of the migration of carbon from the steel side to the stainless steel, and conversely, the migration of chromium and nickel in the opposite direction.
- The heightened hardness exhibited within the interface is primarily attributed to the presence of a minor martensitic phase and the strain hardening that transpires within the juxtaposed grains.
- Overall, cladding ratio showed negligible influence on compressive stresses, with values consistently close to each other. However, higher strength and ductility in tension.
- Adding 0.5 mm cladding increased the toughness by 37% in ND while increased by 17% in RD.

References

[1] Sun, J., et al., Interfacial gradient M7C3 carbides precipitation behavior and strengthening mechanisms of stainless steel/carbon steel clad plates. Journal of Materials Research and Technology, 2022. 21: p. 3476-3488.
[2] Liu, X., et al., Interface Characteristics and Properties of a High-Strength Corrosion-Resistant Stainless Steel Clad Rebar. Metals, 2020. 10 (3): p. 373.

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