**Motivation**

- Porosity
- Loss of Nitrogen
- Nitrides
- Hot cracks

Problems in fusion welding

**Characteristics of FSW**

- Solid welding
- Low heat input
- Large strain and high strain rate deformation

- Integral correlation
- Local correlation

**Research Items**

**Main results**

**Microstructural gradients**

Distribution of Nitrogen element

**Mechanical properties gradient**

Hardness distributions

- Tensile properties

**Discussion**

There are no loss of nitrogen and weld defects in the as-welded joint of this high nitrogen steel.

The gradients of microstructure and hardness distribution in the as-welded joint result in internal restrain effect between different zones of the joint. As a result, the strength is increased but the elongation of the integral joint is decreased. PWHT effectively reduced this gradient feature in the joint. Consequently, the property of the integral joint was restored to the level of BM.

**Conclusions and Prospects**

1. FSW can effectively mitigate the loss of nitrogen and avoid other metallurgical problems associated with fusion welding of high nitrogen austenitic steel;

2. The as-welded FSW joint exhibited high strength and low elongation due to grain refinement in the NZ.

3. PWHT effectively tailored the microstructure in the as-welded joint and consequently the mechanical property of the joint was restored to the level of BM;

4. It was revealed that there existed a quantity of sub-grain boundaries in the NZ of as-welded joints. These sub-structures have significant effect on the properties of the NZ. A modified Holl-Petch relation between the hardness and effective grain size in the NZ was established.

This work not only verified the feasibility to weld high nitrogen steels by using FSW, but also identified the key factors including the internal restrain effects among different zones and sub-grain boundary strengthening that determine the property of the joints.

**Acknowledgements**

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**Materials and Methods**

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<th>Element</th>
<th>Fe</th>
<th>Cr</th>
<th>Mn</th>
<th>Mo</th>
<th>N</th>
<th>C</th>
<th>Cu</th>
<th>Si</th>
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**Welding conditions**

- Rotational speed: 800rpm
- Travelspeed: 50mm/min
- Tool material: W-La alloy
- Tool size: shoulder diameter/16mm, Pin length/2.3mm

**Post-weld heat treatment**

1100°C × 1h, quenched in water

**Modified Holl-Petch Relation of Hardness and Microstructures in the NZ**

\[ H_v = H_0 + k_H D_{eff}^{-1/2} = H_0 + k_{Rc}(k_{Rc} + k_0^*)l/k_{Rd}1/2d^{-1/2} \]

- \( H_v \): Holl-Petch slope
- \( k_{Rc} \): Recrystallization factor
- \( k_0^* \): Deformation factor
- \( d \): Grain Size

<table>
<thead>
<tr>
<th>Position</th>
<th>( d/\mu m )</th>
<th>( k_{Rc} )</th>
<th>( k_0 )</th>
<th>( k^* )</th>
<th>( D_{eff}/\mu m )</th>
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