

Fatigue Risks in Friction Stir Welding: The Impact of Manufacturing Defects

Pre-existing Damage & Rapid Failure

Research on AA2024-T3 FSW joints shows manufacturing defects act as pre-existing damage, causing joints to skip the crack-initiation phase and rapidly propagate cracks, significantly reducing fatigue performance.



Lack of Penetration (LOP)



Tunnel Defect



Oxide Inclusion



The Hierarchy of Defect Severity

Fatigue Strength Degradation at 2 Million Cycles



Sound Joint

100% Strength Retention

S-N Curve Slope (m):
7.14
(High Reliability)

Oxide Inclusion

34.8% Strength Retention

S-N Curve Slope (m): 3.41

Systematic degradation of fatigue strength.

Tunnel sops comced ligue strengths.

Tunnel Defect

28.2% Strength Retention

S-N Curve Slope (m): 3.39

Tunnel defects and Oxide inclusions reduce fatigue strength by 71.8% and 65.2% respectively.

Lack of Penetration (LOP)

13.4% Strength Retention

S-N Curve Slope (m): 2.74

Lack of Penetration (LOP) is the most critical risk.

Retains only 13.4% of a sound joint's fatigue strength at 2 million cycles.

Defects dictate the failure location.

Cracks originate at the defect site rather than the weld boundary or base material.

The Failure Mechanism: Initiation vs Propagation

Sound Joint
(High Reliability)



CRACK INITIATION
(Dominated by Initiation)

PROPAGATION & FAILURE

High S-N Slope (m) indicates reliability

Sound joint's high m (7.14) shows life is dominated by the initiation stage.

Defective Joint
(Rapid Failure)



RAPID CRACK PROPAGATION
m=2.74

CRACK INITIATION

Shift from Initiation to Propagation.

Defects compress the crack initiation stage, shifting the failure mode to rapid propagation.



Geometric sharpness accelerates failure.

Sharp tips and weak bonding in LOP defects bypass the initiation stage entirely.