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DECLARATION

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D**ate:**

C.R.SENTHILKUMAR

Research candidate

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ABSTRACT

Aircraft components suffer from fatigue failures, the majority of failures take place at the component welded joints. Friction Stir Welding (FSW) is a new candidate in advanced joining method, that promises cost reduction and structural efficiency compared to conventional joining processes such as riveting, bolting, TIG welding, plasma welding and laser beam welding. Nevertheless, until now FSW not yet been demonstrated as a sound quality joining process that is resistant to fatigue as for AA7075-T6 aerospace behaviour is concern

In the present work, FSW of AA7075-T6 aluminum alloy was characterised in terms of defect free, macrostructure, microstructure, hardness, tensile and weld residual stress. Cyclic load related properties such as fatigue endurance of the FSW joints were investigated and discussed. And numerical modeling were adopted to for the fatigue crack growth study, critical areas for fatigue crack initiation, propagation, and final failure of FSW joints were evaluated, and identified. FSW joints possess some amount of residual stress, and its effect on Post Weld Heat Treatment is identified.

The investigation of residual, tensile, hardness and fatigue crack growth behaviour properties of the FSW joints are based on As Welded and Post Weld Heat Treatment characterisation, such as artificial aging, solution treated and solution treated and aged of the joints. Thus the study is made to regain the base material property which is lost by FSW process.

Even though the experimental study is made in various aspects, the trend is to have a numerical aspect of study on the problem, where the specimens can’t be applied for experimental testing. So based on crack growth observations and

experimental characterisation of FSW joints with fatigue load is complicated, which requires numerically expensive program.

To determine fatigue crack growth life by the finite element method the fatigue crack propagation rate with applied load must be calculated uniformly in FEA modeling of crack tip propagation. There are two approaches followed traditional method and interface element method in the traditional method, were continuum is meshed with fine finite elements at the crack tip and the node release scheme involve one element length per cycle and in the interface method the model crack growth considering the energy released whenever the new surface is formed as the crack grows along the fraying planes of the crack surface is adopted and studied.

The crack do not generally propagate with each cyclic loads, because material do not change after cyclic load therefore, in traditional methods the crack tip mesh is redefined are the crack tip node is released in each cycle and the crack propagates one element length in each cycle. But in reality crack advance take place in very small increments over many cycles. To reduce these limitations the interface element approach is used in this analysis

This model replaces to calculate the accurate results for large welded structure which cannot be subjected to experimental testing. The good correlation achieved between the experimental data and the model predictions suggests that, the fundamentals of the model are correct. The crack growth model is successful in handling the crack, causing crack coalescence, based on applied stress data of FSW joints.

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ABBREVIATIONS

AA	-	Artificial Aging
ASTM	-	American Society for Testing of Metals
AW	-	As Welded
BM	-	Base Metal
CGHAZ	-	Coarse Grained Heat Affected Zone
EBW	-	Electron Beam Welding
FGHAZ	-	Fine Grained Heat Affected Zone
FCI	-	Fatigue Crack Initiation
FCP	-	Fatigue Crack Propagation
FF	-	Final Failure
FSW	-	Friction Stir Welding
GB	-	Grain Boundary
GP	-	Guinner-Preston
GMAW	-	Gas Metal Arc Welding
GTAW	-	Gas Tungsten Arc Welding
HAZ	-	Heat Affected Zone
NTS	-	Notch Tensile Strength
NSR	-	Notch Strength Ratio
PAW	-	Plasma Arc Welding
PFZ	-	Precipitate Free Zone
PMZ	-	Partially Melted Zone
PWHT	-	Post Weld Heat Treatment
SCE	-	Saturated Calomel Electrode
SEM	-	Scanning Electron Microscope
SIF	-	Stress Intensity Factor
ST	-	Solution Treatment
STA	-	Solution Treatment and Aging
TEM	-	Transmission Electron Microscopy
UTS	-	Ultimate Tensile Strength
VPPAW	-	Variable Polarity Plasma Arc Welding
YS	-	Yield Strength

NOTATIONS

a	-	Half crack length
$2a$	-	Crack length
A	-	Intercept of S-N curve
C	-	Crack growth intercept
da/dN	-	Crack growth rate
E_{pit}	-	Pitting potential
K	-	Stress Intensity Factor (SIF)
K_f	-	Fatigue notch factor
K_t	-	Theoretical stress concentration factor
m	-	Crack growth exponent
n	-	Slope of S-N curve
N	-	Number of cycles
N_f	-	Final failure life
N_i	-	Fatigue crack initiation life
N_p	-	Fatigue crack propagation life
q	-	Fatigue notch sensitivity factor
R	-	Stress ratio
S, σ	-	Applied stress
ΔS, $\Delta\sigma$	-	Applied stress range
ΔK	-	SIF range
ΔK_{cr}	-	Critical SIF range
ΔK_o	-	Initial SIF range
ΔK_{th}	-	Threshold SIF range

NOMENCLATURE

a	Half crack length for a central crack, constant
a_f	Final crack length
a_o	Initial crack length
B	Breadth, width of plate
c	A constant
C	Material dependent constant
C_p	Specific heat
da /dN	Crack growth rate (crack length per cycle)
E	Modulus of elasticity
f	Load vector, restraining force
h_t	Tangent modulus
DXZ	Dynamically Stirred action zone.
HAZ	Heat-affected zone.
TMAZ	Thermo-mechanical affected zone.
K	Stress intensity factor (MPa√m) (SIF)
K_c	Fracture toughness
K_{crit}	Critical stress intensity factor
K_{max}	Maximum stress intensity factor
K_{min}	Minimum stress intensity factor
K_{open}	Crack opening stress intensity factor
K_s	Spring stiffness
K_{th}	Theoretical stress concentration factor
ΔK	Range of stress intensity factor
ΔK_{th}	Range of threshold stress intensity factor
L	Length, latent heat of fusion

m	Material dependent constant
m (x, a)	Weight function
N	Number of cycles
n	Shape parameter
N_i	Shape function
N_p	Fatigue crack propagation life
r	Distance from crack-tip
r_{ol}	Overload radius
R	Stress ratio
r_o	Scale parameter
r_p	Plastic zone radius
S	Nominal stress
S_{ys}	Yield stress (same as ζ_y)
t	Thickness of plate
ΔS	Range of stress
Π	Total energy
α	Weld toe angle
δ	Crack opening displacement
ε	Strain
φ	Lennard-Jones surface potential
γ	Surface energy per unit area
η	Natural (local) coordinate, efficiency of welding
κ	A coefficient, constant
μ	Shear modulus
ν	Poisson's ratio
θ	Angle in radian

π	Density
ζ	Nominal stress (local)
ζ_{cr}	Critical bonding strength
ζ_{y}	Yield stress (same as S_{ys})
ζ_{open}	Crack opening stress
ξ	Natural (local) coordinate