INVESTIGATION INTO CRACK GROWTH LIFE PREDICTION OF A STRUCTURAL PANEL WITH REPEATING RIVET HOLES

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Abstract

Fatigue failure analysis plays a significant role in all industrial design applications. Many components are subjected to some form of fluctuating stress/strain, and thus fatigue failure potentially plays a significant role in the assessment of structural integrity. The occurrence of cracks in structures and components poses a real threat to the well-being of the structures. These cracks may grow and result in loss of integrity and at times, total structural failure.

Presented in this paper are the results of a research program on damage tolerance analysis and design of aerospace structures. The problem considered is an aircraft fuselage structural panel plate between two repeating rivet holes with a crack originating from one hole and approaching to the other hole is generic problem. The first problem generates accurate Stress Intensity Factor solution for Fatigue crack growth test panel using ANSYS. The second problem provides verification of fatigue crack growth life prediction using AFGROW software. Foreman, Harter, NASGRO and Walker FCG equations are used for prediction of crack growth life under constant amplitude loading.

Keywords: Stress Intensity Factor, Fatigue, Fatigue Crack Growth Life.

1. Introduction

Overall aim of this project is to investigate fatigue crack growth life prediction methodology for components and structures.

Specific objectives are:

- Finite element model development using ANSYS software.
- Determination of stress intensity factor solution for fatigue crack growth test panel using ANSYS.
- Prediction of crack growth life under constant amplitude, variable amplitude and spectrum loading using AFGROW software.

An aircraft fuselage structural panel plate between two repeating rivet holes with a crack originating from one hole and approaching to the other hole is generic problem addressed in this paper is as shown in figure1a and 1b and dimensions are shown in table1. Accurate determination of crack tip stress intensity factor as a function of crack length is a fundamental prerequisite. This is achieved by developing appropriate FE model using ANSYS software and determining the stress intensity factor using a special purpose post processing subprogram called **3MBSIF**.

AFGROW is public domain software for fracture machines analysis. With the material properties and SIF solutions as inputs, the AFGROW software is used to predict the residual strength and Crack growth life.

2. Methodology

The finite element method in general and ANSYS software in particular offers a universal procedure for computation of the crack tip stress intensity factors for the panel under investigation for different crack lengths. AFGROW uses this information and offers a number of options to predict crack growth life under variable amplitude and spectrum loading. These are exploited in the current study.

2.1 Stress Intensity Factor Solution to Fatigue Crack Growth

KI is stress intensity factor obtained from ANSYS for corresponding crack length. The correction factor ($\beta = K1/K0$) for FCG test panel is determined for different crack length and it is used as input for AFGROW software. We can see from figure 2 that the correction factor increases with increase in crack length.

2.2 Fatigue crack growth life prediction using AFGROW

The AFGROW analytical crack propagation program was used to determine fatigue Crack growth rate of FCG test panels.

The different material models available in AFGROW used in this research are Harter-T method, Forman Equation, NASGRO Equation, Walker Equation.

Material used is 2024 T3 aluminium alloy.

Young's modulus=10110 ksi

Yield strength=42.8 ksi

Plane stress fracture toughness=130

Forman constants: c=4e-7: N=2.9

2.3 Figures and tables

Table.1 Geometric dimensions of an aircraft fuselage structural panel plate

Width (W)	26 mm
Length(L)	60 mm
Pitch (P)	46 mm
Radius of hole (R)	10 mm
Young's Modulus(E)	74 GPa
Poisson's Ratio (υ)	0.33
Tensile Stress (σ)	100 MPa

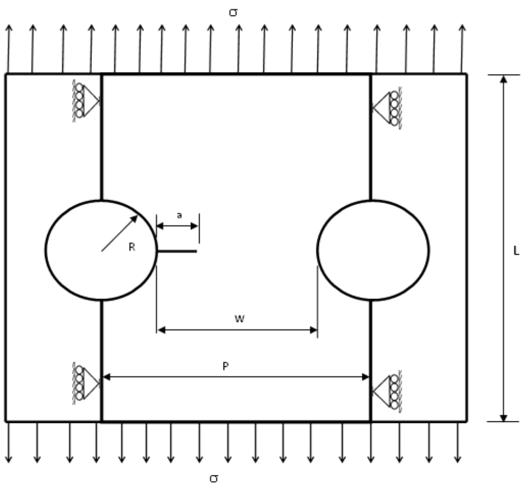


Figure 1a: Aircraft fuselage structural panel with periodic rivet holes.

Paris crack growth constant=0.8e-8

Paris exponent in NASGRO Equation=3.2

Exponent in NASGRO Equation, p=0.25

Exponent in NASGRO Equation, q=1

Threshold coefficient=1.21

Alpha=2

Smax/S0=0.3

Walker equation constants for 2024 T3 alluminium alloy are:

C=0.167e-8

n=3.273; m=0.618

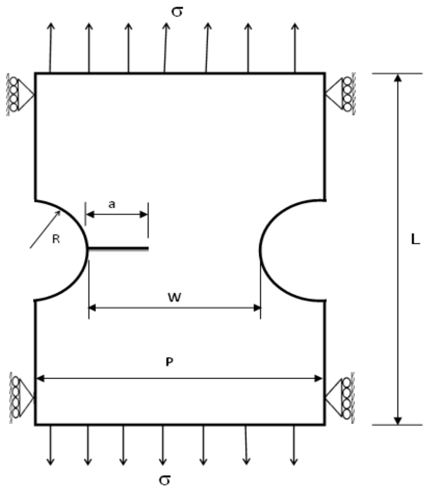


Figure 1b: Actual specimen to analysis

Nomenclature

a	crack length in mm
E	Young's modulus in N/m^2
K_I	Mode1 Stress intensity factor.
K_0	Reference Stress intensity factor used for normalisation.
υ	Poison's ratio.
σ	tensile stress
β	correction factor
ΔK	Stress intensity factor range
N	Number of cycles

da/dN Fatigue Crack growth rate

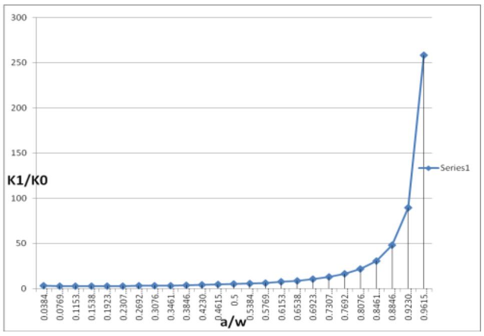
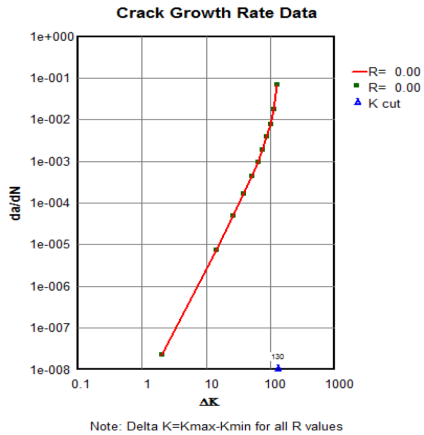


Figure 2: β factor for different a/W ratio.



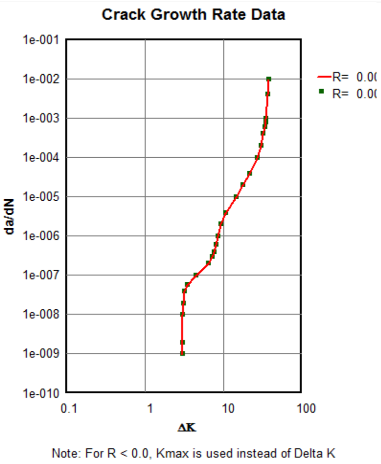
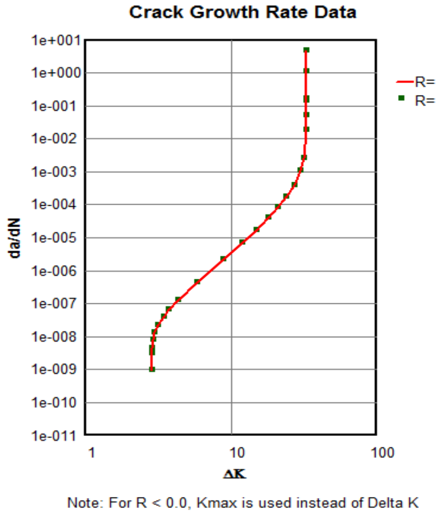


Figure 3: Fatigue crack growth rate for 2024 T3 using Forman and HARTER Equation



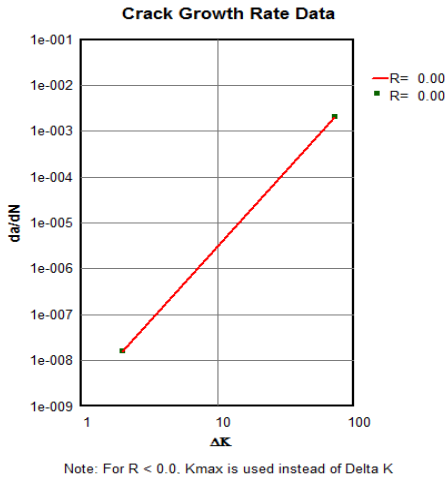
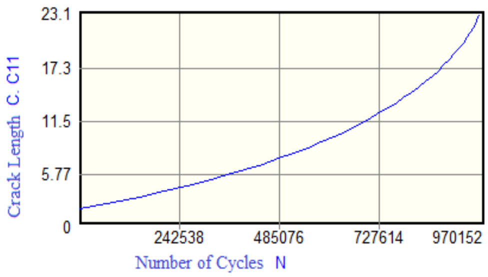


Figure 4: Fatigue crack growth rate for 2024_faa_t13 using Nasgro and walker



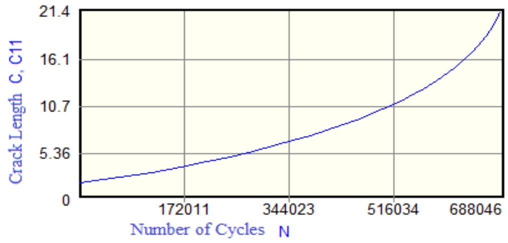


Figure 5: crack length verses no. of cycles for 2024 T3 using Forman and HARTER-T Equation

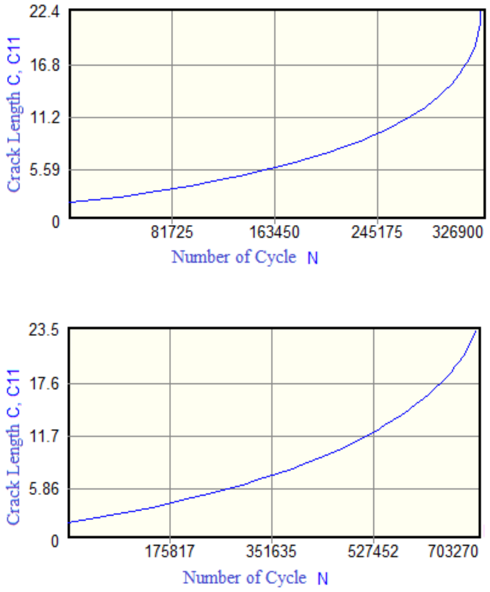


Figure 6: crack length verses no. of cycles for 2024 T3 using Nasgro and walker Eqation

3. Result & Discussion

"a" versus "N" and da/dN versus ΔK curves for four test panels are predicted using different Fatigue crack growth laws in AFGROW.The results are shown in the figure 3-6

4. Conclusion

The finite element modelling using ANSYS is demonstrated to provide highly accurate stress intensity factor solutions to complex cracked body problems encountered in practice. However there is a clear need to update the post-processing capabilities for application to curved stiffened panels which are encountered in aerospace and automotive structures. The pre-processing using the KSCON command enables progressively refined modelling around a crack tip to achieve reliable and accurate SIF solutions.

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