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Prediction of crack growth life 2A97-T3 lithium aluminum alloy under Mini-Twist load spectrum

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Prediction of crack growth life 2A97-T3 lithium aluminum alloy under Mini-Twist load spectrum

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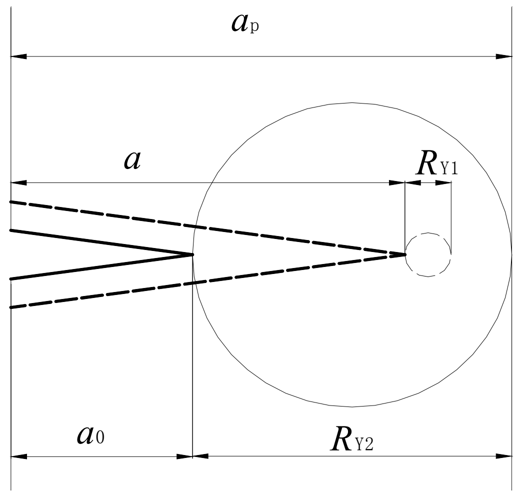
Abstract. An important aspect of life analysis and damage tolerance design of modern aircraft structures is a reasonable model and method for prediction of fatigue crack growth behavior and growth life under actual flight spectrum loading. Mini-Twist load spectrum and constant amplitude crack propagation curves test have been conducted towards the 2A97-T3. Coefficients of Paris equation and Walker equation for constant amplitude crack propagation curves are given. The Wheeler retardation model and AFFDL closure model are used to predict the aboved crack growth life. The predicted results of Wheeler retardation model and AFFDL closure model agree well with the experimental results.

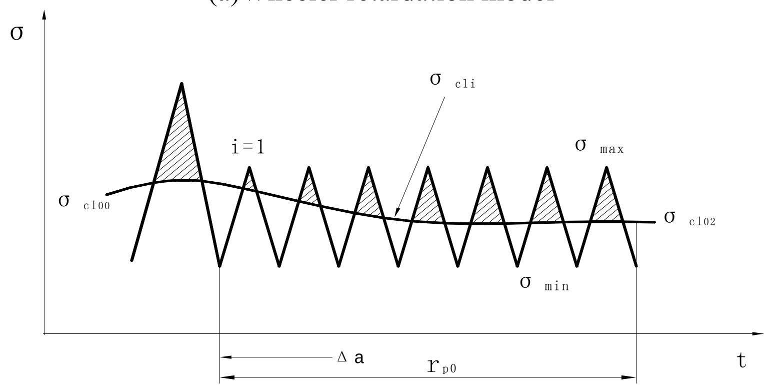
1. Introduction

In actual service, the aircraft structure usually bears variable amplitude load. Under variable amplitude fatigue loading, the crack propagation behavior is significantly affected by the interaction effect of load[1,2]. Therefore, an important aspect of life analysis and damage tolerance design of modern aircraft structures is a reasonable model and method for prediction of crack growth behavior life under actual flight spectrum loading[3].

A number of models have been proposed to account for load interaction effects in fatigue crack propagation. The fatigue crack growth model under variable amplitude loading condition can be divided into three types:(1) Retardation models[4,5]; (2) Closure models[6]; (3) Strip yield models[7]. Retardation models developed by Wheeler and Willenborg are based on the premise that residual stresss in front of the crack influence the growth rate. Figure 1 illustrates fatigue crack growth following an overload. More recent models were based on the assumption that plasticity-induced closure is responsible for load interaction effects, such as AFFDL closure model. An alternative to retardation models that focus on residual stress in front of the crack tip is a closure-based model.



(a)Wheeler retardation model



(b) AFFDL closure model

Figure 1 The Wheeler retardation model

This paper conducted the crack growth life experimentals for 2A97-T3 under constant amplitude and Mini-Twist load spectrum. The Wheeler retardation and AFFDL closure model are used to predict the aboved crack propagation life. The predicted results of Wheeler retardation and AFFDL closure model agree well with the experimental results.

2 Test materials and methods

2.1 Static property

Static performance test of 2A97-T3 was conducted through plate specimen as shown in Figure 2. The test method is GB/T 228[8].The static tensile properties are shown in Table 1.

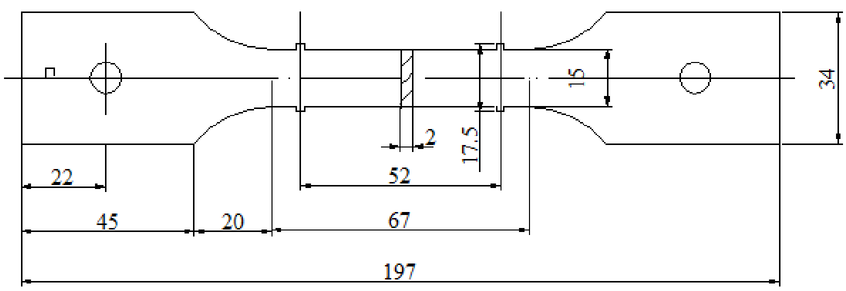


Figure 2 Static tensile property test plate specimen

Table 1 Static tensile properties of 2A97-T3

Material	σ_b[MPa]	$\sigma_{0.2}$[MPa]	δ_5[%]
2A97-T3	460	316	19.4

2.2 Constant amplitude crack propagation curve measurement

Choosing the center crack specimen (see Figure 3) to conduct the constant amplitude and Mini-Twist load spectrum crack propagation curve test of 2A97-T3. The test method is GB6398[9]. The width and thickness of center crack specimen are 1.5mm and 300mm, respectively. The fatigue tests were performed at room temperature and cyclic stress ratio of -1, 0.06 0.5. The constant amplitude crack growth da/dN~ΔK datas are shown in the Figure 4. Coefficients of Paris equation and Walker equation are shown in Table 2 and 3.

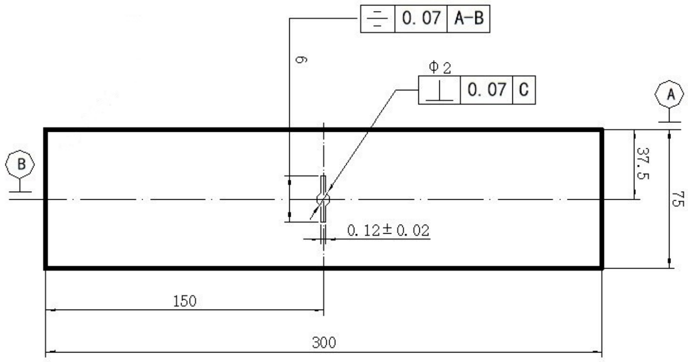


Figure 3 Cack propagation test specimen

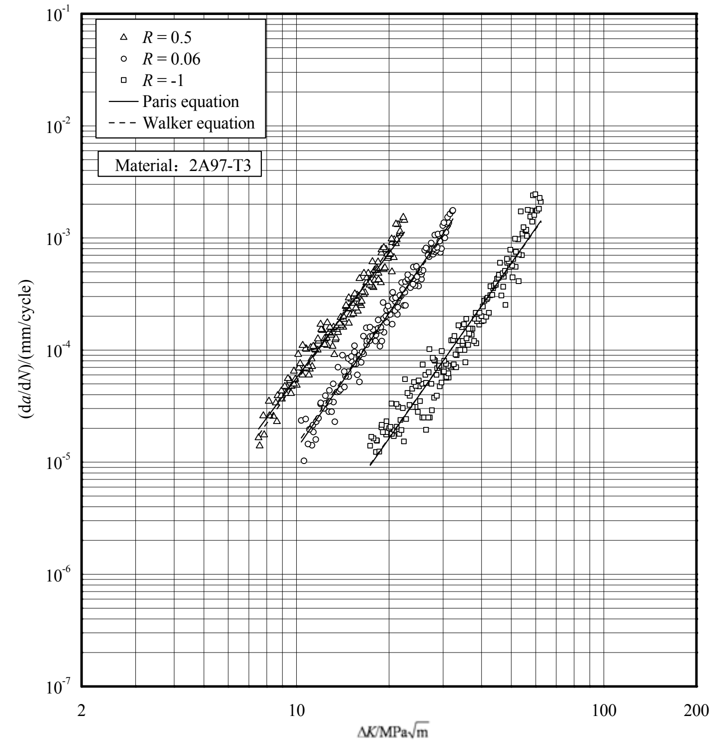


Figure 4 The constant amplitude crack growth da/dN~ΔK datas of 2A97-T3

Table 2 Coefficients of Paris equation

Paris equation	R	C	n	Regression judgment coefficient (r^2)
$da/dN=C(\Delta K)^n$	0.5	1.130×10^{-8}	3.70	0.965
	0.06	1.200×10^{-9}	4.04	0.974
	-1	1.247×10^{-10}	3.93	0.942

Table 3 Coefficients of Walker equation

Walker equation	C $(MPa.m^{1/2})^{-n}$.mm/cycle $(MPa.mm^{1/2})^{-n}$.mm/cycle	n	M_1	M_2	Regression judgment coefficient (r^2)
$da/dN=\begin{cases} C[(1-R)^{M_1-1}\Delta K]^n & (R\geq0) \\ C[(1-R)^{M_2-1}\Delta K]^n & (R<0) \end{cases}$	1.565×10^{-9} 2.186×10^{-15}	3.90	0.468	0.102	0.957

2.3 Crack propagation curve measurement under Mini-Twist load spectrum

The crack growth *a-N* datas under Mini-Twist load spectrum are shown in the Figure 5. The predicted results of Wheeler retardation model and AFFDL closure model agree well with the experimental results. Coefficients of Wheeler retardation model and AFFDL closure model are shown in Table 4.

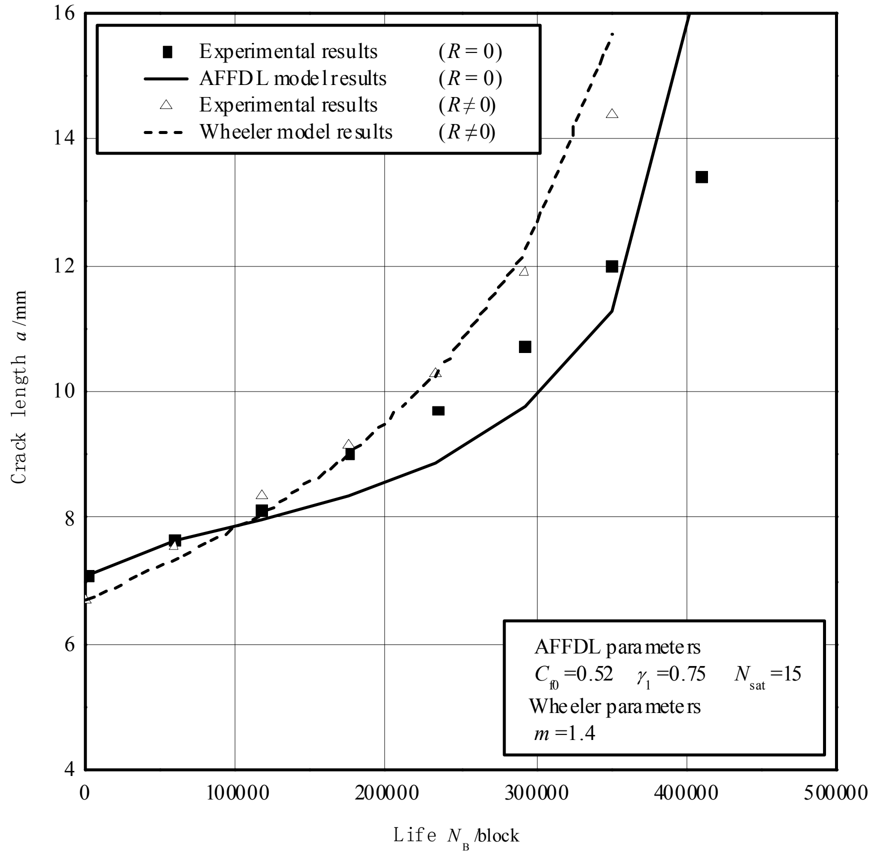


Figure 5 The Mini-Twist load spectrum crack propagation *a-N* datas and the predicted results of Wheeler retardation model and AFFDL closure model of 2A97-T3

Table 4 Coefficients of Wheeler retardation model and AFFDL closure model

Walker equations	C $(MPa.m^{1/2})^{-n}$.mm/cycle $(MPa.mm^{1/2})^{-n}$.mm/cycle	n		M_1		M_2
	1.565×10^{-9} 2.186×10^{-15}	3.90		0.468		0.102
AFFDL equations	C $(MPa.m^{1/2})^{-n}$.mm/cycle $(MPa.mm^{1/2})^{-n}$.mm/cycle	n	C_{f0}	C_{f-1}	p	R_{cutoff}
	1.508×10^{-9} 2.107×10^{-15}	3.90	0.520	0.480	3.56	0.90
AFFDL model	N_{sat}	B	γ_1	——		
	15	1	0.750			
Wheeler model	m	——				
	1.400					

3 Conclusions

(1) Constant amplitude and Mini-Twist load spectrum crack propagation curves test have been conducted towards 2A97-T3.

(2) Coefficients of Paris equation and Walker equation for constant amplitude crack propagation curves are given.

(3) The Wheeler retardation model and AFFDL closure model are used to predict the aboved crack propagation life. The predicted results of Wheeler retardation and AFFDL closure model agree well with the experimental results.

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