Determination of the nondestructive inspection interval accounting for the probability of detection in damage tolerance design

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1. Introduction

In the aircraft structure design, the damage tolerance design is used to prevent the maximum size of the assumed initial crack from growing to the critical size during service life and before next scheduled nondestructive inspection.

Traditionally, the inspection interval has been determined by using deterministic crack growth analysis referred as the Aircraft Structural Integrity Program(ASIP) method[1]. Later, the Reliability Centered Maintenance Analysis(RCMA) method, which uses the stochastic crack growth method to accounts for the uncertainty of crack growth rate, was developed[2-3]. In both methods, to determine the repeat inspection interval, the crack size with high detection probability is used as the minimum detectable crack size limit.

In this study, a modified RCMA method based on fatigue reliability analysis method[4-5] is proposed that incorporates the probability of detection(PoD) in the RCMA to determine the inspection interval considering the detection probability of any crack size. Under different PoD curves, the inspection scheme and class A mishap risk rate per flight hour are estimated and compared with those by the original RCMA.

2. Modified RCMA

It is assumed that the part always contains the initial crack with the maximum probable size[1]. The part is subjected to the nondestructive inspection at the scheduled inspection time. If a crack is detected, the maintenance action is taken, and then it is assumed that the part is replaced to the new one[4-7]. The crack always grows during the operation and the distribution of crack growth rate is the lognormal distribution[2-3].

The class A mishap risk rate per flight hour is as follow[2]:

$$R_a(\mathrm{t}) = \frac{P_a \times F(\mathrm{t})}{t} \tag{1}$$

where P_a is the conditional probability that the class A mishap occurs when the crack exceeds the critical size, $F(\mathrm{t})$ is the cumulative probability of failure and $R_a(\mathrm{t})$ is the class A mishap risk rate per flight hour.

For given initial inspection time, the maximum repeat inspection interval would be found by analyzing the cumulative probability of failure $F(\mathrm{t})$ and the class A mishap risk rate per flight hour $R_a(\mathrm{t})$ for the entire serviceable time of the part.

3. Application

The example of crack growth curve and PoD(Probability of detection) curves for application is shown in Figure 1 and Figure 2 respectively[2,8] :

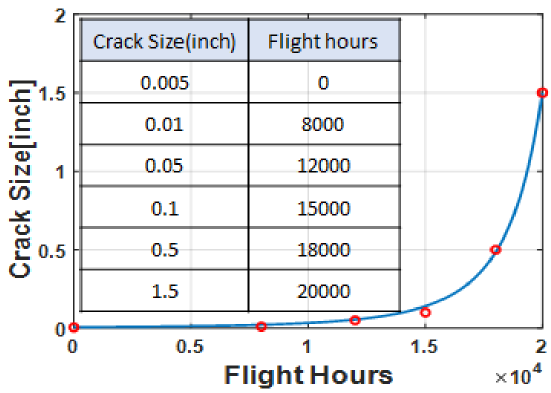

Fig.1 The example of crack growth curve[2]

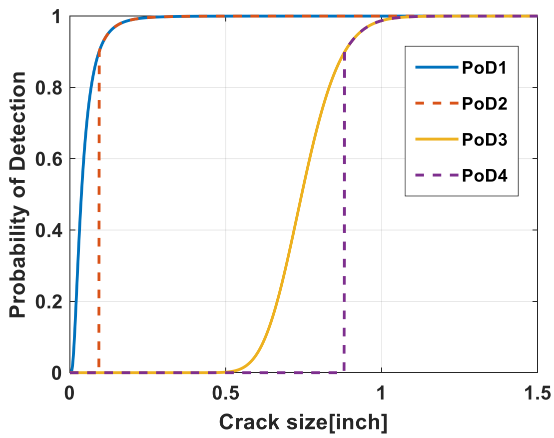

Fig.2 The example of probability of detection

The empirical crack growth rate is as follow[4-5]:

$$\frac{da}{dt} = XQa^{b} \quad (2)$$

where X is the lognormal random variable, a is the crack size, and Q and b are the parameters of the crack growth rate. Given R_a =5e-8/FH, P_a =0.8 and the initial inspection time τ_1 =7676FH, the maximum repeat inspection interval $\nabla\tau$ and the class A risk rate per flight hour during the service life are shown in Table 1 and Figure 3 respectively :

Table 1 Inspection plans

	PoD1	PoD2	PoD3	PoD4
τ_1	7676	7676	7676	7676
$\nabla\tau$	2704	2697	414	362

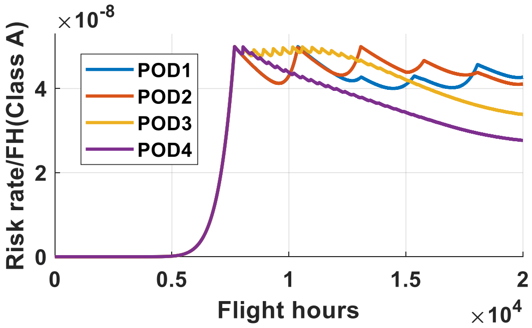

Fig.3 Class A mishap risk rate per flight hour

4. Conclusion

In this study, the modified RCMA is proposed, that is the method to determine the maximum repeat inspection interval for given initial inspection time. By using the probabilistic fatigue reliability analysis method, considering the probability of detection of the crack and using the maximum probable size as the assumed initial crack size, this method determines the reasonable maximum repeat interval complying with the original RCMA criteria and conservative requirement of the damage tolerance design.

Future work would contain the method to determine the inspection interval using the real time inspection data.

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