LIFE-CYCLE OF DETERIORATING STRUCTURES: EMPHASIS ON FATIGUE DAMAGE DETECTION DELAY AND ITS EFFECT ON RELIABILITY AND LIFE-EXTENSION OF BRIDGES AND SHIPS

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Abstract: Life-cycle management of deteriorating structures is essential for optimum inspection and maintenance planning, in which damage detection and service life extension need to be considered in an efficient and effective way. This paper deals with life-cycle management of deteriorating bridges and ships with emphasis on fatigue damage detection and its effect on reliability and life-extension. The fatigue damage detection delay is assessed considering uncertainties associated with the fatigue crack initiation and propagation, and inspections. The formulations of the state function for reliability analysis and the service life-extension are based on the damage detection delay. The relations among the damage detection delay, reliability and service life-extension are investigated. Furthermore, this paper presents a multi-objective optimum inspection planning approach by minimizing the expected damage detection delay, maximizing the reliability and maximizing the expected service life-extension.

Keywords: damage detection delay, inspection, reliability, safety, life-extension, uncertainty

1. Introduction

The damage detection with little or no delay can lead to improvement of structural reliability and service life-extension through the application of appropriate and timely repair/maintenance actions. For this reason, the damage detection delay, reliability and service life-extension should be assessed in an integrated way for efficient and effective life-cycle management [1,2]. This paper deals with such issues with emphasis on fatigue damage detection and its effect on reliability and life-extension. The probabilistic fatigue damage detection delay assessment is presented considering uncertainties associated with the fatigue crack initiation and propagation, and damage detection by inspections. The relations among the damage detection delay, reliability and service life-extension are investigated. The multi-objective optimum inspection planning based on minimizing the expected damage detection delay, maximizing the reliability and maximizing the expected service life-extension is also provided for fatigue sensitive structures.

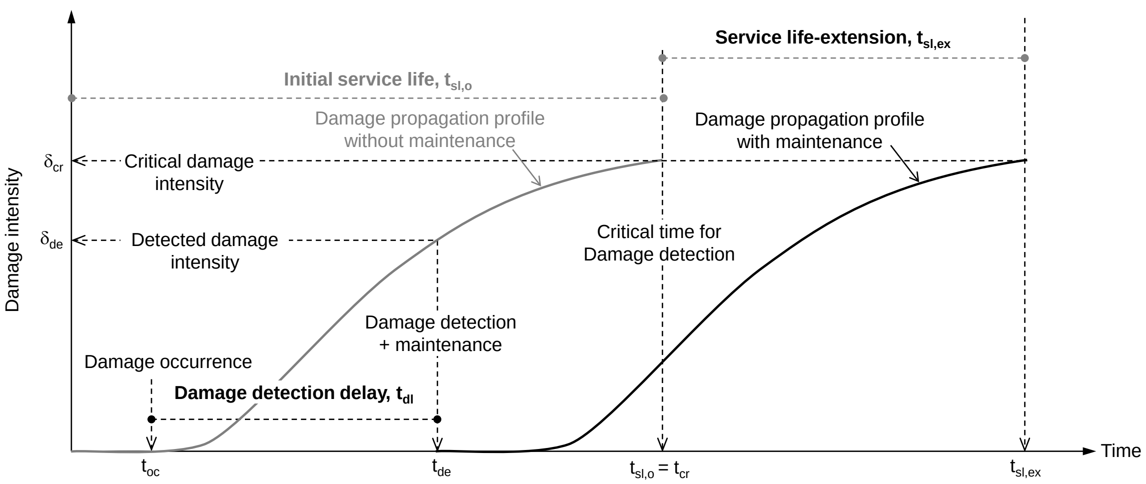

Fig. 1. Time-dependent damage intensity profile used to formulate the damage detection delay, reliability and service life-extension.

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2. Relation among damage detection delay, reliability and service life-extension

The damage intensity over time, which is used to formulate the fatigue damage detection delay, reliability, and service life-extension, is illustrated in Fig. 1. The interdependencies among f_1 = expected fatigue damage detection delay, f_2 = reliability and f_3 = expected service life extension are estimated using the coefficients of correlation $\rho(f_i, f_j)$ as

$$\rho\left(f_i, f_j\right) = \frac{E\left[\left\{f_i(\mathbf{x}) - E\left[f_i(\mathbf{x})\right]\right\} \cdot \left\{f_j(\mathbf{x}) - E\left[f_j(\mathbf{x})\right]\right\}\right]}{\sigma_i \cdot \sigma_j} \tag{1}$$

where **x** is the vector of the design variables (i.e. inspection times $t_{ins,1}$, $t_{ins,2}$,..., $t_{ins,n}$), and σ_i and σ_j are the standard deviations of the objective functions f_i and f_j, respectively. For the purpose of illustration, the application of a ship structure under fatigue [2] is presented in this paper. As a result, Table 1 provides the correlation coefficients among f_1, f_2 and f_3 for a single ultrasonic inspection (i.e. N_{ins} = 1) applied at time t_{ins} ranging from 1 to 10 years.

Table 1. Correlation coefficients ρ among f_1, f_2, and f_3 for a single ultrasonic inspection (i.e. N_{ins} = 1)

	f_1	f_2	f_3
f_1	1	-0.990	-0.853
f_2	-0.990	1	0.874
f_3	-0.853	0.874	1

The relations associated with {f_1, f_2} and {f_1, f_3} are illustrated in Fig. 2(a) and 2(b), respectively.

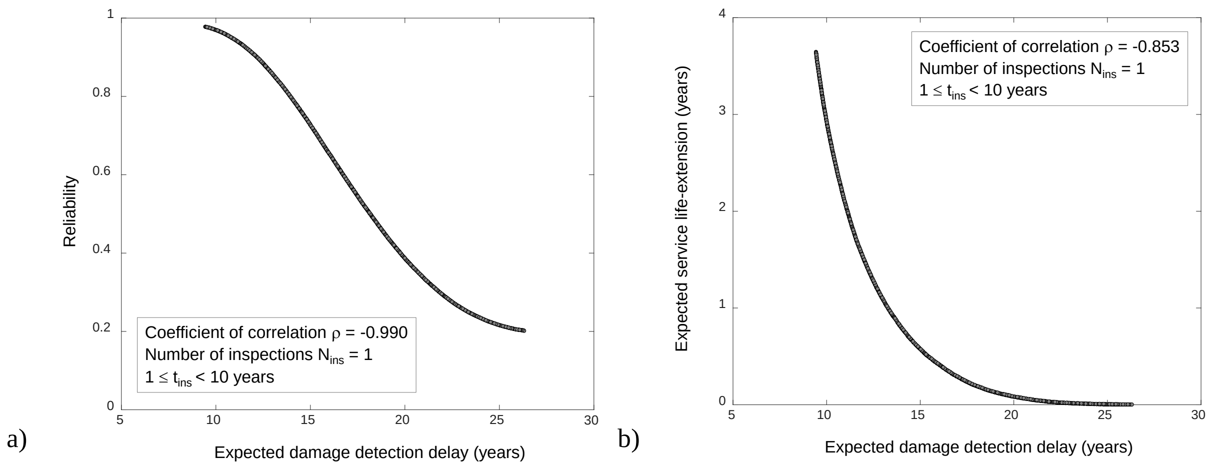

Fig. 2. a) Reliability versus expected damage detection delay; b) expected service life-extension versus expected damage detection delay.

3. Conclusions

This paper present the life-cycle management of deteriorating bridges and ships with emphasis on fatigue damage detection and its effect on reliability and life-extension. The effects of fatigue damage detection delay on structural reliability and service life-extension were estimated by using coefficients of correlation. From the result of the application of a ship structure under fatigue, it can be concluded that an increase in the expected damage detection delay leads to reduction of both the reliability and expected service life-extension of the damaged structure.

References

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