Engineering Failure Analysis 76 (2017) 44–54

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Fatigue crack analysis in a bolster of a metro train

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ARTICLE INFO

Article history:
Received 13 July 2016
Received in revised form 10 February 2017
Accepted 13 February 2017
Available online 22 February 2017

Keywords:
Fatigue damage assessment
Fatigue crack growth
Unstable crack growth
Metro train
Bolster

ABSTRACT

A Metro train is one of the heavily designed structures and is capable of having long life span of 20–30 years. The occurrence of fatigue crack in the bolster of a metro train is very unusual. In this paper, a series of fatigue damage assessments on a bolster was performed to understand the possibility of fatigue crack initiation under normal operating conditions. Additionally, fatigue crack growth analysis was performed to check for the possibility of unstable crack growth during normal service operation. In the fatigue damage assessment, minimum safety margin of 2.71 was calculated until the end of design life span of 30 years. In the crack growth analysis, operable years of 6.9 was calculated even a 30 mm-sized-initial-crack grows to unstable crack growth. From these two results, we can conclude that the cracks found at the bolster thought to initiate due to accidental over loadings during service, and even though the 30 mm-sized-initial-crack can be detected before it brings unstable crack growth considering maintenance period of normally every 3 years.

1. Introduction

Initiation and growth of fatigue cracks in a bolster of a metro train as shown in Fig. 1 is very unusual, because the bolster is heavy designed and manufactured with 6 to 9 mm thickness plates. The bolster transmits braking and acceleration forces generated at a railway bogie to the car-body through a king pin for moving and stopping the metro train. And it is the main component to support the dead weight of car-body and passenger weight. This is why the bolster is heavily designed to have a long life span even under unpredictable and excessive overloads such as dynamic impact load due to track irregularities, passenger load in rush hour [1]. Fatigue cracks in the car-body of metro train can be initiated due to various reasons such as material imperfection, manufacturing defect, unpredictable and excessive overloads during service. In this day, with the progress in material, manufacturing and pre-service non-destructive inspection technologies, the cracks originated from material and manufacturing defect are hardly found. While, cracks initiated by fatigue loading are found only once in a while in the weak points of the car-body. Therefore, it is important to understand the fatigue damage process on weak points to prevent similar crack problem in the future. Fracture mechanics [2–7] is a popular and practical method to understand the progress of crack initiation and propagation, and although many models to predict fatigue considering crack growth in real conditions have been proposed [8–11], but none of these methodologies have yielded satisfactory results under all conditions. Many factors contribute to crack growth, such as crack size and orientation, loading magnitude, direction and sequence and material characteristics. Therefore applying fracture mechanics in a real structure is still limited, but it is still valuable in identifying trends.

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http://dx.doi.org/10.1016/j.engfailanal.2017.02.005
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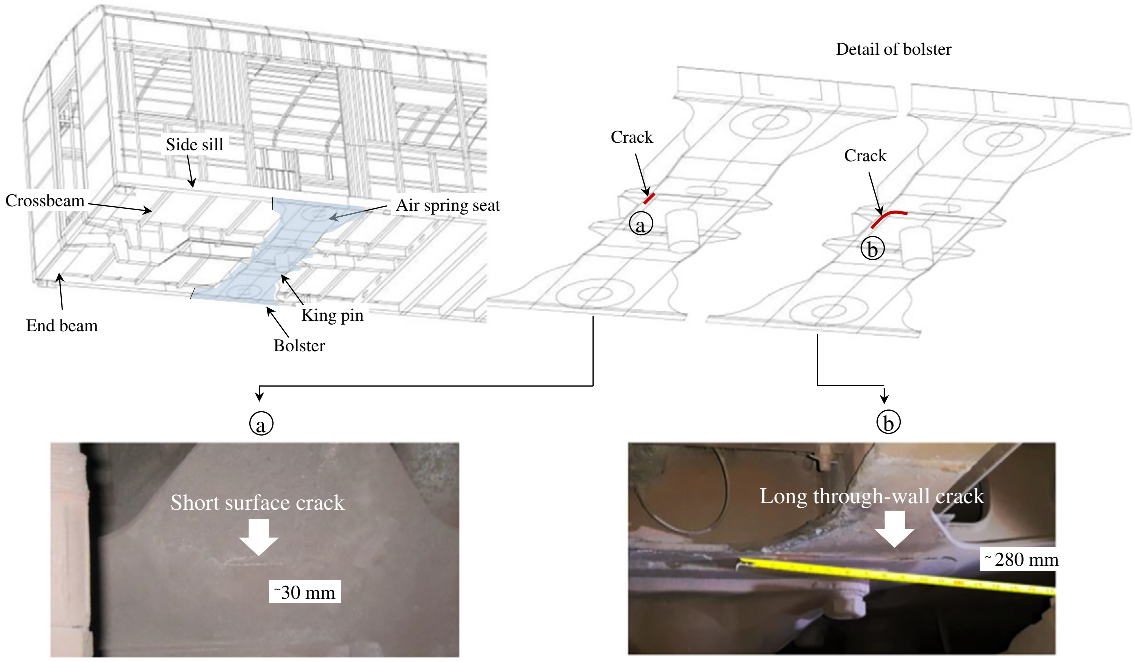

Fig. 1. Photos of two cracks found in a bolster of metro train.

Xiaoping et al. [8] presents an engineering model of fatigue crack growth under variable amplitude loading. They introduce a concept of equivalent stress intensity factor range and a modified Wheeler model to consider the phenomena of retardation of crack growth due to overload. They calculate the equivalent stress intensity factor when $R = 0$ by introducing a scaling factor which condenses different R-ratio curves into one $R = 0$ curve. Richard et al. [9,10] calculate the fatigue crack growth in a real structure by introducing the equivalent stress intensity range and growth angle. Pais et al. [11] present a simple analytical-numerical method to calculate dynamic stress history from the usage of monitoring data and stress on the fatigue crack growth model is used with the extended finite element method (XFEM). Recently, XFEM [12,13] has been successful for calculating crack path and growth speed for more realistic simulation of a real structure. To the author's knowledge, the main drawback of XFEM occurs in simulations with huge complex real structures that require millions of fatigue loading cycles, because the FE model should be changed in every step with the increment of crack size. In contrast, comparatively little research [14–17] has been presented on railway applications especially on the car-body structure. The authors [14] studied the effect of corrosion on fatigue strength

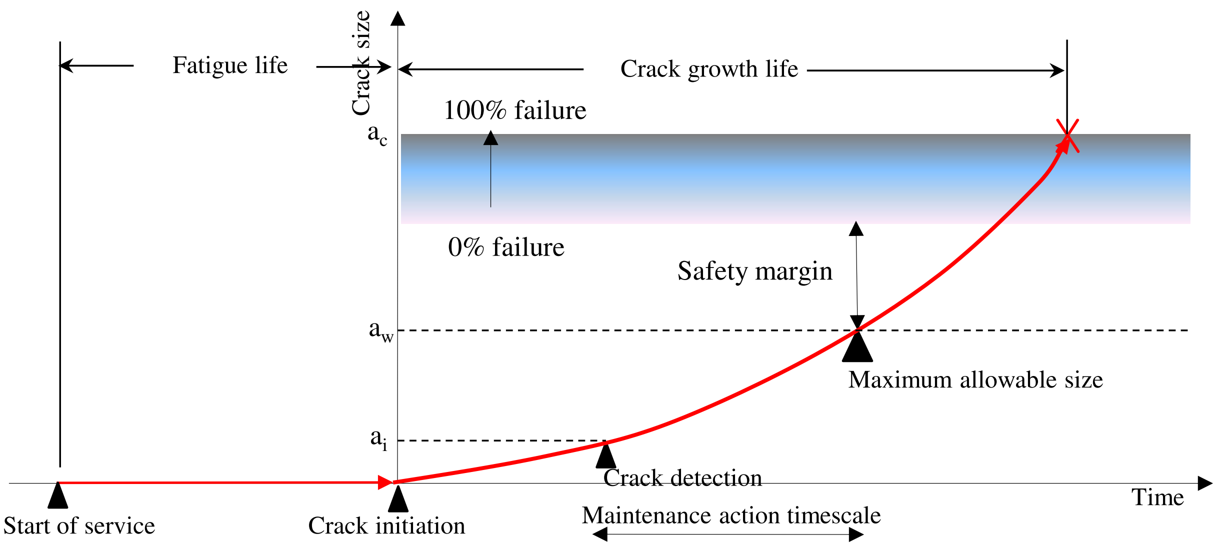

Fig. 2. Schematic of fatigue process of a long life span structure.