Engineering Failure Analysis 55 (2015) 169–181

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Investigation into the causes of fracture in railway freight car axle

Zoran Odanovic [a], Mileta Ristivojevic [b], Vesna Milosevic-Mitic [b,*]

[a] IMS Institute, Bulevar Vojvode Misica 43, 11000 Belgrade, Serbia
[b] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11120 Belgrade 35, Serbia

ARTICLE INFO

Article history:
Received 5 February 2015
Received in revised form 11 May 2015
Accepted 13 May 2015
Available online 3 June 2015

Keywords:
Railway engineering
Stress concentrations
Failurediagnostics
Finite element analysis
Non-destructive testing

ABSTRACT

Railway axles are vital parts of railway. Their failure in the form of dynamic fracture is commonly of disastrous outcomes for railway vehicles. Accordingly, railway axles are designed to be highly reliable, while the maintenance system requires regular inspection in terms of crack initiation. However, due to complex exploitation conditions, complex stress state and multiple stress concentration, railway axles often experience fatigue failures. This occurrence has been studied in a large number of papers. This paper too sheds light on the causes of fracture occurrence in the axle of railway freight car for coal transport in a thermal power plant. Detailed analyses were conducted on the axle fracture surface and mechanical properties. Also, microstructure of the axle material, as well as on exploitation conditions and stress state was examined. Calculations indicated that, apart from working load impact, the influence of press fit joints, especially of the one between the labyrinth seal and the axle is of crucial importance for the analysis of railway axle stress state. The entire numerical–experimental analysis has shown that the considered axle failure was caused by inadequate maintenance, insufficient axle strength and adverse stress state in the railway axle critical cross-sections.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Increasing demands for speed and carrying capacity of railway have far reaching effects on working capacity of the vital parts, primarily railway axles, with respect to their reliability and danger of fatigue failure. Railway axles are the most loaded parts of the railway vehicles, which have the most intensive multiple stress concentration. In addition to bending, regular strains, axles can be simultaneously torsional stressed. Those are locomotive's driving axles and disc brake axles. In that case, axles operate as shafts. It has been previously shown in the literature that complex and variable stress state, multiple stress concentration, inadequate maintenance and exploitation conditions, material-related errors and inadequate mechanical properties are the most common causes of failure – fracture of the railway axle-shafts. In [1] a mathematical model was developed for monitoring initial crack growth in railway axles under conditions of variable amplitude loading. Besides theoretical investigations, experimental research was carried out to verify the developed mathematical model. The influence of stress intensity factor on crack formation in railway axle critical cross-sections was analysed in [2]. The analysis was carried out by numerical finite elements method (FEM). Considerations involved stress states at the source of stress concentration located on the bearing journal directly behind the railway wheel as well as on the section of the axle between the railway

* Corresponding author. Tel.: +381 11 3302 237.
E-mail address: vmilosevic@mas.bg.ac.rs (V. Milosevic-Mitic).

http://dx.doi.org/10.1016/j.engfailanal.2015.05.011
1350-6307/© 2015 Elsevier Ltd. All rights reserved.

wheels, with no source of stress concentration. The effects of rotary bending and press fits, at the wheel and gear, on fatigue crack growth and residual lifetime were discussed in [3]. Computational modelling of fatigue crack propagation was presented in [4] and applicable stress intensity factor solution was derived by FEA. The influence of stress fitting on the crack propagation in a fillet was discussed. In [5] fracture of the driving axle–shaft in the locomotive of the passenger train was analysed. The fracture occurred in the axle-shaft section located between the railway wheels in the cross-section without stress concentration source. It has been shown that the axle-shaft fracture occurred due to a high level of torsional vibrations. Vibrations were generated immediately after the locomotive was set in motion as well as in braking process due to stick-slip phenomenon. In the review paper [6] different forms of destruction in the vital parts of railway are analysed: railway axle-shaft, railway wheel, and rails. A draft procedure for damage tolerance analysis is presented in [7]. As a result of the analysis of the axle, a crack size was provided which has been detected by Non-Destructive Testing (NDT) inspection. One application method of the NASGRO crack growth algorithm to estimate the propagation lifetime of railway axles was presented in [8]. The Paris-Erdogan fatigue crack growth model was found in [9] to be efficient in predicting the fatigue life of the defective railway axle. An overview on safe life and damage tolerance methods applied to railway axles was given in [10]. Some specific features, such as corrosion, which may reduce the fatigue strength of axles were discussed.

The railway axle considered in this paper is the axle of a railway freight car used in the past 35 years, for transportation of coal from the coal mine to the thermal power plant. The axle fracture occurred under exploitation conditions at the source of stress concentration in the cross-section located on the section of the axle between the roller bearing and railway wheel. In order to clarify the cause of this failure, the paper analyses in detail the fracture surface of the axle. Detailed examinations of the mechanical properties and microstructure of the axle material were performed to analyse the effects of the material on the axle fracture. In order to identify potential locations for crack initiations and to evaluate the effects of multiple stress concentration, press fit joints and working load on the axle fracture, the axle stress state was subjected to throughout numerical analysis. Based on numerical calculation (FEM), the axle cross-sections with the highest values of stress were registrated. It has been shown that the most unfavourable stress state is generated in the axle cross-section where the fatigue failure has previously occured. In this study an attempt was made to connect material characterisation results with numerical calculations of the fractured axle, with the aim to improve control and maintenance of the axels in exploitation and to avoid future accidents.

2. Fracture of the railway axle

The freight car for coal transportation from the mine to the thermal power plant has two axles. The failure has taken place on an industrial gauge used for coal transport, as shown in Fig. 1. Under exploitation conditions nominal axle load amounts to 200 kN, while railway car speed of motion is up to 70 km/h. The stopping and braking of railway car is done by brake shoes. Accordingly, under exploitation conditions, the axle is bending stressed only.

Available data show that the railway axle is regularly periodically inspected and overhauled. However, irrespective of this fact, the axle fracture was detected on the axle assembly journal of the railway rear axle, on the transition radius, on the location of the source of stress concentration, between the roller bearing journal and railway wheel seat. The fracture

Fig. 1. Appearance of damaged railway car.

Download English Version:

https://daneshyari.com/en/article/763344

Download Persian Version:

https://daneshyari.com/article/763344

Daneshyari.com