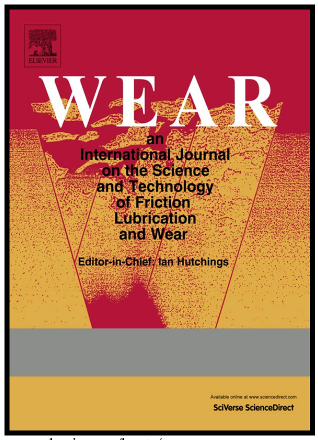
Author's Accepted Manuscript



www.elsevier.com/locate/wear

Prediction of railway wheel wear and its influence on the vehicle dynamics in a specific operating sector of Indian railways network

Smitirupa Pradhan, Arun Kumar Samantaray, Ranjan Bhattacharyya

PII: S0043-1648(17)31763-5
DOI: https://doi.org/10.1016/j.wear.2018.03.020
Reference: WEA102390

To appear in: *Wear*

Received date: 10 December 2017
Revised date: 10 February 2018
Accepted date: 29 March 2018

Cite this article as: Smitirupa Pradhan, Arun Kumar Samantaray and Ranjan Bhattacharyya, Prediction of railway wheel wear and its influence on the vehicle dynamics in a specific operating sector of Indian railways network, *Wear,* https://doi.org/10.1016/j.wear.2018.03.020

Prediction of railway wheel wear and its influence on the vehicle dynamics in a specific operating sector of Indian railways network

Smitirupa Pradhan, Arun Kumar Samantaray*, Ranjan Bhattacharyya

Center for Railway Research (CRR-IIT Kharagpur), Systems, Dynamics and Control Laboratory, Department of Mechanical Engineering, Indian Institute of Technology (IIT), Kharagpur, 721302, India.

*Corresponding author. Email: samantaray@mech.iitkgp.ernet.in, Phone: 913222 282999, Fax: 913222 28277

Abstract

In railway operations, wear prediction due to wheel-rail interaction is crucial for different aspects such as running stability, passenger safety and comfort, life cycle optimization and maintenance scheduling. In this article, wheel wear is estimated through co-simulation between multi-body vehicle dynamic model developed in Adams™ VI-Rail™ software and wear evolution model developed in MATLAB® software. Semi-Hertzian/STRIPES approach and modified Kalker's FASTSIM approach are used for calculating normal and tangential stresses, respectively. The contact patch obtained from dynamic analysis is discretized into strips and variations of contact angle and spin for each strip, although small, are taken into account. Archard's wear formulation is applied for each strip within the contact patch. The wheel profiles are smoothened and are updated at intervals for further dynamic analysis. This way, the outputs from dynamic analysis (contact patches, creep forces, etc.) are input to the wear evolution model and the outputs from the wear evolution model (worn wheel profiles) are fed to the dynamic analysis. The wear at the flange and tread portions of the wheels during the normal service condition in an operational track sector between two major rail stations in India, containing curved and straight portions, speed variation (acceleration and braking), and corresponding track configurations (super-elevation, irregularities, etc.) are estimated and the wheel re-profiling schedule was obtained. In addition, the influences of the various stages of wheel wear on the dynamic responses such as curving performance, critical speed and ride comfort of the railway vehicle on the simulated test track are evaluated to justify the maintenance/wheel re-profiling schedule.

Keywords: Co-simulation, dynamic analysis, semi-Hertzian contact, traction and braking, wear distribution, wheel-rail contact.

1. Introduction

Wear due to wheel-rail critically influences railway operations. Wear of the wheel alters its profile which compromises the vehicle stability and increases the derailment risk. The life of the wheel may be extended by re-profiling the wheel; however, frequent re-profiling may change the properties of the material. Wheel wears out due to creepage and contact (creep) forces. The causes behind the high creep forces are primarily due to friction forces during braking and acceleration of the vehicle, sharp curving, hunting vibrations and track irregularities, etc. Slip occurs due to the tangential and lateral creep forces and the normal force is responsible for both wear and plastic deformation. In recent years, problems associated with wheel wear have increased due to heavy haul, growing traffic, and increased frequency of operation.

Different approaches have been proposed to estimate wear on the wheel profile experimentally and numerically. Some of these approaches have considered elliptical and some have considered non-elliptical contact patches whereas the effect due to plastic deformation is mostly neglected. The amount of material removed from the wheel is calculated by using Archard's model in [1] where the wear coefficient has been found from the experimental setups such as pin-on-disc and disc-on-disc machines. A mathematical model to estimate wear distribution on the wheel is developed in [2] by using wear index approach and the simulated results have been compared with the results of full scale wear test machine and twin disc test machine. The effect of disc braking and lubrication on wear is predicted in [3] where the influence of local elastic deformation due to sliding velocity is considered. The wear evolution model proposed in [4] considers wear due to sliding and rolling contact fatigue.

Note that to predict the rail and wheel life, accurate wear prediction is necessary and this requires estimation of the dimensions of the contact patch, and the normal pressure and tangential stress distribution at the wheel-rail interface. The most difficult aspect is the calculation of contact forces at the wheel and rail contact interface because many factors such as the design parameters of the bogie and track, vehicle speed variation and vehicle dynamics, are involved. It takes a long time for the wheels to develop appreciable wear and hence experimental methods to characterize wear in actual situation using a full scale coach running on the real track is expensive. Also, such real case experiments can interfere with other operations in the railway network. In laboratory tests, experiments are usually conducted on the wheel sets and this does not replicate the real scenario of varying loads and creep forces and the effect of the vehicle dynamics, such as the varying suspension forces due to track irregularities and centrifugal forces during curving. Therefore, often, wear coefficients are characterized