International Journal of Mechanical Sciences 53 (2011) 1000–1007

Contents lists available at ScienceDirect

International Journal of Mechanical Sciences

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

Rolling cylinder on an elastic half-plane with harmonic oscillations in normal force and rotational speed. Part II: Energy dissipation receptances and example calculations of corrugation in the short-pitch range

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ARTICLE INFO

Article history:
Received 9 August 2010
Received in revised form
29 July 2011
Accepted 3 August 2011
Available online 12 August 2011

Keywords:
Short-pitch corrugation
Rolling contact
Wear

ABSTRACT

In this paper, starting from results of Part I (Afferrante et al. [1]), we develop a procedure to evaluate the frequency dependent receptances of the energy dissipation at the contact interface, which is the quantity of interest in corrugation studies as the most known wear laws assume the local wear proportional to the frictional dissipation.

These results are applied to the calculation of the growth rate of corrugation in railway tracks with an initial sinusoidal undulation. In particular, the wheel inertia and the transient contact mechanics effects are considered using a continuum description of the rail (hence neglecting pinned–pinned resonance due to the beam bending between two successive supports) by the simplest model (the Euler beam) which we can use to describe the normal receptance of the rail. The presence of a finite partial slip zone in the contact area can significantly modify the results, partially explaining the scatter of the experimental data collected in the literature.

In particular, we found that partial slip affects the predicted apparent wavelength of highest growth of corrugation, and with respect to the full stick conditions, higher tractive ratio increases significantly the growth factors and non-linearity, showing an unexpected absolute maximum of growth at intermediate velocities, and the "resonance-free" regime becomes increasingly not a constant "frequency", spanning a range of frequency between 700 and 1500 Hz even for a given system and set of loads. Only a full investigation involving all other resonances in the system may clarify further the correspondence with experimental values, since the corrugation "enigma" may be due to a combination of effects.

1. Introduction

Short-pitch rail corrugation ("roaring rails") in the range of 20–80 mm wavelength is a process correlated to periodic wear, rather than to plastic indentations caused by periodic overload. In corrugation problems of railway tracks it is hence important to know how the wear evolves in time and space: material is worn from the rail preferentially in the troughs of the corrugations, so that their amplitude grows with time. This has driven the attention on the tangential creep caused by traction and braking forces and on the energy dissipation which develops at the interfacial microslip and is correlated to the local wear. Archard's wear law [2], for example, suggests to assume the local wear rate proportional to the energy dissipation rate per unit area and experimental investigations by Bolton and Clayton [3] and Clayton et al. [4] clearly show the proportional dependence of the wear on the frictional energy dissipation. Within the assumptions of linear perturbation analysis, therefore, it should be relatively easy to find the most "unstable" wavelength of initial corrugation. However, measured corrugation wavelength does not relate well with wear-instability models for short-pitch rail corrugation: some authors [5,6] have called this a "corrugation enigma", whereas others (Frederick [7], and more recent ones) suggest the pinned–pinned resonance regime as the cause, despite there is no complete of this resonance regime in the experimental data.

Recently, some works [8–11] have shed only partial ligth into the "enigma", suggesting that some of the early models which had completely negative conclusions about the possibility of a corrugation regime independent on the systems resonances, like

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doi:10.1016/j.ijmecsci.2011.08.005