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Modeling of Worn Profile Evolution and Contact Fatigue in Rail/Wheel Interaction

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1 INTRODUCTION

The lifetime of friction elements is usually predicted based on wear and contact fatigue analysis. Wheels and rails are the typical examples of the units admitted relatively large surface wear before the fracture due to contact fatigue arises. So the formation of fatigue cracks is in a strong dependence on the wear process. Many factors (material properties, contact conditions, etc.) influence the wear and damage accumulation processes in wheel/rail contact. Among them the important role belongs to railway irregularities and the vehicle dynamic properties. The wear process in turn influences the vehicle dynamic motion. That's why the vehicle motion and the wheel/rail interaction should be considered simultaneously in modeling of worn profile evolution and contact fatigue. Some approaches to analyze the wheel and rail wear and damage accumulation were developed in [1-5].

In this study the model for analysis of wear and fatigue defect formation is developed based on the approaches of contact and fracture mechanics, and the complete solution of the dynamic problem of the vehicle motion [6]. The model includes the solution of the wheel/rail contact problem, and calculations of the wheel profile evolution due to wear process and the damage accumulation functions in the rail and wheel. The influence of the evolution of the rail/wheel profiles due to wear on the damage accumulation process is analyzed.

2 PROBLEM FORMULATION AND THE METHOD OF SOLUTION

The deterministic model [6] is used to analyze the vehicle motion in straight and curved tracks. It takes into account all limited perturbations of the motion process. The dynamic and contact problems are solved simultaneously using FastSim algorithm developed by Kalker [7].

To study the contact characteristics the forces applied to the contact zone are calculated from the dynamic model analysis. One-point and two-point contacts are considered: the one-point contact occurs at the tread, the two-point contact realizes at the tread and at the wheel flange. The solution of the contact problem allows us to calculate the contact stress distribution, the shape, size and the position of the contact zones.

Based on the wear equation obtained experimentally, on the slippage determined from the dynamic model, and the calculated contact stresses, the linear wear at the contact zone is obtained and used to find the worn profile of the wheel at each step of iteration in the dynamic model.

From the solution of the contact problem the internal stresses and damage accumulation function in the wheel are calculated taking into account the evolution of the wheel profile. The phenomenological approach based on the linear summation theory of damage is used to analyze the contact fatigue and to predict the possible places of crack initiation.

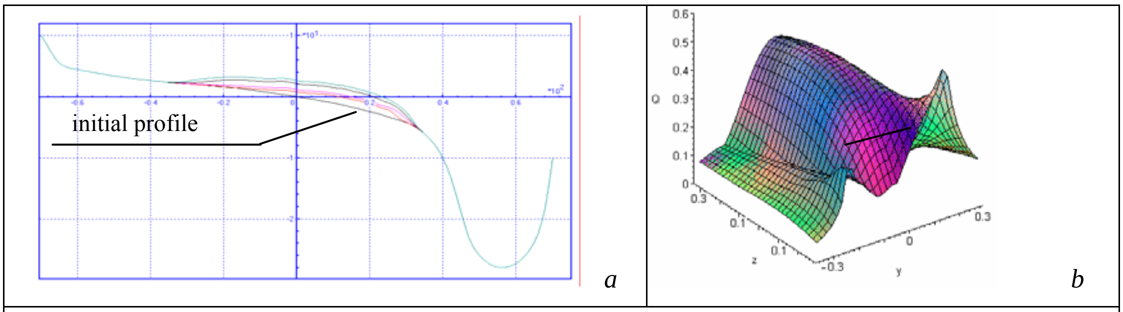

Figure. Worn profiles after 50, 100, 150, 200 wear iterations (a) and damage function after 200 wear iterations (b).

3. RESULTS AND CONCLUSIONS

The wheel profile evolutions due to wear were calculated for various initial wheel profiles, different types of wear equations, and various types of tracks. For some conditions the stabilization of the worn wheel profile and the uniform wear rate distribution after a number of iteration were established.

It was concluded that wear has an appreciable influence on the damage accumulation process. Uniform wear rate distribution over the wheel profile leads to the stabilization of damage distribution in subsurface layers; the maximum value of damage is below of the fatigue limit. Non-uniformity of the wear (Figure, a) leads to the damage concentration in subsurface layer (Figure, b) and the fatigue crack initiation.

The tribo-dynamic model was used to study the effect of surface wear on defect formation in the wheels of heavy-haul vehicles. The optimization of the initial wheel/rail profiles corresponding to different tracks was developed from the model [8]. The approach can also be used for the analysis of the shape evolution and the damage accumulation process at other junctions characterized by high cyclic loading and the essential wear of their elements.

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