Kalker's algorithm Fastsim solves tangential contact problems with slip dependent friction and friction anisotropy

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1 INTRODUCTION

Kalker's algorithm Fastsim of the simplified theory of rolling contact [1] has proved to be one of the most useful computation tools in rail vehicle dynamics. Originally, Kalker wrote Fastsim algorithm for elliptical contact zones resulting from solution of the Hertzian normal contact problem. But Fastsim algorithm is general in the sense that it is not restricted to the elliptical contact zone. The difficulty is that the elasticity parameter is not easily available for non-elliptical contact zones. Despite of this it is used in computer codes oriented for rail vehicle dynamics such as ADAMS Rail, Medyna and Voco for example. In fact at present time there is no alternative for a fast creep force generator in situation when the normal contact problem for wheel and rail is solved as the non-Hertzian problem. For realistic simulation of rail vehicle dynamics it is necessary to solve the normal contact problem as non-Hertzian one because geometry of wheel/rail profiles usually leads to non-elliptical, frequently multiply contact zones.

There exist some extensions of Fastsim algorithm for specialized tasks. It is worth mentioning the extension of Fastsim oriented for calculation of the frictional power density in non-elliptical contact zone that was used in investigation on the temperature in contact [2]. Alonso and Giminez [3] extended Fastsim for non-steady rolling with infinitesimal creepage. The other extensions of Fastsim are possible.

In the presented paper two extensions of Fastsim algorithm are described. One solves the tangential contact problem for slip dependent friction and other the for friction anisotropy. Both extensions have been described using the same language of formulation and they can be easily merged into one algorithm.

2 SLIP DEPENDENT FRICTION

The objective has been to extend Fastsim algorithm for conditions where coefficient of friction depends on slip velocity. The magnitude of the slip that is not directly available within Fastsim has been determined analytically. The extension contains an iterative solution of a non-linear relation between slip and traction.

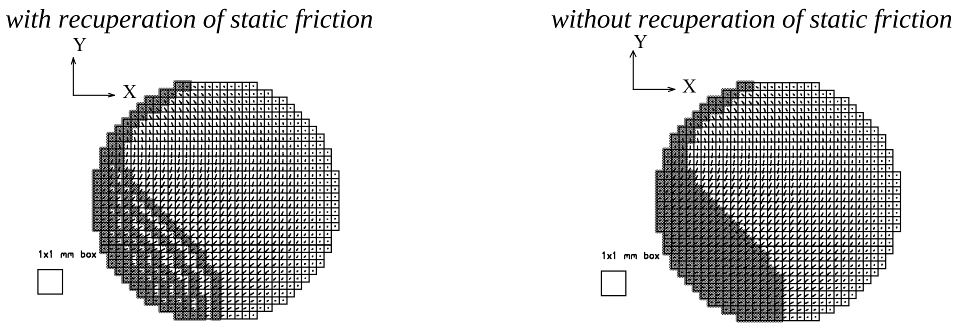

Fig. 1 Contact area, traction and division to slip and adhesion. Sliding elements filled grey

Presented solutions of the tangential contact problem show the local quantities in the contact zone as well as global ones. The solutions have been calculated for two friction laws: with and without recuperation of the static friction.

In the first case the particle may alternately slip and adhere several times during its passage through the contact zone. The traction in the stick-slip-stick region is not smooth. The creep force-creepage curves decay after reaching a maximum but in a complicated manner. For the friction law without recuperation, there is usually one transition of given particle from adhesion to slip. One exception is the case of high pure spin, where an enclave of adhesion forms. The resulting traction is smooth. The creep force-creepage curves decay after reaching a maximum but in a smooth manner, see Fig.2.

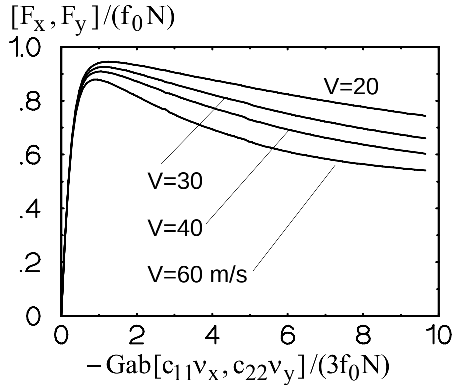

Fig.2 Tangential force for spin = 0.
Without recuperation of static friction

The creep force depends on rolling velocity.

The main difficulty in validating this extension of Fastsim is that the complete theory using more realistic constitutive equations in the form of the Boussinesq-Cerruti influence functions has not been extended for solving problems, where coefficient of friction depends on slip velocity. Therefore the usefulness of extended Fastsim can be presently judged only upon results of engineering applications in rail vehicle dynamic simulations. The question of the form of a friction law suitable for wheel /rail cannot be addressed on the ground of contact mechanics itself. It requires investigation in the field of tribology.

3. FASTSIM FOR ANISOTROPIC FRICTION

Kalker's algorithm Fastsim has been extended for solving tangential contact problems with friction anisotropy characterized by a convex set of the feasible tangential traction

The effect of the anisotropy is that the direction angles of slip and traction differ.

For the general case of rolling without spin this leads to different direction angles of the total lateral force and the resultant creepage. Also rolling with pure spin is influenced by the anisotropy. For the elliptical set of the feasible traction and friction in lateral direction lower than in longitudinal one the total lateral force is lower than in the isotropic case. The change of traction direction angle is visible in Fig. 3 where in the area of slip (filled elements) the traction angle changes by 16 degrees.

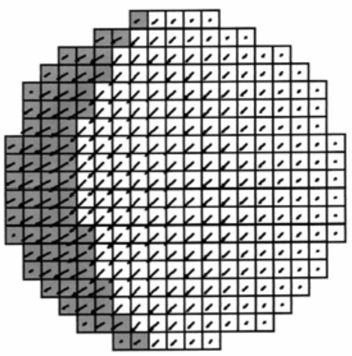

Fig.3 Fastsim solution for
$f_y / f_x = 0.75$, $\nu_x = \nu_y$, spin $\phi = 0$

An open question is the applicability of the elasticity parameter based on Kalker's complete theory for extended Fastsim algorithm because friction anisotropy has not been studied in the framework of the Kalker complete theory.

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