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Wheel-rail contact modeling considering roughness and strain hardening effects

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Abstract

The roughness effects on the wheel-rail contact problem is an essential topic. In this paper, a new analytical-numerical model has considered assessing the specifications of a rough surface in wheel-rail contact problem. The new model includes asperities and strain hardening effects together. In this study, considering the strain hardening effects, the contact results for wheel-rail material are obtained. The contact characteristics variations versus separation, such as contact force, contact stiffness, and contact area, are shown in semilogarithmic diagrams considering different surface roughnesses and hardening parameters. The new model results show the significant influence of the assumed hypothesis on the contact characteristics. Keywords: Wheel rail contact problem; strain hardening; asperities; contact properties.

Introduction

In analytical methods to evaluate a contact problem, many researchers used Hertz's theory[1]. Hertz's theory is a base theory of contact problems considering the elastic range. However, it does not consider the effects of elastic-plastic or plastic deformations. In this regard, Nayak[2-3] worked on the dynamic vibration of a Hertz contact problem by statistical parameters in the surface height distribution function. Ghaednia et al.[4] presented a contact model considering the transition between the elastic-perfectly plastic to elastic regions. They used a bilinear isotropic hardening model of materials. You and Chen [5] developed a statistical model and assumed spherical asperities contact with a rigid plane which is not considered the Hardening effects in their work. This task presents a new analytical-numerical model for contacting asperities based on Amini Sarabi and Hosseini Tehrani[6] and Gao contact model[7]. Besides slip-stick effects in elastic-plastic deformations and strain hardening effects.

Body

Final formulations for the new parts of contact model:

$$F_p = \eta A_n \int_{d^*+110\delta_{bc}^*}^{\infty} \int_0^{2\pi} \int_0^{\pi} \sqrt{((L^2)(2\delta_{vf}^* \cos\varphi)^n) + (\tfrac{3}{2} r_{ipAT}^* \zeta_v^* sin\varphi sin\theta)^2 + (\tfrac{3}{2} r_{ipAT}^* \xi_v^* sin\varphi cos\theta)^2}.\sin\varphi\psi(\varphi,\theta)\,\phi^*(z^*)\,d\varphi d\theta dz$$

$$K_p = \eta A_n \int_{d^*+110\delta_{bc}^*}^{\infty} \int_0^{2\pi} \int_0^{\pi} \sqrt{((L.n)^2(2\delta_{vf}^* \cos\varphi)^{n-2}) + 4.5(r_{ipAT}^*)^2}.\sin\varphi\psi(\varphi,\theta)\,\phi^*(z^*)\,d\varphi d\theta dz$$

$$A_p = \pi\beta_p \int_{d^*+110\delta_{bc}^*}^{\infty} \int_0^{2\pi} \int_0^{\pi} \delta_{vf}^* cos\varphi (\frac{\delta_{vf}^* cos\varphi}{1.9})^{B_H}.\sin\varphi\psi(\varphi,\theta)\,\phi^*(z^*)\,d\varphi d\theta dz$$

Table 1. Material properties.

Properties	E (GPa)	υ	μ	σ_y(MPa)	G (MPa)	ρ (Kg/m3)	H (GPa)	σ_z	n
Material No1	207	0.31	0.5	353	41	7800	1.12	2	2.5
Wheel-Rail Material	209	0.29	0.5	406	80	7800	2.7	2	2.5

Fig.1 shows the results of non-dimensional contact stiffness versus contact distance.

The wheel-rail material is stronger so, by increasing the contact pressure the contact stiffness and force increase. The maximum value of stiffness and force in wheel-rail material is about 83% and 33% bigger than previous material respectively.

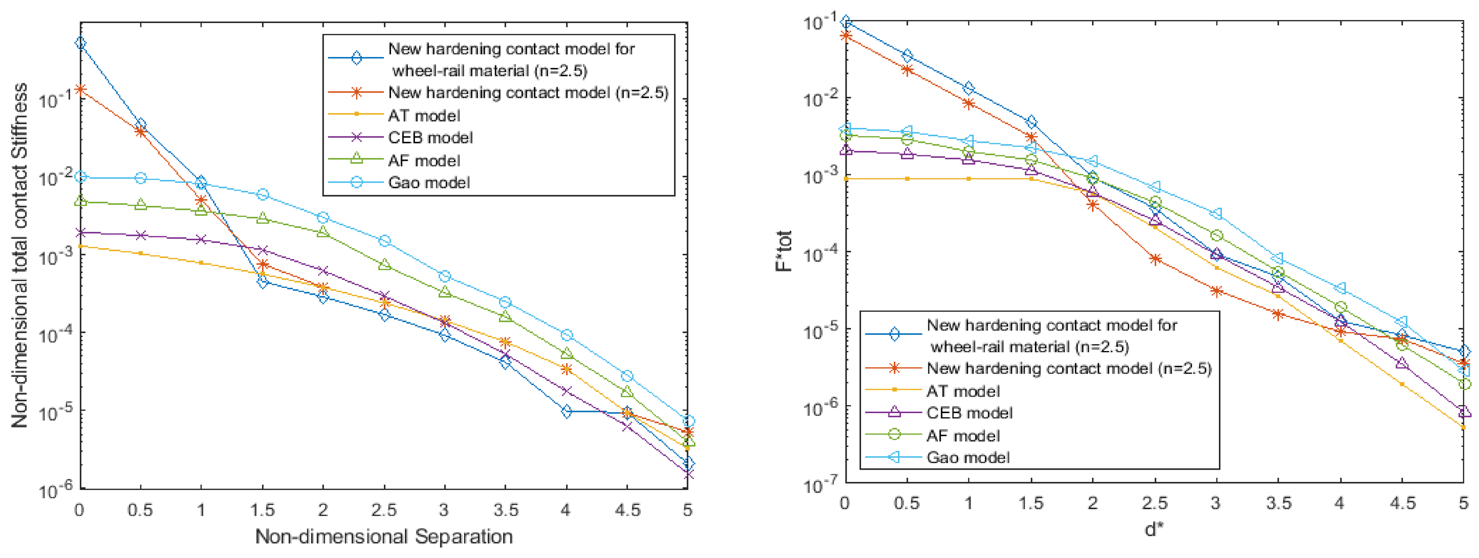

Figure (1)-Non dimensional contact stiffness and force versus mean separation contact distance.

Topic analysis and interpretation

In this study, a code is developed in MATLAB software to determine the results of the introduced analytical-numerical contact model. The results range of our new model is comparable with the experimental study of Zhai et al. [8]. They used a nano-indentation method for aluminum samples with different surface topographies. Their results show that in maximum contact pressure, the values of non-dimensional contact stiffness are between 0.2-0.9. The maximum value of non-dimensional contact stiffness in our new model, considering the material properties of table.1, is about 0.15 and for wheel-rail material is about 0.5 which are reasonable.

Conclusion

1- The results of the contact properties considering the new model showed the great impact of the assumed hypothesis on the results.

2- By using the material properties of the wheel-rail, the results showed that the maximum values of the contact force and contact stiffnesses are about 33% and 83% bigger than the other considered material.

3- The results of new model are in good agreement with other similar analytical and experimental studies.

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