Model for Tangential Contact Damping Energy Dissipation Factor of Plane Joint Interfaces

Jingfang Shen¹²³, Hongbo Yan² and Jiajun Yang¹,*

¹School of Mechanical Science and Engineering, Huazhong University of Science and Technology, 430074 Wuhan, China
²College of Science, Huazhong Agricultural University, 430070 Wuhan, China
³Faculty of Engineering, University of Waterloo, N2L 3G1 Waterloo, Canada

*corresponding author’s e-mail: j97shen@uwaterloo.ca

Abstract. Due to the comprehensive applications of Hertz contact theory and fractal method, we present the model for tangential contact damping energy dissipation factor of plane joint interfaces. The energy dissipation of the entire joint surface is estimated by energy loss equation of single micro-convex body. According to the tangential force in process of micro-convex and micro-slip, the energy storage of the micro-convex body is replaced by the equivalent, and the energy storage of the composite surface of the rectifier is obtained. On the basis of the unique conversion of energy loss and storage, a model is established. The model avoids the invariance of experimental test and enhances the visualization of theoretical derivation, and can more intuitively understand the properties of damping dissipation factor. The influence law of related parameters is obtained by numerical simulation. We can see that damping loss factor of tangential decreases first and then increases when D increase and the roughness arguments are constant. When D is about 1.25, the D reaches the least value. If the D is less than 1.5, the roughness parameter and directly proportional damping dissipation factor relations, when the fractal dimension is 1.5 exactly, the roughness parameters do not produce effect, when the D is larger than 1.5, the increase of roughness, dissipation factor decreases at the same time. Comparing with the laboratory data, the results obtained by numerical simulation are in accordance with the actual situation is found. Therefore, the model is effective in certain conditions.

1. Introduction
The junction surface widely exists in the junction of mechanical parts. The effect of damping and stiffness on the binding surface can be obtained in the process of mechanical equipment operation. CHEN¹ et al. results show that the main reason for dissipation of structural damping energy is due to the energy dissipation of the micro-slip damping, and the analysis of the results of damping energy dissipation resulting from the micro-slip of the joint surface and the tower joint surface by the finite element method shows that it is related to the friction factor and shear force. YOU² have come up with a new statistical model, it contains the accurate finite element analysis results of micro-convex and elastic plastic deformation, normal and tangential contact parameter expressions including contact area, contact load, contact stiffness and static friction coefficient are established. Therefore, the study of tangential damping can study the energy dissipation problem more precisely. To explore the mechanism of tangential damping, there are many researches on tangential contact mechanism of tangential damping. According to the continuous contact theory model and 3d contact fractal theory,
JIANG et al establish the fractal model of the contact damping. The influence of fractal roughness scale parameter, plasticity index and friction factor on tangential contact damping is revealed. From the perspective of parameter accuracy and mechanical system characteristics, ZHANG et al. discussed the method of obtaining the tangential damping parameters of the combination surface, and these methods can meet the actual design requirements. In accordance with the contact fractal theory, its modified model and the mechanism of surface damping loss, ZHANG et al establish the elastic-plastic fractal model of the surface tangential contact damping energy dissipation. LI et al studied the system of tangential contact damping with the influence of friction factor, a combination of solid - gap -solid contact model is proposed. HU et al improve the calculation model of the existing discrete element method, the coulomb friction damping replaces viscous damping to describe the tangential action between particles, the stress characteristics of granular media are more accurately reflected, and the calculation formula and method of two - dimensional discrete unit are established. In this paper, the loss factor of tangential contact damping energy is studied. Based on the contact fractal theory, the mechanism of the damping loss energy of the combination surface, and the theory of the damping loss energy of the sphere in contact with the plane, This paper obtains the shear energy dissipation factor, and the impact of the related arguments on energy loss factor of tangential is revealed by numerical modeling.

2. Tangential energy dissipation
In the light of the consequences of Yamada A and Kakubari T’s study, when an asperity is in touch with the plane, the contact damping energy of a simple harmonic oscillation period can be expressed as

$$e = \frac{(2-v)\mu^3}{36G'\pi\rho}, r = \frac{(a/\pi)^{1/2}}{2}$$

(1)

Among them, G’ is the equivalent shear modulus of the two contact materials, v is the poisson ratio, μ is the friction coefficient, p is applied to micro convex body in normal preload, t is applied to micro convex body in dynamic tangential load amplitude, a is micro contact area, r is the radius of the contact area.

This article assumes that, the microscopic appearance of the rough surface is isotropic, the interaction between the micro convex bodies on the rough surface can be ignored, the force of each micro convex body is proportional to the area of contact. Therefore, the t that acts on a can be expressed as

$$t = aT / a_r$$

(2)

Among them, T is the amplitude of the tangential dynamic load applied to the entire binding surface, a_r is the actual contact area on the surface.

The normal pressure on a is

$$p = aP / a_r$$

(3)

Among them, P is the method preloading which is acted on the macroscopic surface.

According to Wang and Komvopoulos, a domain extension factor for micro contact size distribution is introduced, the micro contact area distribution function is

$$n(a) = \frac{D}{2\pi} a^{D-2} a^{-\frac{D}{2}} \left( \frac{D+2}{2} \right)^{D/2}$$

(4)

The tangential contact damping consumption can be expressed as

$$E_d = \int_{a_c}^{a_r} e n(a) da$$

(5)

Among them, a_c is the Real micro contact area, a_c is the critical contact area. To substitute (1), (2), (3), (4) into (5), we can get
3. Tangential energy storage

There is a microscopic slide when the two interfaces contact. The relation between the tangential force and the displacement of the micro convex body is

$$\delta_s = \frac{3\mu p}{16G'r} \left[ 1 - \left(\frac{t}{\mu p}\right)^{2/3} \right]$$  \hspace{1cm} (7)

Among them, \(t\) is the tangential force of a single micro convex body.

The initial maximum energy of a single micro convex body is

$$w = \int_0^{\delta_s} t \, d\delta = \frac{3\mu p t}{16G'r} \left[ 1 - \left(\frac{t}{\mu p}\right)^{2/3} \right]$$  \hspace{1cm} (8)

The tangential contact damping energy of plane combination surface is stored as

$$W = \int_{a_{pc}'}^{a_{pc}''} n(a') \, w \, da' = \frac{3\mu p t a_{pD/2}^2}{2^{8-D/2} \, G'r} \left( a_{pc} - a_{yc} - a_{D/2} \right) \left[ 1 - \left(\frac{t}{\mu p}\right)^{2/3} \right]$$  \hspace{1cm} (9)

$$a_{pc}' = \left( \frac{2\gamma\pi}{\sqrt{3\pi}} \right)^{1/(D-1)}$$ \hspace{1cm} (10)

$$a_{yc}' = \left( \frac{2\gamma\pi}{\sqrt{3\pi}} \right)^{1/(D-1)}$$ \hspace{1cm} (11)

Among them, \(a_{pc}'\) is the critical micro contact plastic section area, \(a_{yc}'\) is the critical micro contact yield cutting area, \(\gamma\) is the scale parameter, \(\bar{p}_{yc}\) is pressure equalization of complete plastic flow transition point, \(\bar{p}_{pc}\) is the pressure equalization of Initial yield point, \(H\) is the hardness of soft material, \(E\) is equivalent elastic modulus.

4. Energy dissipation factor and simulation

Tangential solid energy dissipation factor can be expressed as

$$\eta = \frac{E_d}{W} = \frac{\sqrt{2(2-v)}D}{27(3-D)a^{3/2}} \left( \frac{T}{\mu p} \right)^2 \left( a_{pc} - a_{yc} - a_{D/2} \right) \left[ 1 - \left(\frac{T}{\mu p}\right)^{2/3} \right]$$  \hspace{1cm} (12)

$$a = \left( \frac{2\gamma\pi}{\sqrt{3\pi}} \right)^{1/(D-1)}$$ \hspace{1cm} (13)

Among them, \(R\) is equivalent curvature radius, \(G\) is roughness parameter.

According to equation 13, the numerical simulation of the contact energy dissipation factor was carried out. It gives \(k=1\), \(E=210\text{GPa}\), \(H=9\text{GPa}\), \(R=0.00125\text{m}\), \(v=0.3\), \(\gamma=1.5\). The following four images can be obtained by simulation drawing.
Fig. 1 shows the variation law of damping dissipation factor in friction coefficient and fractal dimension. It can be seen that as the $D$ increases, tangential damping loss factor decreases first and then increases. If the $D$ is about 1.25, the damping loss factor reaches the least value.

Fig. 2 shows the variation rules of tangential damping dissipation factors under the joint action of friction coefficient and roughness parameters. These three diagrams reveal the different rules of the fractal dimension of 1.5, 1.2 and 1.8. From above, when fractal dimension $D=1.5$, with the roughness argument increases, tangential damping loss factor is basically unchanged. When $D=1.2$, with the roughness argument increases, damping loss factor of tangential increases. When the $D=1.8$, with the roughness argument increases, the damping loss factor of tangential decreases.
On the other hand, combined with (a), (b) and (c) can be found, when the roughness argument and D are fixed, with the friction coefficient increases, the damping loss factor of tangential decreases.

5. Conclusion

From the above analysis, we can draw the conclusion that:

- By adopting the domain extension factor, a model of damping energy loss factor of tangential is established. And the influence of fractal dimension, roughness parameter and friction coefficient on damping dissipation factor is studied.

- The research findings show that, the variations of roughness parameters have different results for tangential damping dissipation factors. It is separated out three categories by the fractal dimension D=1.5. When the D is less than 1.5, the roughness parameter is proportional to the tangent damping dissipation factor. If the D is 1.5, the damping loss factor of tangential remains the same. If the D is greater than 1.5, the tangential damping loss coefficient decreases, and the roughness argument increase at the same time. As well as, when the D aggrandizes, the damping loss coefficient of tangential decreases firstly and then increases. When D is about 1.25, the damping loss factor reaches the least.

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