International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol. 8, No. 5 (2015), pp. 23-34
http://dx.doi.org/10.14257/ijsip.2015.8.5.03

Mathematical Description of Deformation of Micro Convex Body on Rough Surface

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Abstract

Friction and wear process is due to the interaction of the relative motion between friction pair surfaces. Problems of rough surface and contact mechanics are not just appeared in tribology, but they have close relationship with friction or tribology and they are the necessary problem to solve in understanding of friction and wear phenomena. In the paper, we make the assumption of deformation continuity and smoothness of the surface asperity and combined with related theory to establish a mathematical model for the calculation for surface contact. The model is verified with a specified example. The results have been calculated and compared with results of other models. The comparison results show that the calculation model established in this paper has small error when the load is small load but with big difference with test results when the load is higher. The model can be used in the research of influence factors of real contact area of sliding friction surface, but it should take actual factors into consideration.

Keywords: *open pit mining, semi continuous system, intermittent system, economic comparison*

1. Introduction

Friction wear process is due to the interaction of the relative motion between friction pair surfaces. It is the friction phenomenon occurred on relative motion surface. Problems of rough surface and contact mechanics are not just appeared in tribology. They have a close relationship with friction or tribology and they are the necessary problem to solve in understanding of friction and wear phenomena. Recently, contact on surface becomes a specialized research field in tribology. Studies on the characteristics of real contact sliding friction between surfaces play an important role in the analysis of the friction, wear, lubrication and heat transfer performance.

The real contact characteristics on sliding friction surfaces can be classified as rough surface contact with smooth plane and rough surface contact with rough surface. And each class has two subclasses of static and sliding. So far, there are many study articles have been published. They are mostly based on the theory of elastic contact.

(1) Rough surface contact with smooth surface

Contact model (G – W model) for rough surfaces has been firstly developed to predict the relations between real contact area and normal loads [2]. Then, other models based on G – W model have been proposed [3-6]. When two rough surfaces contact with same elastic constants, the tangential force would not affect normal pressure; and if with different elastic constants, problem can be transformed into contact between 1 rough and 1 rigid smooth surface [7]. Then, many finite element method (FEM) studies have been proposed [8-9]. Topography height distribution of a convex body surface has characteristics of stochastic with non-stability. It is not continuous and smooth anywhere and has statistical self-similarity and self-affine characteristics [10-12]. The rough surface has fractal characteristics and can be studied with fractal theory.

ISSN: 2005-4254 IJSIP

For sliding condition, density function of temperature distribution and integral function of temperature rise on the real contact area has been derived with slow sliding of elastic and elastoplastic contact surfaces and slow sliding of elastic contact surfaces [13-15]. With FEM method, variation of stress and strain has been studied with the tangential force and normal force [16-17]; with semi analytic method, elastoplastic contact analysis has been developed for three dimensional model and get the distribution of contact pressure, residual stress, etc. [18]. With fractal theory rough surfaces have been generated, contact adhesive wear model has been studied under different loads [19].

(2) Rough surface contact with rough surface

In order to simplify the analysis, the top surface of micro convex body is assumed as spherical, contact between the balls is the start points and purely elastic or pure plastic contact have been taken to be the actual condition in most models [20-21]. If make the assumption of maximum elastic or plastic deformation at friction interference of 2 balls, contact area of elastic deformation under normal force is the same as results calculated with Hertz theory, and plastic results are similar with slip field theory [22]. Fractal theory is used to establish 2 two-dimensional static contact model. Asperity is defined as elastic or plastic completely without transition stage of elastoplastic, and shear force between asperities is caused by tangential friction stress [23]

Plane strain hypothesis is used to establish surface elastoplastic contact model for the 1 spherical asperity on 1 regular shape and residual stress on the contact surface has also been calculated [24]. Based on previous sliding contact model, a new elastic-plastic finite element model has been proposed with the effect of the sliding friction force taken into account, and 3D rough surface is composed of many by many spherical asperity with different distances [25]. This method may consume a longer time when computing. Combined with the semi analytical method and the finite element method, sliding friction process between the two spheres is analyzed. In the method, formula to calculate the average tangential force and the normal force has been developed and parameters of typical materials are used to verify the accuracy [26].

The fractal theory has a wide range of applications in the calculation of contact for rough surfaces. Many studies have promoted the analysis of the stress level on the rough surface. In this paper, with related theory and assumption of deformation continuity and smoothness of the surface asperity, contact stress on smooth and rough surfaces has been studied, and a mathematical model for surface contact has been established. The new model can be used in the research of influence factors of real contact area of sliding friction surface.

The main contribution of this paper is an investigation on a mathematical model for surface contact. It can help to study the contact mechanics occurred on sliding friction surfaces. The remainder of the paper can be organized as the following: section 2 is the introduction of deformation manners in sliding friction surface. Section 3 is the real contact area of sliding friction surface. Verification has been described in section 4 and the conclusion is shown in section 5.

2. Deformation Manners in Sliding Friction Surface

Assume that sliding friction is a contact between rough surface with smooth rigid plane, and the equivalent roughness characteristics is isotropic; ignore the interaction between adjacent contact in the process of contacting asperities and the elastoplastic contact enhancement [3-9]. Friction face contact model unfolded along the circumferential is shown in figure 1. Where, δ is deformation of the asperity tip; l' is transverse width of the section of asperity before deformation; l is transverse width of the section of asperity after deformation; ρ is the curvature radius of the top of the micro convex body.

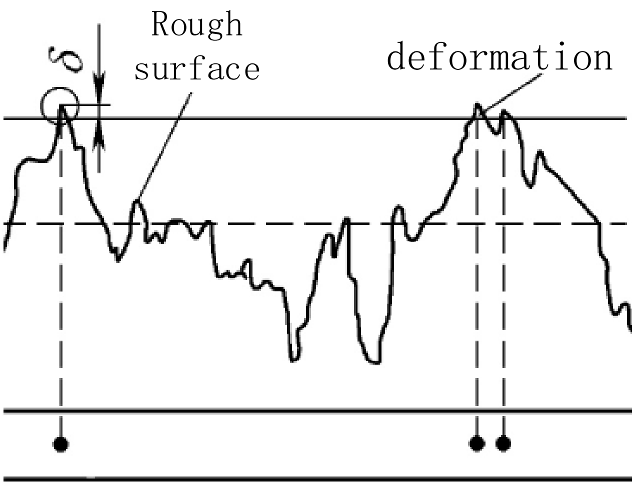

Figure 1. Contact between Rough Surface and Smooth Surface

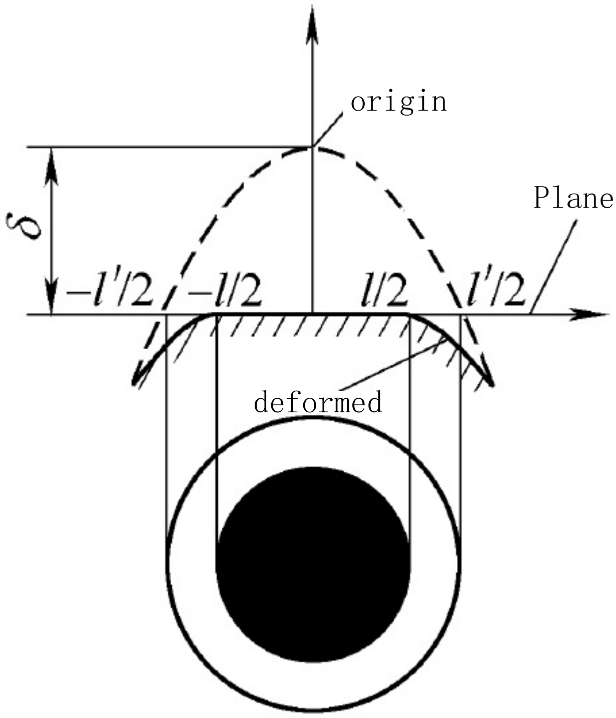

Figure 2. Deformation of Micro Conc Convex Body

Contour line of micro contact area with area of A' on the rough surface can be shown as the Figure 1. Then, the relation between A' and l' is $l' = 2\sqrt{A' / \pi}$. Micro convex body before deformation [27] can be defined as:

$$h(x) = G^{D-1} l'^{2-D} \cos \frac{\pi x}{l'} \qquad -\frac{l'}{2} < x > \frac{l'}{2} \tag{1}$$

Where, $h(x)$ is the height of the asperity contour; x is the position of profile;

G is the characteristic scale coefficient of contour;

D is the number of fractal dimensions of profile, $1 < D < 2$;

From Figure 2, deformation of micro convex body is of $\delta = h(0)$, then we can know that:

$$\delta = G^{D-1} l'^{2-D} = 2^{2-D} G^{D-1} \left(\frac{A'}{\pi} \right)^{\frac{2-D}{2}} \tag{2}$$

Then, we can know the curvature radius of top of the micro convex body by:

$$\rho = \left| \frac{\left[1 + (\frac{dh}{dx})^2 \right]^{\frac{3}{2}}}{\frac{d^2 h}{dx^2}} \right|_{x=0} = \frac{l'^D}{\pi^2 G^{D-1}} = \frac{2^D A'^{\frac{D}{2}}}{\pi^{\frac{4+D}{2}} G^{D-1}} \tag{3}$$

For a contact micro convex body of rough surfaces with certain properties, their deformation manners change with the different tip radius of curvature and deformation. Deformation of contacting asperities has three kinds of elastic, elastic-plastic and plastic manners. As shown in Figure 2. Under certain loads contact, shape of deformation is from the dashed line showed in figure into a solid line. So, the actual contact area is the circle with radius of $l/2$ instead of $l'/2$. The actual micro contact area A has a relation of deformation manners of convex bodies with micro contact section area A'.

2.1 Critical Elastic Deformation of Micro Convex Body

For an ideal rigid extruded asperity, when it is in elastic deformation, maximum contact pressure which the micro convex body suffered is [28]:

$$p\Big|_{\max} = \frac{2E}{\pi} \left(\frac{\delta}{\rho} \right)^{\frac{1}{2}} \tag{4}$$

Where, E is the general elastic modulus, and expressed as:

$$E = \left(\frac{1 - \nu_1^2}{E_1} + \frac{1 - \nu_2^2}{E_2} \right)^{-1}$$

Where, E_1, E_2 are the elastic modulus of materials of hard ring and soft ring;

E_1, E_2 are the Poisson's ratio of materials of hard ring and soft ring;

When in elastic deformation of micro convex body, the actual micro contact area A has a relation with micro contact section area A' as $A = A' / 2$.

Considering the sliding between the end face of friction pair, the critical maximum contact pressure of micro convex body began to yield can be get by: $p_{\max} = 1.1 K_f \sigma_y$

Where, K_f is the modification factor of friction; σ_y is yield strength of the softer material.

Friction correction factor K_f can be approximated by the friction factor f function [29]:

$$K_f = \begin{cases} 1 - 0.228 f & 0 \le f \le 0.3 \\ 0.932 \exp[(-1.58) * (f - 0.3)] & 0.3 \le f \le 0.9 \end{cases} \tag{5}$$

Then, critical elastic deformation of micro convex body began to yield can be calculated by:

$$\delta_{sc} = \frac{2^{\frac{3D}{2}}}{\pi^{\frac{D}{2}}} \left(\frac{11 K_f \phi}{20} \right)^2 \frac{A^{\frac{D}{2}}}{G^{D-1}} \tag{6}$$

In the equation, ϕ is material coefficients, and $\phi = \sigma_y / E$.

Formula (6) shows, size of the actual critical elastic deformation δ_{ec} is related to contact area A of micro convex body. When A is reduced, curvature radius R of the top also decreases and make the critical elastic deformation even smaller.

When micro convex is in elastic deformation, relationship between deformation δ and micro contact area can be described as:

$$\delta = \frac{2^{\frac{3(2-D)}{2}}}{\pi^{\frac{2-D}{2}}} G^{D-1} A^{\frac{2-D}{2}} \tag{7}$$

If we compare the results of δ_{ec} and δ, we can judge whether the micro convex is elastic deformation. Combined with (6) and (7), we can get:

$$\frac{\delta_{ec}}{\delta} = \frac{2^{3(D-1)}}{\pi^{(D-1)}} \left(\frac{11K_f \phi}{20} \right)^2 \frac{A^{(D-1)}}{G^{2(D-1)}} \tag{8}$$

When $\delta_{ec} = \delta$, the critical micro contact area of elastic deformation can be calculated as:

$$A_{ec} = \frac{\pi}{8} G^2 \left(\frac{20}{11K_f \phi} \right)^{\frac{2}{D-1}} \tag{9}$$

Then, we can get $\frac{\delta_{ec}}{\delta} = \left(\frac{A}{A_{ec}} \right)^{D-1}$.

When $1 < D < 2$, it has two conditions: (1) if $A \le A_{ec}$, $\delta \ge \delta_{ec}$, then, contacting asperities is in plastically or plastic deformation; (2) if $A > A_{ec}$, $\delta < \delta_{ec}$, then then, contacting asperities is in elastic deformation. That is to say that small micro contact area would cause elastoplasticity or plastic contact and big micro contact area would cause elastic contact. Although deformation of contact asperity with small contact area is small, the curvature radius is still small for the relationship between micro convex body and micro contact area. The smaller curvature radius is, the less critical elastic deformation δ_{ec} is. More important is that ρ and δ_{ec} are changed with $A^{D/2}$ and δ changes with the variation of $A^{(2-D)/2}$, so, condition of $\delta \ge \delta_{ec}$ can be easily met only in the area of small contact area of $A \le A_{ec}$

2.2 Critical Plastic Deformation of Micro Convex Body

When asperities deformation δ of the top of the micro convex body is bigger than δ_{pc}, the micro convex body would occur plastic deformation. Here, we define the δ_{pc} as the critical deformation. When the contacting asperities in the fully plastic deformation, relationship between the micro contact area A and micro contact section area A' is $A = A'$. When $El'/\sigma_y \ \rho \approx 60$, the contacting asperities would occur the complete plastic deformation [30]. And based on this, micro contact area under critical plastic deformation is:

$$A_{pc} = G^2 \left[\frac{\pi^{3+D}}{900 * 4^D \phi^2} \right]^{\frac{1}{D-1}} \tag{10}$$

3 Real Contact Area of Sliding Friction Surface

3.1 Distribution Function of Contact Area of Asperity

With the fractal theory, Distribution function of contact area of asperity on the sliding friction surface can be expressed as [31]:

$$n(A) = \frac{D}{2}\psi^{\frac{2-D}{2}} A_l^{\frac{D}{2}} A^{-\frac{D+2}{2}} \tag{11}$$

Where, $\dfrac{\psi^{\frac{2-D}{2}} - (1+\psi^{-\frac{D}{2}})^{-\frac{2-D}{D}}}{\frac{2-D}{D}} = 1$

In the formula, ψ is the fractal area expansion coefficient; A_l is the maximum contact area of micro convex body; $A_l = \dfrac{2-D}{D}\psi^{\frac{D-2}{2}} A_r$; A_r is the real contact area of sliding friction surface.

3.2 The Relationship between the Contact Area and the Load

The relationship between the contact area and load of convex bodies are shown in the following:

(1) Relationship between the load and contact area of asperity under plastic deformation. If we define the friction factor K_f , we can get the contact pressure of asperity under plastic deformation condition [32]:

$$p_p = 1.1 K_f \sigma_y \tag{12}$$

The relationship between contact area A and load $F_p(A)$ of asperities under plastic deformation is $F_p(A) = p_p A = 1.1 K_f \sigma_y A$.

(2) Relationship between load and contact area of the asperity with elastic deformation. For an asperity extruded by ideal rigid, when it is in elastic deformation, contact pressure acting on the micro convex body can be calculated by:

$$p_e = \frac{4E}{3\pi}\left(\frac{\delta}{\rho}\right)^{\frac{1}{2}} \tag{13}$$

Then, we can get another expression as:

$$p_e = \frac{2^{\frac{7-3D}{2}} \pi^{\frac{D-1}{2}}}{3} E G^{D-1} A^{\frac{1-D}{2}} \tag{14}$$

So, relationship between contact area A and load $F_e(A)$ of asperity under condition of elastic deformation can be expressed as:

$$F_e(A) = p_e A = \frac{2^{\frac{7-3D}{2}} \pi^{\frac{D-1}{2}}}{3} E G^{D-1} A^{\frac{3-D}{2}} \tag{15}$$

(3) The relationship between contact area and load of asperity in elastic plastic deformation. When $A_{pc} < A \le A_{ec}$, both elastic deformation and plastic deformation are existed in contacting asperities. In this stage, relationship between contact area and contact pressure becomes extremely complex. Based on the basis of asperity deformation

smoothness and continuity principle, contact pressure and contact area at critical transition point of plastic deformation to elastoplastic deformation and elastoplastic deformation to elastic deformation should also be continuously and smoothly without any mutation.

Some published articles show a relationship between deformation with contact area and contact pressure with a polynomial function for micro convex body. This relation meets continuous and smooth conditions of plastic deformation to elastoplastic deformation and elastoplastic deformation to elastic deformation.

If we set the relationship between contact pressure and contact area of micro convex body in elastoplastic deformation on sliding friction surface as a polynomial function, the relationship can be described as the following:

$$y = \frac{3}{2}x^2 - \frac{1}{2}x^3 \tag{16}$$

The contact area of micro convex body with elastoplastic deformation is (A_{pc}, A_{ec}), and contact pressure p_{ep} of elastoplastic deformation belongs to the range of (p_p, p_e). Now we return to the function (16). This function is increases monotonously when in the interval [0, 1]. And the boundary value is $x = 0, y = 0$, or $x = 1, y = 1$

If we define $x = \frac{A - A_{pc}}{A_{ec} - A_{pc}}$, then, $A = A_{pc}$ and $A = A_{ec}$ are relative to $x = 0, y = 0$ and $x = 1, y = 1$.

Take the boundary condition into consideration, we can get:

$$p_{ep} = p_{pc} - (p_{pc} - p_{ec})\left[\frac{3}{2}\left(\frac{A - A_{pc}}{A_{ec} - A_{pc}}\right)^2 - \frac{1}{2}\left(\frac{A - A_{pc}}{A_{ec} - A_{pc}}\right)^3\right] \tag{17}$$

Then, we can get the relationship between contact area A and load $F_{ep}(A)$ of micro convex body with plastic deformation by:

$$F_{ep}(A) = p_{ep}A = 1.1K_f\sigma_y A - \left[1.1K_f\sigma_y - \frac{2^{\frac{7-3D}{2}}\pi^{\frac{D-1}{2}}}{3}EG^{D-1}A_{ec}^{\frac{1-D}{2}}\right] \times \left[\frac{3}{2}\left(\frac{A - A_{pc}}{A_{ec} - A_{pc}}\right)^2 - \frac{1}{2}\left(\frac{A - A_{pc}}{A_{ec} - A_{pc}}\right)^3\right]A \tag{18}$$

Here, we complete the relationship between the contact area A and load $F_{ep}(A)$ of micro convex body with plastic deformation. Next, we would talk about the relation between real contact area with contact load of micro convex body

According to the relationship of maximum asperity contact area A_l, micro contact area A_{ec} of critical plastic deformation, and micro contact area A_{pc} of critical plastic deformation, the relationship between real contact area and micro convex body contact load can be classified in to following 3 kinds of conditions.

(1) $A_{ec} < A_l$. Part contacting asperities is in elastic deformation state; Part is in the elastoplastic deformation state; and part is in the state of plastic deformation. The micro convex body contact load F_c is the sum of elastic load F_e, elastoplastic load F_{ep} and the plastic load F_p.

$$F_c = F_e + F_{ep} + F_p = \int_{A_{ec}}^{A_l} F_e(A)n(A)dA + \int_{A_{pc}}^{A_{ec}} F_{ep}(A)n(A)dA + \int_0^{A_{pc}} F_p(A)n(A)dA \tag{19}$$

With the formulas described before, we would give the dimensional relation. The equation would be divided with the nominal contact area A_a of sliding friction surface and comprehensive elastic modulus E , and then we can get:

$$\begin{aligned} \hat{p} = {} & \hat{G}^{D-1} g_2(D)\hat{A}_r^{D/2}\left[g_3(D)\hat{A}_r^{\frac{3-2D}{2}} - \hat{A}_{ec}^{\frac{3-2D}{2}}\right] \\ & + 1.1K_f\phi g_4(D)\hat{A}_r^{\frac{D}{2}}\hat{A}_{ec}^{\frac{2-D}{2}} - K(D)g_1(D)\hat{A}_r^{\frac{D}{2}} \times \\ & \frac{1}{2}\left\{\frac{3}{(\hat{A}_{ec}-\hat{A}_{pc})^2}\left[f_2(3) - 2f_2(2)\hat{A}_{pc} + f_2(1)\hat{A}_{pc}^2\right] - \right. \\ & \left. \frac{2}{(\hat{A}_{ec}-\hat{A}_{pc})^3}\, f_2(4) - 3f_2(3)\hat{A}_{pc} + 3f_2(2)\hat{A}_{pc}^2 - f_2(1)\hat{A}_{pc}^3 \right\} \end{aligned} \tag{20}$$

For equation above, it should meet the demand of $1 < D < 2, \quad D \neq 1.5$;

$$\begin{aligned} \hat{p} = {} & \frac{\pi^{\frac{1}{4}}}{6^{\frac{3}{4}}}\psi^{\frac{1}{16}}\hat{G}^{\frac{1}{2}}\hat{A}_r^{\frac{3}{4}}\ln\frac{\hat{A}_l}{\hat{A}_{ec}} + \\ & 1.45K_f\,\phi\psi^{\frac{1}{16}}\hat{A}_r^{\frac{3}{4}}\hat{A}_{ec}^{\frac{1}{4}} - 0.33\psi^{\frac{1}{16}}\hat{A}_r^{\frac{3}{4}}K(D) \times \\ & \frac{1}{2}\left\{\frac{3}{(\hat{A}_{ec}-\hat{A}_{pc})^2}\left[f_2(3) - 2f_2(2)\hat{A}_{pc} + f_2(1)\hat{A}_{pc}^2\right] - \right. \\ & \left. \frac{2}{(\hat{A}_{ec}-\hat{A}_{pc})^3}\, f_2(4) - 3f_2(3)\hat{A}_{pc} + 3f_2(2)\hat{A}_{pc}^2 - f_2(1)\hat{A}_{pc}^3 \right\} \end{aligned} \tag{21}$$

For equation (21), $D = 1.5$

Where, $g_2(D) = \dfrac{2^{\frac{7-3D}{2}}\pi^{\frac{D-1}{2}}D}{9-6D}\left(\dfrac{2}{D}-1\right)^{\frac{D}{2}}\psi^{\frac{(2-D)^2}{4}}$;

$$g_3(D) = \left[\frac{2-D}{D\psi^{\frac{2-D}{2}}}\right]^{\frac{3-2D}{2}}$$

$$g_4(D) = \left[\frac{D}{2-D}\right]^{\frac{2-D}{2}}\psi^{\frac{(2-D)^2}{4}}$$

$$f_2(D) = \frac{2}{2n-D}\left(\hat{A}_{ec}^{\frac{2n-D}{2}} - \hat{A}_{pc}^{\frac{2n-D}{2}}\right)$$

(2) $A_{pc} < A_l \leq A_{ec}$. Part contacting area of asperities is in elastoplastic state, and the other part is in plastic deformation state. Total contact load F_c of micro convex body is the sum of elastoplastic load F_{ep} and the plastic load F_p .

With the same method, we can get the $P^{\hat{}}$ in this condition:

$$P^{\hat{}} = 1.1K_f\phi A_r^{\hat{}} - K(D)g_1(D)A_r^{\hat{}\frac{D}{2}}$$
$$\times \frac{1}{2}\left(\frac{3}{(A_{ec}^{\hat{}} - A_{pc}^{\hat{}})^2}\left[f_1(3) - 2f_1(2) - 2f_1(1)A_{pc}^{\hat{}\,2}\right] - \quad (22)$$
$$\frac{2}{(A_{ec}^{\hat{}} - A_{pc}^{\hat{}})^3}\left[f_1(4) - 3f_1(3)A_{pc}^{\hat{}} + 3f_1(2)A_{pc}^{\hat{}\,2} - f_1(1)A_{pc}^{\hat{}\,3}\right]\right\}$$

Where, $K(D) = 1.1K_f\phi - \frac{2^{(7-3D)/2}\pi^{(D-1)/2}}{3}G^{\hat{}D-1}A_{ec}^{\hat{}(1-D)/2}$

$K(D)$ is an combination parameters;

$g_1(D)$ is constant with fractal dimension, and $g_1(D) = \frac{D}{2}(\frac{2-D}{D})^{D/2}\psi^{(2-D)^2/4}$;

$f_1(n)$ is the intermediate function, n is an integer from 1 to 4, and

$$f_1(n) = \frac{2}{2n-D}(A_l^{\hat{}(2n-D)/2} - A_{pc}^{\hat{}(2n-D)/2})$$

$G^{\hat{}}$ is the dimensional scale coefficient, and $G^{\hat{}} = G/\sqrt{A_a}$.

$A_{ec}^{\hat{}}$ is the critical contact area of elastic deformation, and $A_{ec}^{\hat{}} = A_{ec}/A_a$;

$A_{pc}^{\hat{}}$ is the critical contact area of plastic deformation, and $A_{pc}^{\hat{}} = A_{pc}/A_a$;

$A_l^{\hat{}}$ is the maximum contact area of micro convex body , and $A_l^{\hat{}} = A_l/A_a$

(3) $A_l \le A_{pc}$. Contacting asperities are in the state of plastic deformation, and then micro convex body contact load F_c is equal to total plastic load F_p.

$$F_c = F_p = \int_0^{A_l} F_p(A)n(A)dA \quad (23)$$

With the same method, dimensional relationship between contact load of micro convex body and the real contact area can be expressed as:

$$P^{\hat{}} = 1.1K_f\phi A_r^{\hat{}} \quad (24)$$

Where, $P^{\hat{}}$ is the dimensionless load, $P^{\hat{}} = F_c/(A_aE)$;

$A_r^{\hat{}}$ is the dimensionless real contact area, $A_r^{\hat{}} = A_r/(A_a)$.

4. Verification of the Method

The algorithm the paper proposed is used to compare with other algorithms. In the comparison, we choose one theory model and a group experimental result. The theory is GREENWOOD-WILLIAMSON model and experiment results are got from BHUSHAN.

Figure 3 shows the comparison results. From the figure, we can get some useful conclusions. Due to the basement of statistical characterization to calculate rough surface morphology, G-W model has a large deviation from the experimental data, and only relatively small error in the high load. Calculation model established in this paper has a small error in a small load. When the higher load, the error is relatively big. G-W model takes the impact between adjacent contacting asperities in to consideration and it can get satisfactory results when it is in condition of high load. The model established in this paper didn't give the consideration and it leads to a large error.

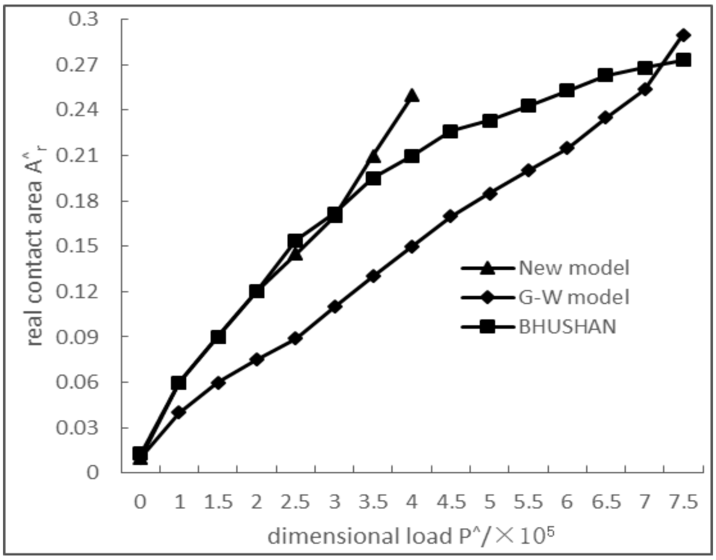

Figure 3. Comparison Results between Different Model and Test

5. Conclusions

The fractal theory has a wide range of applications in the calculation of contact for rough surfaces. Many studies have promoted the analysis of the stress level on rough surface. In this paper, we make the assumption of deformation continuity and smoothness of the surface asperity and combined with related theory to establish a mathematical model for surface contact. The model can be used to study the contact stress on smooth and rough surfaces.

G-W model is based on statistical characterization. When used to calculate rough surface morphology, it has a large deviation from the experimental data and only relatively small error in the high load. Calculation model established in this paper has small error in small load, but it has big difference when the load is higher. The main reason may be that interaction between asperities is not taken into consideration.

The model can be used in the research of influence factors of the real contact area of sliding friction surface, but it should take actual factors into consideration.

Acknowledgements

The work was supported by the youth scientific research projection in Hechi University (2014QN-N006).

References

[1] Z. Zhongrong, “The development frontier of tribology”, Beijing: Science Press, **(2006)**.
[2] J. A. Greenwood and J. B. P. Williamson, “Contact of nominally flat surfaces”, Proc Roy Soc, vol. A295, no. 3, **(1966)**, pp. 300-319.
[3] J. A. Greenwood and J. H. Tripp, “The elastic contact of rough spheres”, ASME J Appl Mech, vol. E34, **(1967)**, pp. 153-159.
[4] T. Thisakado, “Effect of surface roughness on contact between solid surfaces”, Wear, vol. 28, no. 2, **(1974)**, pp. 217-234.
[5] A. W. Bush, R. D. Gibson and T. R. Thmos, “The elastic contact of a rough surface”, Wear, vol. 35, no. 1, **(1975)**, pp. 87-111.
[6] J. Mccool, “Predicting micro fracture in ceramics via a micro contact model”, ASME Journal of Tribology, vol. 108, no. 3, **(1986)**, pp. 380-386.
[7] J. A. Greenwood and J. H. Tripp, “The contact of two nominally flat rough surfaces”, Proc Inst Mech Eng, vol. 185, no. 48, **(1971)**, pp. 625-633.
[8] K. Komvopoulos and D. H. Choi, “Elastic finite element analysis of contacts. Multiasperity”, ASME Journal Tribology, vol. 114, no. 3, **(1992)**, pp. 823-831.

[9] L. Kogut, “ETSION contact analysis of a sphere and L. Elasticplastic a rigid flat”, ASME J Appl Mech, vol. 69, no. 5, **(2002)**, pp. 657-662.
[10] R. S. Sayles and T. R. THOMAS, “Surface topography as a nonstationary random process”, Nature, vol. 271, no. 2, **(1978)**, pp. 431-434.
[11] A. P. Thomas and T. R. Thoms, “Engineering surface as fractals, fractal aspects of materials”, Pittsburgh: Materials Research Society, **(1986)**.
[12] J. Krim and G. Palasantzas, “Experimental observations of scaling and kinetic roughening at Selfaffine Submicron lengthscales”, Int J of Modern Phys, vol. 9, no. 6, **(1995)**, pp. 599-630.
[13] S. Wang and K. Komvopoulos, “A fractal theory of the interfacial temperature distribution in the slow sliding regime: part 1 elastic Contact and heat transfer analysis”, ASME Journal of Tribology, vol. 116, no. 4, **(1994)**, pp. 812-823.
[14] S. Wang and K. Komvopoulos, “A fractal theory of the interfacial temperature distribution in the slow sliding regime: part 2 multiple Domains, elastoplastic contacts and Applications”, ASME Journal of Tribology, vol. 116, no. 4, **(1994)**, pp. 824-832.
[15] S. Wang and K. Komvopoulos, “A fractal theory of the temperature distribution at elastic contacts of fast sliding surfaces”, ASME Journal of Tribology, vol. 117, no. 2, **(1995)**, pp. 203215.
[16] V. Brizmer, Y. Kligerman and I. Etsion, “The effect of contact conditions and material properties on the elasticity terminus of a Spherical contact”, International Journal of Solids and Structures, vol. 43, no. 1819, **(2006)**, pp. 5736-5749.
[17] V. Brizmer, Y. Kligerman and I. Etsion, “Spherical contact under combined normal I. Elasticplastic and tangential loading in full stick”, Tribology Letters, vol. 25, no. 1, **(2007)**, pp. 61-70.
[18] D. Nelias, E. Antaluca and A. Boucly, “A semi analytical model for sliding contacts Three dimensional Elasticplastic”, ASME Journal of Tribology, vol. 129, no. 4, **(2007)**, pp. 761-771.
[19] X. Yinin and K. Komvopoulos, “An adhesive wear model of fractal surfaces in normal contact”, International Journal of Solids and Structures, vol. 47, no. 7-8, **(2010)**, pp. 912-921.
[20] Z. Lisowski and T. Stolarski, “An analysis of contact between a pair of surface asperities during sliding”, J Appl Mech, vol. 48, no. 3, **(1981)**, pp. 493-499.
[21] Y. Xie and J. A. Williams, “The prediction of friction and wear when a soft surface slides against a harder rough surface”, Wear, vol. 196, no. 1-2, **(1996)**, pp. 21-34.
[22] Z. Lisowski and T. Stolarski, “An analysis of contact between a pair of surface asperities during sliding”, J Appl Mech, vol. 48, no. 3, **(1981)**, pp. 493-499.
[23] J. Yang and K. Komvopoulos, “A mechanics approach to static friction of fractal surfaces (J Elasticplastic)”, ASME Journal of Tribology, vol. 127, no. 2, pp. 315-324.
[24] Z. Q. Gong and K. Komvopoulos, “Effect of surface patterning on contact deformation of layered media”, ASME Elasticplastic Journal of Tribology, vol. 125, no. 1, **(2003)**, pp. 16-25.
[25] A. Faulkner and R. D. Arnell, “Development of a finite element model to simulate the sliding interaction between two, Three dimensional, Elastoplastic, hemispherical asperities”, Wear, vol. 242, no. 1, **(2000)**, pp. 114-122.
[26] L. J. Robert, S. D. Ravi, M. Hasnain, *et al.*, “An analysis of sliding spherical asperity interaction Elastoplastic”, Wear, vol. 262, no. 12, **(2007)**, pp. 210-219.
[27] A. Majumdar and B. Bhushan, “Fractal model of elasticplastic contact between rough surfaces”, ASME, Journal of Tribology, vol. 113, no. 1, **(1991)**, pp. 1-11.
[28] B. Bhushan, “Introduction to tribology”, New York: John Wiley Sons, **(2002)**.
[29] W. Shao and K. Komvopoulos, “A fractal theory of the interfacial temperature distribution in the slow sliding regime PartⅡ－multiple domains, elastoplastic contacts and applications”, ASME, Journal of Tribology, vol. 116, no. 4, **(1994)**, pp. 824-832.
[30] K. L. Johnson, “Contact mechanics”, Cambridge: Cambridge University Press, **(1985)**.
[31] W. Long, G. Boqin, F. Xiu, *et al.*, “Contact fractal model of friction face of mechanical seals”, CIESC Journal, vol. 60, no. 10, **(2009)**, pp. 2543-2548.
[32] C. Guoan and G. Shirong, “Prediction model of sliding wear during running-in process based on fractal theory”, Chinese Journal of Mechanical Engineering, vol. 36, no. 2, **(2000)**, pp. 29-33.

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