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CONTOUR CONTACT AREA OF THE BLOCK AND DISK OF THE DISK BRAKE UNDER THE CONDITIONS OF THERMAL DEFORMATIONS

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Summary. The article presents the analysis of the contour contact area changes of the block and the disk of the disk brake under the action of thermal deformations of the disk which appear while braking. The design is offered which promotes the influence decrease of the thermal deformations on the value of the contour contact area.

Key words: disk brake, thermal deformations, contour contact area.

INTRODUCTION

According to classical ideas of interaction of the bodies, contour contact area is the area which is formed while touching the bodies which have macrodeviations from regular geometrical shapes.

One of the factors which influence the macrodeviations of the block and disk of the disk brake are the thermal deformations of the materials which are caused by the heating of the interacting surfaces (700 – 800 and more degrees Celsius). In connection with this, the purpose of this article is the analysis of the peculiarities of the formation of the contour contact area of the block and disk of the disk brake under the conditions of the disk thermal deformations.

The nature of thermal (reversible and irreversible) deformations of the surfaces of the block and disk is caused by the conditions of considerable non-stationarity of the process both in the quantity and durability of the cycles of the thermal heating in the result of braking and in the level of realized temperatures.

The heating of the working elements of the disk brake is characterized by irregularity of temperature spreading in the volume of the materials of the block and the disk and it causes irregular deformations of the disk surface. As the result, the working surface of the disks is distorted and acquires macrodeviations from the plane [1, 2, 5, 6, 8 – 14, 16, 17].

CALCULATION MODEL

The evaluation is given of the changes in the contour contact area of the block and disk of the disk brake under the conditions of deformations caused by the heating of the disk because of friction (the disk is approximated by cylindrical and spherical surfaces, the block is approximated by the plane). The analysis is carried out for two cases: in the first one the block is represented by one working plane, in the second case it is represented by two planes. Calculation diagrams are given in Figure 1. The following assumptions are taken into account:

- voltage in the zone of contact does not exceed the limit of elasticity;
- the areas of contact are small in comparison with the surfaces of the touching bodies;
- pressure forces spreading along the surface of contact are normal to this surface;
- deformations of the disk surface: volume – symmetrical;
- deformations of the block are small.

The areas of contact for the case of interaction of the above surfaces are calculated with the help of dependencies known from the theory of elasticity [3, 4, 15].

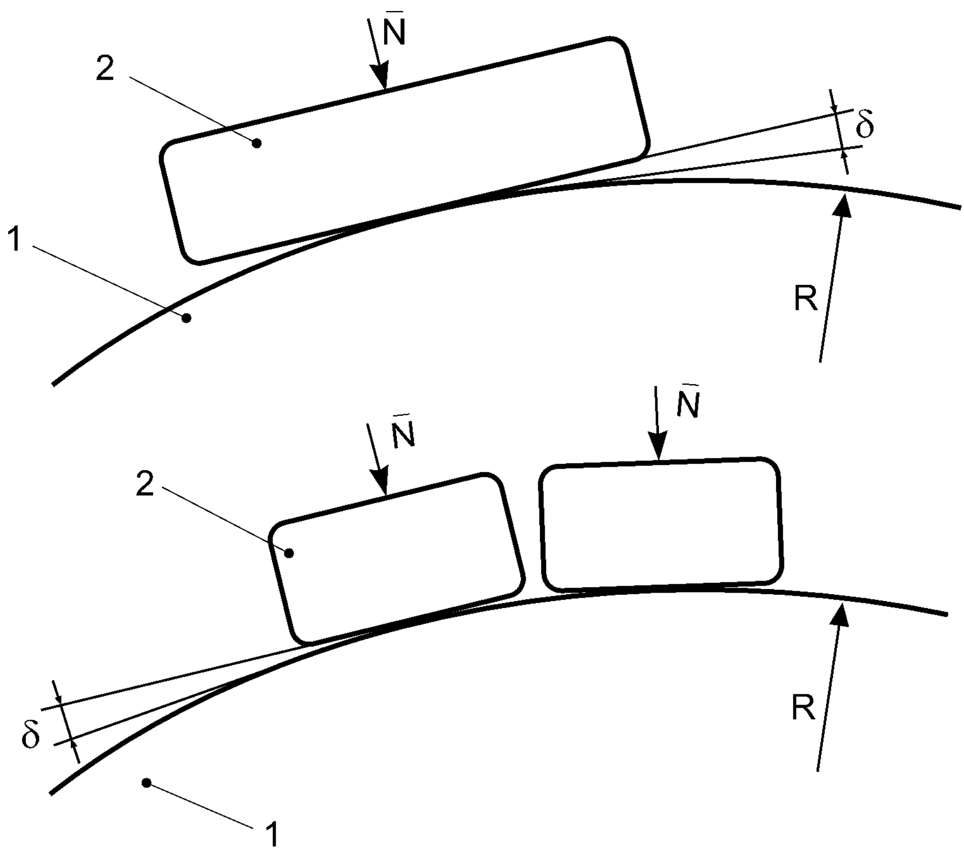

Fig. 1. Calculation diagrams in the estimation of contour contact area of the block and the disk of the disk brake under the conditions of thermal deformations: a) – block presented by one working plane; b) – block presented by two working planes. 1 – brake disk; 2 – block; N – pressing force of the block to the disk; δ - level of deformation stipulated by the curvature radius of the surface R.

The contact of the flat and cylindric surfaces is estimated by the expression:

$$b = 1{,}131\sqrt{\frac{N \cdot R}{H}\left(\frac{1-\mu_1^2}{E_1} + \frac{1-\mu_2^2}{E_2}\right)}, \tag{1}$$

where: b – semi-width of the strip contact;
R – curvature radius of the surface in the zone of contact;
H – length of the contact strip (width of the block);
$\mu_{1,2}$ - Puasson coefficient of the materials of the contacting surfaces;
$E_{1,2}$ – elasticity modulus of the materials of the contacting surfaces.

Contact of flat and spheric surfaces:

$$r = 0{,}909\sqrt[3]{N \cdot R\left(\frac{1-\mu_1^2}{E_1} + \frac{1-\mu_2^2}{E_2}\right)}, \tag{2}$$

where: r – radius of the contact spot.

Curvature radius of the contacting surfaces R, which is a member of the formula (1) – (2) is determined in the following way (see Fig. 2).

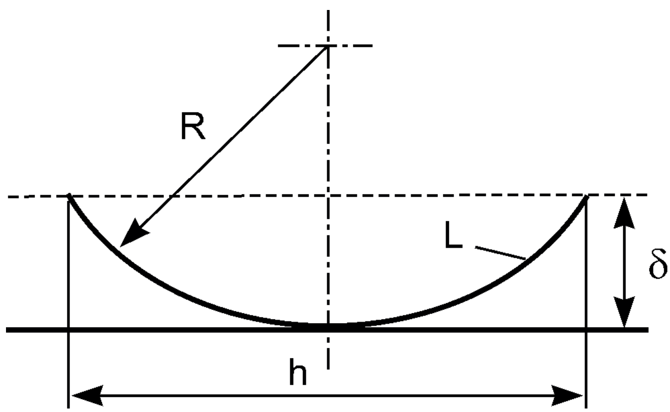

Fig. 2. Diagram in the value estimation of the curvature radius R of the contacting surfaces in the zone of contact

Lengths of the chord h and arc L (Fig. 2) are estimated as [7]:

$$h = 2\sqrt{2 \cdot \delta \cdot R - R^2}\ ;\ L = \sqrt{h^2 + \frac{16 \cdot \delta^2}{3}}. \tag{3}$$

Having manipulated these expressions we obtain:

$$R = \frac{L}{8 \cdot \delta} - \frac{2}{3}\delta + \frac{1}{2}\delta\ . \tag{4}$$

The value L in the calculations corresponds to the outer radius of the brake disk. The values of summary nominal areas of the working surfaces of the blocks of the brake disk for the two above-mentioned cases (a) and (b) are considered to be equal.

Cast-iron and steel with corresponding use in the formulas (1) – (2) of the average values of their mechanical characteristics are taken as the materials of the blocks and brake disk. The seize of the block for the condition (a) (fig. 1): 0,20 ´ 0,121 m: for the condition (b): 0,10 ´ 0,121 m; outer radius of the brake disk: 0,35 m.

RESULTS OF CALCULATIONS

The results of the calculations in the above dependencies are given in Fig. 3. (Notes: the values for the condition (b) are given in the brackets, for the condition (a) the values are given without brackets; S_H – nominal area of contact of the considered surfaces before deformation.

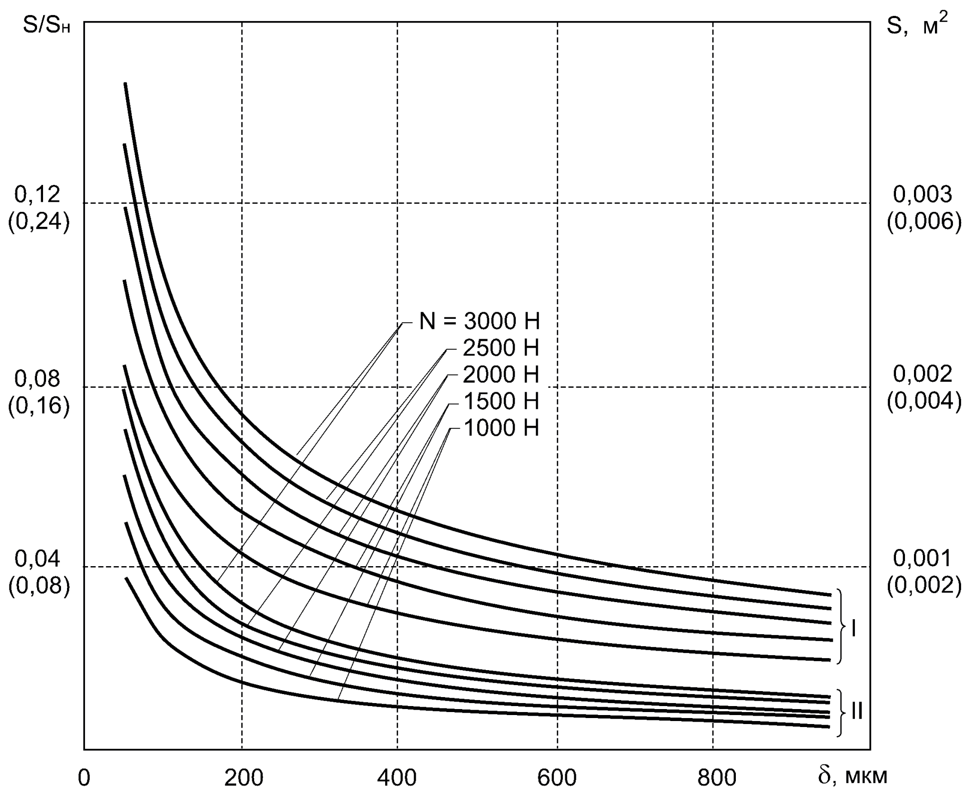

Fig. 3. Dependencies of the contour S and relative $S/S_н$ areas on the thermal deformation δ and normal pressing force N of the block to the disk:
I – contacting surfaces: plane (block) – cylinder (disk);
II – contacting surfaces: plane (block) – sphere (disk)

The analysis of the given dependencies showed that in the result of thermal deformations of the disk its contour area of contact with the block has the tendency to decrease. While level growing of the thermal deformations (parameter δ) from 0,0 mkm to 1000 mkm a contour area of contact Has , on average, 81% of decrease.

Decrease levelling of the contour area of contact of the block and disk under the conditions of thermal deformations can be provided due to the block which is presented in the form of two working planes (condition b). In this case the decrease of the contour area of contact under the conditions of thermal deformations can be two times less and makes 40%.

CONCLUSION

Thermal deformations of the brake disk have a considerable influence on the formation of its contour area of contact with a block under the conditions of force interaction. General tendency of influence of thermal deformations on the contour area consists in the decrease of the latter while growing deformations.

With the growth of thermal deformations from 0,0 mkm to 1000 mkm a contour area of contact decreases by mean 81% (for a block presented by one plane) and by mean 40% (for a block presented by two planes).

Design improvement of the block of the disk brake can be achieved due to the presentation of the working surface of the block as the system of kinematically connected of two and more planes.

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КОНТУРНАЯ ПЛОЩАДЬ КОНТАКТА КОЛОДКИ И ДИСКА ДИСКОВОГО ТОРМОЗА В УСЛОВИЯХ ТЕРМИЧЕСКИХ ДЕФОРМАЦИЙ

Аннотация. В статье представлен анализ изменений контурной площади контакта колодки и диска дискового тормоза под воздействием термических деформаций диска, возникающих при торможении. Предложен конструктивный способ уменьшения влияния термических деформаций на величину контурной площади контакта.

Ключевые слова: дисковый тормоз, термические деформации, контурная площадь контакта.