DETERMINING THERMAL RESISTANCE OF CONTACT BETWEEN
FINISHED WAVY METALLIC SURFACES

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A design formula for determining the thermal resistance of a contact is obtained
using functions describing the relief of real wavy surfaces.

Previously completed comparative experimental investigations into the thermal contact
resistance (TCR) of metallic contacts between flat-rough and wavy surfaces [1, 2] have estab-
lished a significant increase in the TCR for the latter for virtually identical grades of
surface finish, while an increase in the height of the waves in the surface causes a marked
increase in the TCR. At the same time, the theoretical model given in [2, 3] for determining
the thermal contact resistance of wavy surfaces is to a certain extent idealized, inasmuch
as a homogeneous distribution of the waves by height relative to a standard plane is taken
as one of the basic premises. An analysis of profilograph traces from finished metallic sur-
faces shows that real surfaces represent in most cases a set of waves of a usually spherical
or ellipsoidal form with a constant radius subject to a normal (Gaussian) law of distribution
by height [4].

Let us examine a contact couple with a wavy surface [2]. In general, the thermal con-
tact conditions presuppose a temperature drop common to all macrocontacts:

$$\Delta T_C = \frac{Q}{2\kappa a} \varphi.$$ 

Hence for all macrocontacts the following equality obtains:

$$2\kappa \Delta T_C = \frac{Q}{a/\varphi}.$$ 

According to the last equality, the total heat flow is divided as it passes through the
individual macrocontacts, i.e., we have the following relation:

$$\frac{Q_1}{a_1/\varphi_1} = \frac{Q_2}{a_2/\varphi_2} = \ldots = \frac{Q_m}{a_m/\varphi_m};$$

hence with an unvariable $\varphi$
Fig. 1. Diagram of cross section of wavy surface through a plane parallel to the geometrical plane.

\[ Q_i = Q \frac{a_i q_i}{\sum_{k=1}^{m} a_C q_C} = Q \frac{a_i}{\sum_{k=1}^{m} a_C} \]

The model examined for a thermal contact between two solids presupposes the existence (at a distance from the interface) of thermal channels with cross sections \( S_{N_1}, S_{N_2}, \ldots \), through which the heat flux is fed to the appropriate macroscopic regions of the contact, i.e.,

\[ S_{N_i} = S_{N_i} \frac{Q_i}{Q} = S_{N} \frac{a_i q_i}{\sum_{k=1}^{m} a_C q_C} = S_{N} \frac{a_i}{\sum_{k=1}^{m} a_C} \]

It is possible, using the relations given, to express the thermal resistance for one or several macrocontacts in the form

\[ R = \frac{\Delta T_G}{Q/S_N} = S_{N} \sum_{i=1}^{n} \frac{\Delta T_G}{Q_i} = \frac{S_{N}}{2 \bar{R}_M} \sum_{i=1}^{n} \frac{Q_i}{a_i} = \frac{q}{2 \bar{R}_M} \sum_{i=1}^{n} a_i \frac{S_N}{\pi} = \frac{\pi}{2} \frac{|\bar{L}| q}{2 \bar{R}_M \bar{r}^{1/2}}. \tag{1} \]

Dependence (1) can be realized for a contact between real wavy surfaces given information on the magnitude of \( qa_i/S_N \) or \( n_2 \) taking into account the probability of projections of the waves coming into contact with the plane.

Let us examine a profilograph trace on a line of length \( L \) (Fig. 1) plotted from a wavy surface of area \( S_N \) with a stationary profile at an angle of \( \beta \) to the direction of finishing. For an arbitrarily selected level of the profilograph trace the values for the length of the segments of the secant along a given direction are equal to, respectively, \( \Delta L_1, \Delta L_2, \ldots, \Delta L_n \). If the AA' and BB' lines are continued parallel to CC' for a distance of \( d/2 \), significantly less compared with the dimensions of \( S_N \) and \( S_C \), then by virtue of the stationary nature of the profile the relative contour area of the wave cross sections can be represented as

\[ n_2 = \frac{S_C}{S_N} = \sum_{i=1}^{n} \frac{\Delta S_{C_i}}{\Delta S_N} = \frac{d \sin \beta}{\sum_{i=1}^{n} \frac{\Delta L_i}{ld \sin \beta}} = \frac{\sum_{i=1}^{n} \Delta L_i}{l}. \tag{2} \]

Here \( \Delta S_N \) and \( \Delta S_{C_i} \) are, respectively, the areas of the AA' and BB' zone and of the wave cross sections in the zone.