



Fig. 2. Variation of the specific force of friction with normal pressure for elastomer material of natural rubber with equilibrium modulus 18.1 kgf/cm². 1) in vacuum; 2) in air at 20°C; 3) in vacuum at 40°C. Velocity of sliding 0.8 mm/min.

Some experimental results of the dependence of frictional force on the normal pressure and on the velocity of sliding in vacuum and in atmospheric conditions, which are described below, refer to the stabilized process of rubbing reticular materials made of natural rubber.

Variation of the specific force of friction with normal pressure for NR in air and in vacuum is shown in Fig. 2. Under low normal pressures, the data obtained in vacuum and in air practically coincide, as was shown previously [5]. Under pressure above 50 kgf/cm² the force of friction is somewhat higher in vacuum than in atmospheric conditions. Most probably, the effect of the air basically amounts to the formation of an air film on the surface of the contact, which prevents the formation of the area of real contact [6]. Under low normal pressures, when real contact is increasing, there are many vacant places where a new area of contact can be formed, and therefore the data in air and in vacuum coincide. Under high normal pressures, different data were observed in vacuum and in atmosphere, because all possible areas of contact have been formed when the air did not prevent their formation.

Let us analyze the dependence of the specific force of friction f on the normal pressure in vacuum (Fig. 2, curve 1). This dependence contains three characteristic ranges.

Within the range from 1 to 200 kgf/cm² the observed increase of the force of friction corresponds to equations [2, 7]

$$f = C\varphi, \quad (1)$$

$$\varphi = 1 - e^{-\frac{\beta}{E}p}, \quad (2)$$

where C is the coefficient of friction depending on the nature of the frictional pair, speed of sliding, and temperature, $\varphi = S/S_n$ is the relative area of real contact which depends on the elastic properties of the polymer and on the normal pressure p , S is the area of real contact, S_n is the area of nominal contact, β is the coefficient which characterized roughness, and E is the modulus of elasticity.

Under pressures of about 200 kgf/cm² the relative area of real contact, in correspondence with Eq. (2), attains its limiting value approaching unity, while C , the coefficient of friction, is practically constant under these pressures. In consequence, a plateau appears on the curve in range II.

Under higher normal pressures in range III, further increase of the force of friction commences with the increase of the pressure above 400–500 kgf/cm²; this phenomenon was first discovered in the atmosphere by Lavrent'ev and Voevodskii [8].

A considerable change of the free volume occurs in elastomers under normal pressures above 400–500 kgf/cm² [2]. This leads to the reduction of the specific volume which in turn causes an increase in the number of contacting chains per unit of area. In consequence, the specific force of friction increases, in agreement with the equation resulting from the molecular kinetic theory of friction [10]:

$$f = \frac{2}{\lambda} n_k (U - kT \ln v_0/v), \quad (3)$$

where λ is the mean magnitude of chain migration, n_k is the number of contacting chains per unit of area, U is the activation energy of the rubbing process, k is Boltzmann's constant, T is absolute temperature, and v_0 is a constant and v is the sliding velocity.

Furthermore, according to Aibinder [11, 12], reduction of the specific volume leads to the increase of the modulus of volume compression and adhesive interaction, since the forces of adhesion are determined by the distance between surfaces of interacting bodies, in particular when the main effects are those of nondirectional van der Waals forces. Therefore, within range III the frictional force increases due to the increase of the number of contacting chains per unit of contact area n_k ,