OTS: 60-41,421

JPRS: 4051

21 September 1960

4051

RECORD
COPY

MAIN FILE

THE ABRASION INDEX OF RUBBER AND ITS CONNECTION WITH THE COEFFICIENT OF FRICTION

By S. B. Ratner

- USSR -

RETURN TO MAIN FILE

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

Distributed by:

OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D. C.

~~Price: $0.50~~

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
205 EAST 42nd STREET, SUITE 300
NEW YORK 17, N. Y.

Reproduced From
Best Available Copy

20000707 183

DTIC QUALITY INSPECTED 4

JPRS: 4051

CSO : 1047/B-S

THE ABRASION INDEX OF RUBBER AND ITS CONNECTION WITH THE COEFFICIENT OF FRICTION

- U S Ŝ R -

/Following is a translation of the article "O pokazatele istriraniya reziny i yego soyazi e koeffitsientan treniya" (English version above) by S. B. Ratner in Doklady Akademii Nauk SSSR (Reports of the Academy of Sciences of the USSR), Vol LXXXVII, No 5, 1952, pages 743-746./

(Submitted to Academician P.A. Rebinder on 4 October 1952)

1. In literature (1) concerned with the problem of connection between wear and friction we have failed to find data on the interrelationship between the abrasion index and the friction coefficient of rubber. The work before us lists some experimental results and physical concepts on that question. Materials presented here apply to cases where lubricant is absent.

2. The index of abrasion of rubber is expressed by (2) the formula:

$$\nu = \frac{\Delta V}{W} \qquad (1)$$

It is assumed that decrease of volume ΔV is proportional to the work of friction W, independently of the factor at the expense of which the given mechanical work is obtained: at the expense of the quantity /magnitude/ of the force of friction F, or the dimensions of relative shifting of x, so that

$$W = Fx, \qquad (2)$$

$$\Delta V = \nu F x. \qquad (3)$$

In the last formula ν is the coefficient of proportionality; the same must play the role of the material's constant, characterizing the ability of material to resist abrasion. Such a quantity can fill that role, provided it does not depend on the normal load, N. In that case, it is possible to transpose the results obtained in testing of a sample onto the work of the manufactured article, insofar as its various elements can work under different, frequently unknown, loads.

However, experiment [experience] shows that the generally accepted index of abrasion depends on the load N (see Fig. 1a, b, c for experimental findings for rubbers (on the base of caoutchoucs SKN and SKB) being abraded by friction against sandpaper on a machine of the Grasselli type) (2). Such regularity is apparently connected with the factor of increase of small loads, whereby the particles of sandpaper are pressed deeper into the rubber with the result of increased abrasion. This effect gradually wears off at large loads, when those reach the limit of durability of rubber, or even exceed it. When loads become sufficiently large, their increase is bound to accelerate work without substantial increase in the abrasion index, because sandpaper cannot be pressed into the surface layers of rubber any more strongly since the resistance of those layers to indentation is already overcome. Curves of the type presented (Fig. 1a, b, c) are outwardly reminiscent of Langmuir's isotherms of absorption and can be approximately described by the formula

$$\nu = \frac{\nu_\infty N}{A + N}, \qquad (4)$$

where ν_∞ - represents the maximal value of the abrasion index at $N \to \infty$, A -- is constant which has dimensionality of force.

Formula (4) may be transformed to (4a)

$$\frac{1}{\nu} = \frac{1}{\nu_\infty} + \frac{A}{\nu_\infty}\frac{1}{N}, \qquad (4a)$$

where dependence of 1/v on 1/N is linear and in satisfactory agreement with presented experimental data.

3. It is known from our works (3) that the friction coefficient of rest decreases as loads increase, as per formula

$$\mu = \mu_\infty + \frac{F_c}{N} \qquad (5)$$

where μ_∞ -- is coefficient of friction at $N \to \infty$ -- tangential component of the forces of molecular interaction between the members of the working pair.

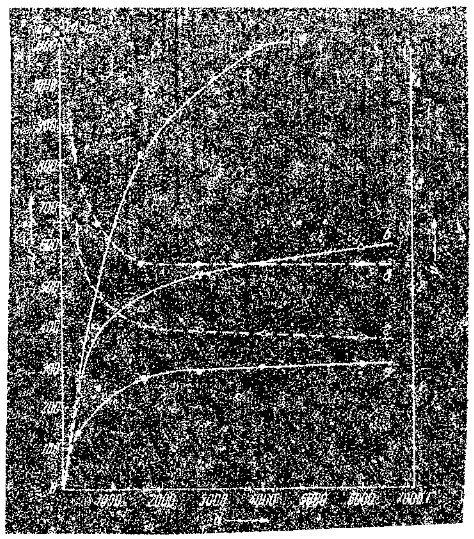

Figure 1: The effect of load N on the abrasion index v(a,b,w) and on the friction coefficient μ (g,d) -- rubber #1, on base SKN-26, containing 10 weight parts of soot; g - rubber #2, same base, containing 45 weight parts of soot (standard recipe); b - rubber #4, same base, containing 120 weight parts of soot; w - rubber for rubber shoes, base SKB.

Analogous findings were obtained in research into friction of motion (Fig. 1g, d). Curves g and d in Fig. 1 pertain to friction of rubber against steel. An analogous visualization has a place also in the friction of rubber against sandpaper, which is also borne out by agreement between the experiment and the formula (8-10).

Inasmuch as

$$F = \mu N \tag{6}$$

substituting (4), (5) and (6) in (3), we obtain:

$$\Delta V = x V_{\infty} \mu_{\infty} N \frac{N + F_0/\mu_{\infty}}{N + A}. \tag{7}$$

In view of the fact that the value of fraction is almost independent from N, and that in each experiment x = const, then approximately:

$$\Delta V = const\ N. \tag{8}$$

Indeed, the quantity for abrasion of rubber must, apparently, by proportional to the quantity of "pinning efforts" which, in their turn, are proportional to normal load N. According to formula (8), we must have:

$$\frac{\Delta G}{N} = const, \tag{9}$$

since decrease in weight of samples ΔG is proportional to the quantity ΔV, because specific unit weight does not depend on N. Formula (9) is actually validated by experiment (see Table 1 for rubbers with base SKN and SKB).

Analogous data was obtained by Vogt (4) on a machine of his own construction for rubber, base HK_3 the loss of volume of which goes up from 4.7 to 15.3 cm^3 when loads on the sample are increased from 6.75 to 24.4 kilograms. These findings on the abrasion of rubber did not find rational interpretation and application for a period of a quarter of a century, because they were separated from the study of friction.

Table 1. Relation of Weight Diminiution of Rubbers to Load $\left(\frac{\Delta G}{N} \cdot 10^5\right)$ for Varying Loads

Load in grams	## of Rubbers*					
	1	2	3	4	5	6
286	7	8	10	22	23	47
754	9	9	10	17	22	55
1534	8	10	11	16	35	39
2534	8	8	14	13	23	32
3954	11	12	10	18	36	32
5954	-	9	9	17	-	-
Median	8.6 ± 0.9	9.3 ± 1.1	10.7 ± 1.2	17.1 ± 1.8	28 ± 6	41 ± 8

* ## of rubbers 1,2,4,5 correspond to ## mentioned in caption to Fig. 1. Rubber #3 is the same as ##1,2,4, but contains 70 weight parts of soot. Rubber #6 - on base SKB, applies to conveyor belts.

4. Thus, the relationships $\Delta G/N$ or $\Delta V/N$ characterize the resistance of the material to abrasion, regardless of load.

Combining formulas (3), (6), and (8) and taking into account that x = const, we can obtain:

$$\nu\mu = K = const. \tag{10}$$

It is possible to arrive at this very same correlation independently, by combining formulas (4) and (5). Consequently, any of the formulae (1), (4), (8) and (10) may be regarded as a direct result of both the noted physical concepts and the experimental data.

Since $\mu = 1/\nu$ where ν is the coefficient of slippage, it follows from (10) that the abrasion index is in proportion to the coefficient of slippage.

Formula (10) also shows that the characteristic of rubbers, independently of load, lies in the resultant $\nu\mu = K$, which defines the properties of sample as well as those of the manufactured product with its various elements performing under any loads. Abrasion of rubber is proportionate to quantity K, which may be called the abrasion index.

5. On the basis of the above we may arrive at the following conclusions.

a) The generally accepted index of rubber abrasion ν is not a constant for material, owing to its dependence on load;

b) The abrasion index ν increases when friction coefficient of rubber μ decreases;

c) The constant for rubber, independent from load and characterizing the abrasion-resistance of both sample and manufactured article, lies in a new quantity: abrasion coefficient $K = \nu\mu$;

d) These results, obtained through examination of rubber, may be of interest in study of wear and friction of other materials also.

The author expresses his gratitude to V. V. Il'in, N. V. Zakharenko and F. Kh. Mustafinova for assistance in the conduct of experiments and to G. M. Bartenevu for discussion of results.

Scientific Research Institute
of the Rubber Industry

Received
8 July 1952

REFERENCES

1. Compiled Anthologies of Works /Collected Works/ of the Conference on Friction and Wear of Machines, publ. AN SSSR, 1939 and 1947.
2. Testing of Rubber for Abrasion on the Grasseli Machine, GOST 426-41, 1947, page 45.
GOST (Gosudarstbennyy Obshchesoyuznyy Standart - Governmental All-Union Standard)
3. Ratner, S. B., DAN, 83, No 3, 443 (1952); Ratner, S. B, Sokol'skaya, V. D., DAN, 86, No 1, 121 (1952).
4. Vogt, W., Ind. Eng. Chem., 20, No 3, 302 (1928).

10,065
10,123

- END -

FOR REASONS OF SPEED AND ECONOMY
THIS REPORT HAS BEEN REPRODUCED
ELECTRONICALLY DIRECTLY FROM OUR
CONTRACTOR'S TYPESCRIPT

THIS PUBLICATION WAS PREPARED UNDER CONTRACT TO THE
UNITED STATES JOINT PUBLICATIONS RESEARCH SERVICE
A FEDERAL GOVERNMENT ORGANIZATION ESTABLISHED
TO SERVICE THE TRANSLATION AND RESEARCH NEEDS
OF THE VARIOUS GOVERNMENT DEPARTMENTS