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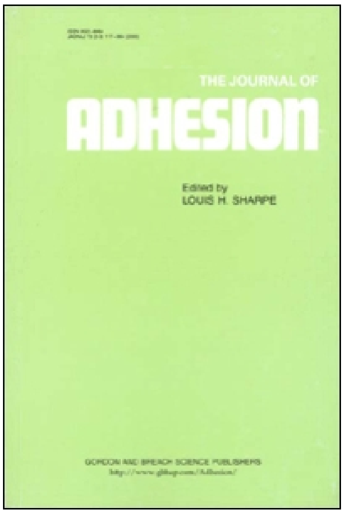

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Letters

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LETTERS

THE CONTACT ADHESION OF SELF-ADHESIVE STRAIN GAUGES

Dear Sir:

In the paper by Norman and Wake [1], the normal force between two solids in contact was attributed to capillary attraction while the tangential force needed for sliding was supposed to depend on the mechanical properties (modulus of elasticity and maximum strain) of the solids. However, condensation of liquid around the asperities on solid surfaces must, of itself, give rise to a friction-like force whenever hysteresis of wetting takes place; no properties of the solid, except their wettability, enter the picture.

If there are n droplets of liquid around the points of "contact" per square centimeter, and if the mean cross-section of the droplet (parallel to the solid surfaces) is ω cm^2, then the normal force per cm^2 is $2\,n\omega\gamma/d$; γ g/sec^2 is the surface tension of the liquid and d cm is the separation of the two parallel solids. In the presence of hysteresis of wetting, each drop resists any tangential displacement of a plate with a force $k\sqrt{\omega\gamma}$ [2]; k is a number which depends on the contact angle and the surface roughness but in many instances is near 0.5. The resistance offered by all n droplets is $nk\sqrt{\omega\gamma}$. From the above expressions, the ratio of the tangential to the normal force (analogous to the coefficient of friction) is $kd/2\sqrt{\omega}$ which often will be about $d/4\sqrt{\omega}$. If the edge of the droplets (parallel to the solid surface) is 4 times as great as its height d, then $d/4\sqrt{\omega} = 1:16$, that is equal to the "coefficient of friction" preferred by the authors [1].

J. J. Bikerman

[1.] R. H. Norman and W. C. Wake, *J. Adhesion* 1, (1969), p. 7.
[2.] J. J. Bikerman, *J. Colloid. Sci.* 5, (1950), p. 349; "Surface Chemistry", 2nd ed., p. 350; Academic Press, New York 1958.

REPLY

Dear Sir:

We have read your correspondent's letter with interest and we cannot fault his alternative explanation for the immediate (short-term) phenomenon. There is, additionally, a need to explain the absence of creep over at least 24 hr, a known feature of these strain gauges. The argument used by your correspondent implies a large difference between advancing and receding contact angles. Advancing contact angles are usually subject to decay with time, moreover the difference between advancing and receding contact angles tends to decrease as the surface becomes smoother while the evidence given to us emphasized the advantages of smooth surfaces. If the equilibrium contact angle is zero, but the advancing angle is finite, shearing will decrease the distance between the surfaces and therefore increase the direct interaction between asperities. Your correspondent's expression for normal force, like our own, is only strictly true for zero contact angle, whereas the reference he quotes leading to his value of k depends upon data relating to high (ca. 60°) contact angles. We would prefer to leave both explanations standing as an attempt to rationalise what is, to many, an inexplicable phenomenon.

R. H. Norman and W. C. Wake

Dear Sir:

Two instances of a weak boundary layer are described in The Journal of Adhesion, vol. I, No. 2 but they are likely to remain unnoticed because of the nomenclature used by the authors.

In the first example, a permanently tacky alkyl acrylate copolymer was the adhesive. On p. 116-117 it is stated that this material can be quantatively removed from the surface of a polycaprolactam by peeling. To prove this removal, the wettability of this surface was measured before and after the contact with the copolymer. Unfortunately, the liquids employed in the test were powerful solvents. Tetrabromoethane and α-bromonaphthalene visibly dissolved the acrylate, see Table 3 on p. 106, during the short time needed for determining a contact angle. As the dissolution was noticed visually, the dissolved layer must have been many microns thick. If the layer of the adhesive remaining on the polycaprolactam adherend after peeling was of the order of one micron (as in the experiments on polyethylene [1], this layer was completely dissolved away before the contact angle could be measured.

Thus, the above wettability tests do not help in determining the locus of rupture of the joint. However, the relative values of the peeling force render it almost certain that a weak boundary layer was present between the acrylate and the poly(tetrafluoroethylene) used as an adherend. The highest value of this force was about one-tenth of the maximum force observed with other adherends. At the highest peeling rates tested, the peeling force still was about 0.02 to 0.05 of the maximum force for the other adherends but it was zero for poly(tetrafluoroethylene). This ease of separation strongly points to a weak boundary layer. As an alkyl acrylate is not likely to wet "Teflon", it is very probable that a zone of air pockets was present between the copolymer and the "Teflon" before the rupture of the joint. Thus, a weak boundary layer of the first class [2] presumably was present.

The other example, pp. 136-141, deals with joints of "aluminum—an epoxy adhesive—aluminum". When loaded under water, these joints seemed to fail between the aluminum and the adhesive. The description of their behavior reminds one of the observations made by Black and Blomquist [3]. Water gradually invaded the adhesive—adherend interface, starting from the 3-phase line (in which water, the adhesive and the adherend meet). Unfortunately, the chemical nature of the interfacial phase formed is not known. Was this material simply alumina, or swollen epoxy resin, or the product of a chemical reaction between water, aluminum and a component of the adhesive? It is hoped that this question will be answered in due course.

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1. J. J. Bikerman, J. Appl. Chem. *11,* 81 (1961).
2. J. J. Bikerman, *Ind. & Eng. Chem.*, *59,* 40 (1967); "The Science of Adhesive Joints", p. 164, Academic Press, New York 1968.
3. J. M. Black and R. F. Blomquist, *Ind. & Eng. Chem.*, *50,* 918 (1958).