SOME REMARKS ON SURFACE TENSION MEASUREMENTS BY THE WILHELMY METHOD USING A TILTED OR A ROUGHENED PLATE

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Recently, a report on the theoretical consideration for the measurements of surface tension by the Wilhelmy method in the case of a tilted plate and a roughened plate have been presented by Jordan and Lane.[1] These authors derived the equation for the vertical force acting on the tilted plate and explained "the good results obtained from the measurement of surface tension using a deliberately roughened glass plate" by the presumption that "the effect of the vertical grooves could be almost compensated by the effect of the horizontal grooves". Smith[2] later cited the work of Jordan and Lane and made a similar explanation.

However, according to our theoretical considerations and the experimental confirmation, Jordan and Lane's calculation of the vertical force exerted on the tilted plate is in error, and their explanation of the effect of the roughened plate is consequently unacceptable.

The vertical force $\mathscr{F}$ acting on the plate of perimeter L dipped in the liquid of surface tension σ, and tilted at an angle α to the vertical should be expressed by

$$\mathscr{F} = \sigma L/\cos\alpha \qquad (1)$$

instead of the relation

$$\mathscr{F} = \sigma L\cos\alpha \qquad (2)$$

presented by Jordan and Lane (equation (26) of their paper) as shown in Figure 1 (*a*),(*b*). The equation (1) is proved to hold as seen in Figure 1(*a*), where the principle of virtual work is illustrated for the vertical displacement dz of the tilted plate.

To confirm experimentally the relation between the vertical force acting on the tilted plate, the value of $\mathscr{F}$ was measured for the platinum plate dipped in water at varying angles α. The results obtained are shown in Table 1. It is evident from this table that the vertical force $\mathscr{F}$ for a tilted plate is larger than the force for a vertical plate; $\mathscr{F}$ increases with α, and equation (1), not (2), is confirmed to hold experimentally. Therefore, the subsequent explanation of Jordan and Lane for the effect of roughness of the plate is considered to be incorrect. The compensation of the effects of roughness along the periphery and across it (as Smith inferred) cannot be expected to occur but the two effects would rather become additive. It has been

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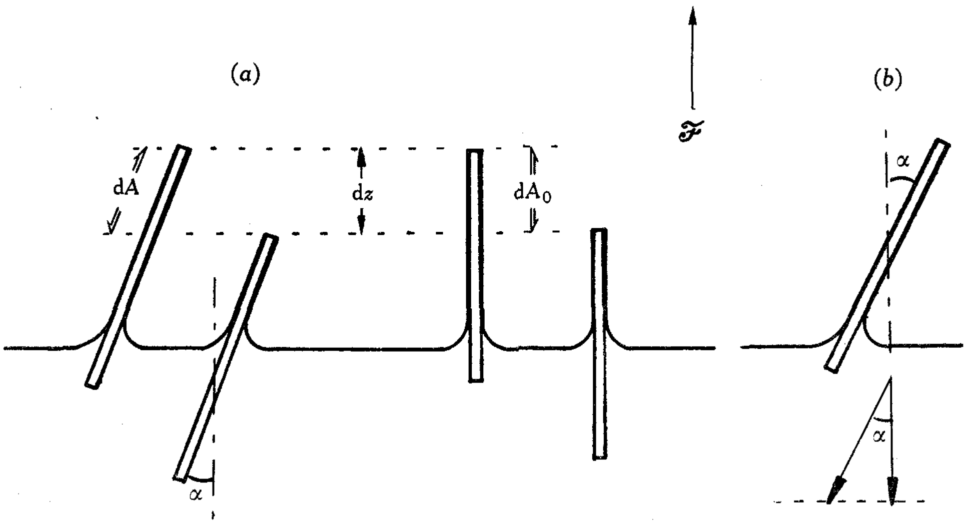
[1] Jordan, D. O., and Lane, J. E., *Aust. J. Chem.*, 1964, **17**, 7.

[2] Smith, T., *J. Colloid Interface Sci.*, 1968, **26**, 509.

shown[3,4] experimentally, however, that the vertical force acting on a finely roughened plate is the same as that on a smooth plate. This may be due to the fact that the surface of the liquid wetting the finely roughened plate is smooth, without being



$$\mathscr{F}\,dz = \sigma\,dA = \sigma\,dA_0/\cos\alpha = \sigma L dz/\cos\alpha$$

$$\mathscr{F} = \sigma L/\cos\alpha \quad (1)$$

$$\mathscr{F}\,dz = \sigma\,dA_0 = \sigma L\,dz$$

$$\mathscr{F} = \sigma L$$

σ $\quad \sigma\cos\alpha$

$$\mathscr{F} = \sigma L\cos\alpha \quad (2)$$

Fig. 1.—Vertical force exerted on tilted plate.

substantially affected by the roughness of the plate. Actually, the vertical force acting on the glass plate roughened with a coarse emery (*c.* 50 mesh) is about 1·2% larger than for the plate roughened with an emery finer than 500 mesh. It may be that the surface of liquid wetting a solid surface of roughness finer than a certain

TABLE 1

COMPARISON OF THE VERTICAL FORCE DUE TO THE SURFACE TENSION OF WATER ACTING ON THE TILTED PLATES

$L = 2{\cdot}053$ cm

Angle (α) of Tilt	Vertical Force (dyn) Observed Value	Eqn. (1): $\sigma L/\cos\alpha$	Eqn. (2): $\sigma L\cos\alpha$
0°	147·4±0·1	147·4	147·4
32	174·1±0·5	173·8	125·0
42	197·6±0·5	198·3	109·5

degree can be regarded practically to be smooth irrespective of the nature of the roughness. A more elaborate calculation would show the quantitative aspect of this problem but this is outside the scope of this paper.

[3] Abribat, M., and Dognon, A., *C. r. hebd. Séanc. Acad. Sci., Paris*, 1939, **208**, 1881.

[4] Rideal, E. K., and Davies, J. T., "Interfacial Phenomena." (Academic Press: New York 1961.)