Prepared discussion contribution

A METHOD OF MEASURING WET WEB ADHESION AND MODULUS ON THE PAPER MACHINE

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THE availability of accurate draw measuring equipment makes it possible to measure these two properties of the wet web running on the paper machine. An example has occurred recently, which illustrates the principle of such measurements.

The machine in question makes LWC of 38 g/m^2, at some 300 m/min, with an open draw from the wire to the first press. The furnish is 100 per cent bleached chemical, with equal proportions of soft and hardwood, moderately beaten. In a recent experiment, the machine speed was reduced in steps to nearly 200 m/min, with the draw adjusted at each step so as to maintain the line of separation of the web from the wire in the same position (i.e. keeping the angle of the draw constant at some 50°). The moisture content of the web was sampled at each step, and found to be constant at 86 per cent; and the draw between the couch and the press was read off a digital instrument.

TABLE 1—EXPERIMENTAL RESULTS

Velocity of 1st press, m/min:	276	266	255	246	236	226	281	291	305.5
Draw of the couch, m/min:	17.3	15.2	13.4	12.5	11.2	11.6	18.7	20.2	22.5

According to Mardon and others (Reference 1), the force needed to transfer the web consists of two terms

$$T = W/(1-\cos\phi) + MV^2 \quad . \quad . \quad . \quad . \quad (1)$$

where T	is the total force	N/m width
W	is the work done in overcoming the adhesion	J/m^2
ϕ	is the angle of the draw	—

Under the chairmanship of J. Mardon

M	is the mass of the web	kg/m^2
V	is the (final) velocity of the web	m/sec

T may be measured in the laboratory, and the inertial term MV^2, easily calculated, and hence W is determined. However, the application of such measurements to a running paper machine is difficult, because W has no fundamental significance—in particular, it is not certain, how it varies with speed.

By analogy with the equation connecting surface tension, contact angle and surface energy, W is often tacitly assumed constant. Alternately, Radvan, Karpati (Reference 2), found W to be proportional to speed in the range 0–300 m/min. Given a set of data as in Table 1, it is possible to calculate T and W, by correlating the draw and speed according to either assumption.

Thus either

$$D/V = A_1 + C_1 V^2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

or

$$D/V = B_2 V + C_2 V^2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

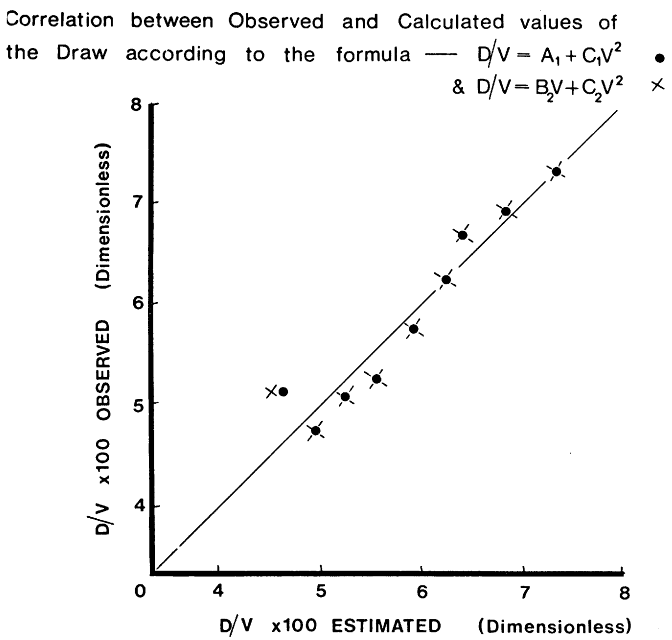

Fig. 1

where D is the draw m/min
D/V is the relative draw, i.e. the strain of the web dimensionless

and $A_1 C_1 B_2 C_2$ are the constants to be determined by the correlation.

Figure 1 shows the two correlations (which are hardly distinguishable). We may identify the CV^2 terms with the inertial term MV^2 in (*1*) which may be calculated. Hence, the total force, and the force of adhesion may be calculated on either assumption, and dividing the total force T by the strain D/V we also obtain a value of the 'modulus' of the wet web.

Two numerical examples illustrate the results for a velocity of 300 m/min, then

$$V = 5 \quad \text{m/sec}$$
$$M = 0{\cdot}24 \ \text{kg/m}^2$$
$$MV^2 = 6{\cdot}0 \quad \text{N/m width}$$

Example 1—Assuming that correlation (2) applies:

$$A_1 = 0{\cdot}134 \times 10^{-1} \ \text{dimensionless}$$
$$C_1 = 0{\cdot}232 \times 10^{-2} \ \text{sec}^2\text{m}^{-2}$$

strain due to inertia: $C_1 V^2 = 0{\cdot}058 =$ 82 per cent

strain due to adhesion: $A_1 = 0{\cdot}013 =$ 18 per cent

total strain: $D/V = 0{\cdot}071 =$ 100 per cent

hence: 'force of inertia' $MV^2 = 6{\cdot}0$ N/m width $=$ 82 per cent
force of adhesion $W/(1-\cos\phi) = 1{\cdot}3$ N/m width $=$ 18 per cent
total force of draw $T = 7{\cdot}3$ N/m width $=$ 100 per cent

and, the 'modulus': $T \div (D/V) = 102$ N/m width (i.e. $4{\cdot}2 \times 10^{-5}$ N/m^2 per unit strain).

Example 2—Assuming that correlation (3) applies:

$$B_2 = 0{\cdot}595 \times 10^{-2} \ \text{sec m}^{-1}$$
$$C_2 = 0{\cdot}167 \times 10^{-2} \ \text{sec}^2\text{m}^{-2}$$

strain due to inertia: $C_2 V^2 = 0{\cdot}042 =$ 58 per cent

strain due to adhesion: $B_2 V = 0{\cdot}030 =$ 42 per cent

total strain: $D/V = 0{\cdot}072 =$ 100 per cent

hence: 'force of inertia' $MV^2 = 6{\cdot}0$ N/m width $=$ 58 per cent force of adhesion $W/(1-\cos\phi) = 4{\cdot}3$ N/m width $=$ 42 per cent

total force of draw $T = 10{\cdot}3$ N/m width $=$ 100 per cent

and, the 'modulus' $= T \div (D/V) = 142$ N/m width (i.e. $6{\cdot}0\times10^5$ N/m^2 per unit strain).

Discussion

CLEARLY, the data are not sufficient to distinguish between the two assumptions. Both suggest that the effects of inertia predominate over those of adhesion, a result of some practical interest.

The numerical values are of the right order of magnitude. For instance, the most recent published results (Reference 3), give the value of adhesion (laboratory experiment, low speed) as 3–9 N/m (compare also the surface tension of water, approximately 0·7 N/m); and a 'modulus' of $1{\cdot}6\times10^5$ N/m^2.

References

1. Mardon, J., Meadley, C. K., O'Blenes, G. and Truman, A. B., *Pulp & Paper Mag. Can.*, **59** (9), 135–155, 1960
2. Radvan, B. and Karpati, D., *Paper Technology*, 1962, **3**, No. 2, 143–225
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