3	May 6, Friday 13:45-17:00	T. Enomae	Evaluation of water absorption rate of paper by an automatic scanning absorptometer

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Gathering place: 2D110 in Bldg.2D Experiment place: SogoA618

1. General

Paper composed only of pulp superbly absorbs water because cellulose, which constitutes paper, is hydrophilic. However, sizing agents are always added to paper used for printing and writing because this paper moderately absorbs water. In offset printing, for example, water designated as dampening solution is simultaneously transferred to paper with ink. If the dampening solution is not absorbed by the paper at the proper rate, the succeeding ink cannot be applied to the paper. In the case of paper for inkjet printing, because the transverse spreading of ink results in a blur, a fast absorption rate of ink is required to ensure satisfactory printing quality without blur. Accordingly, water absorbency is an important factor affecting printability; for quality control of paper, it is necessary to accurately evaluate and control the sizing degree (water repellency).

Simple methods for testing the sizing degree include the Stöckigt method and the Cobb test, which test the water absorbency of paper that has contacted water for many hours. The Bristow method is used to quickly measure the water absorbency of the surface of paper immediately after it contacts water under a condition similar to printing. In this experiment, initial water absorption rate will be measured with an automatic scanning absorptometer, which is based on an improved Bristow method.

1-1 Bristow method

The Bristow method was devised to rapidly measure water absorbency immediately after contact with water. Figure 1 shows a liquid supply head and a specimen mounted on the wheel of a Bristow tester. In this method, a certain amount (V) of liquid is poured into a head box with a narrow slit, this slit is brought into contact with paper mounted on a wheel rotating at a certain speed (v), and the area (wL) of transferred liquid is measured. Because contact time (t) is given by dividing slit width (b) (length parallel to the scanning direction) by scanning speed (v), behavior can be rapidly observed (on the order of milliseconds).

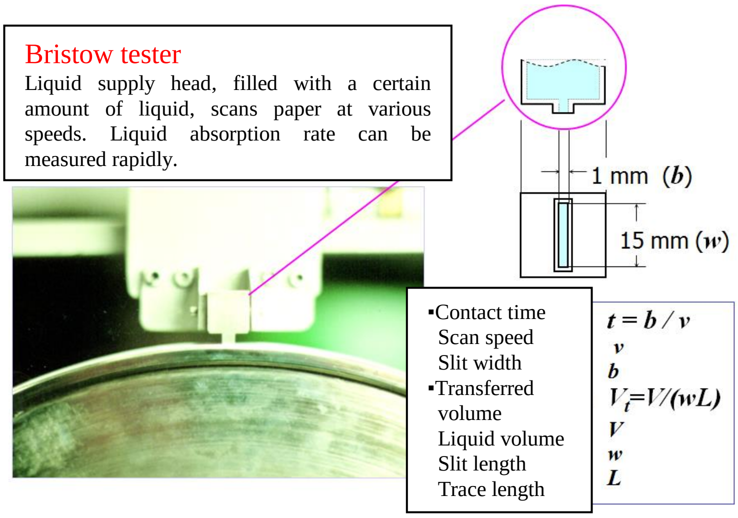

Figure 1 Bristow tester for measuring liquid absorption rate

The Bristow method is a unique, powerful analysis method, but has the following disadvantages:

i) It requires extensive time and effort because it is necessary to prepare multiple strips of paper as specimens for every measurement point, perform scanning by applying liquid on the specimen, and repeatedly measure the lengths of the strips until one absorbency curve is obtained (Bristow’s plot).

ii) It is difficult to measure volatile liquids and viscous liquids by using this method.

iii) Errors can be produced due to uneven liquid application.

1-2 Automatic scanning absorptometer

To overcome these disadvantages, an automatic scanning absorptometer (ASA) was developed by drastically improving the measuring system, although it is based on the same principle. Figure 2 shows the ASA and sensor that measure water absorbency. In this experiment, the water absorption behavior of several types of paper will be investigated by using the ASA.

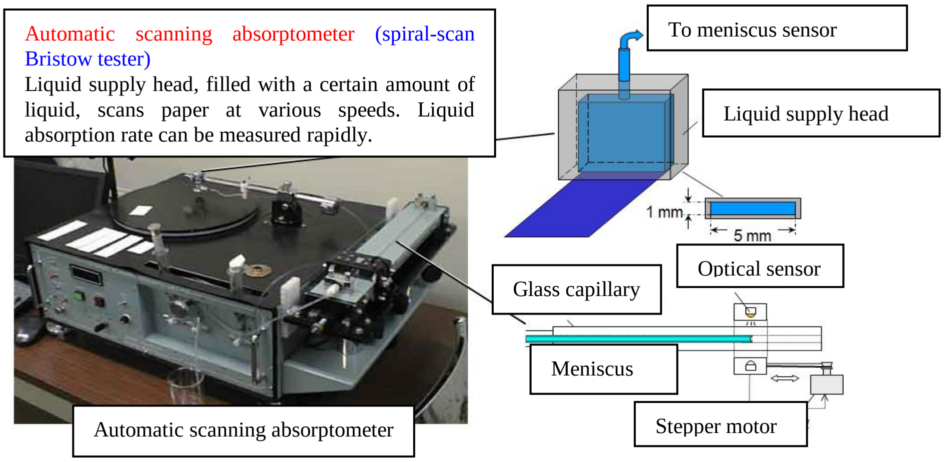

Figure 2 Automatic scanning absorptometer (improved Bristow tester)

2. Experiment

Specimens: Four types of paper (copy paper, high-quality paper for offset printing, high-grade coated paper for inkjet printing, and super-high-grade coated paper for inkjet printing).

Test liquid: 0.1% toluidine blue solution (this solution is sufficiently dilute that its absorption behavior of this solution mimics that of water; it is colored to track observations).

Apparatus: Automatic scanning absorptometer (Kumagai Riki Kogyo).

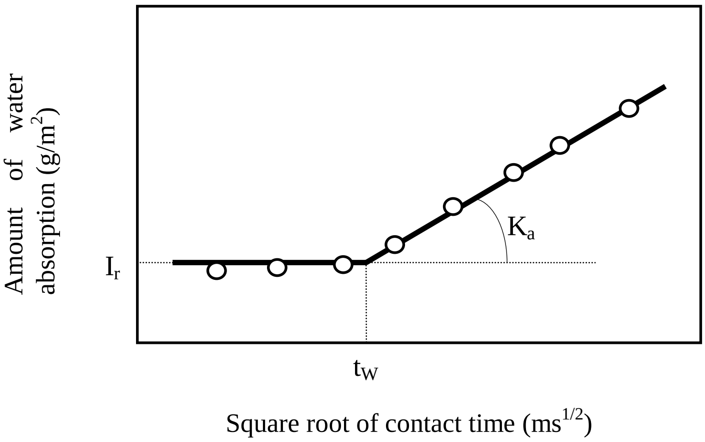

Figure 3 Absorbency curve obtained using Bristow tester

2-1 Water absorbency measurement test

(1) Place an A4-sized specimen on the stage of the tester and restrain the specimen with magnets.
(2) Define a file name and scanning speed on a program. Generally, use the "hard-sized paper" (paper with high water repellency) mode.
(3) After verifying that the glass tube is completely filled with the solution, begin scanning.
(4) Create a Bristow's plot on the basis of the generated data file.
(5) The data file includes approximately 20 sets of data on contact time (ms) and amount of water absorption (g/m^2) below several lines of experimental conditions (this may be ignored). The data file will be uploaded to the "Laboratory" menu on the left side bar of http://www.enomae.com/; download this file.
(6) Create separate graphs for the front and back sides of the specimens. Curves of the data obtained from the same side of the same paper will be drawn in one graph.

2-2 Analysis

It is known that the amount of liquid permeating into a porous body is approximated to first order and is proportional to the square root of contact time; the following Lucas-Washburn equation is applicable. If the data are plotted with the square root of contact time (calculate the square root from the downloaded data by entering an appropriate function in the cells) on the abscissa and the amount of liquid absorbed per unit area on the ordinate, a linear line will be obtained.

$$h = \sqrt{\frac{\gamma r t \cos\theta}{2\eta}}$$

γ: Surface tension, r: Radius of capillary, t: Contact time,
θ: Contact angle, η: Viscosity of liquid.

However, when water is absorbed in the paper, sized paper usually changes because fiber swells or contact angle decreases due to the size effect.

As shown in Figure 3, the slope of an upward straight line in the Bristow's plot is designated the absorption coefficient (K_a). This upward straight line corresponds to the actual permeation process.

When water is absorbed in hard-sized paper, the appearance of such behavior is delayed for a certain period. This period is designated the wetting time (or wetting delay) (t_w). Actually, because a section corresponding to wetting time is not always a horizontal line, the section that is visually almost horizontal can be defined as the wetting time. If the surface is uneven, the amount of liquid required to compensate for this unevenness is always reflected in the transferred amount, even though the head contacts rapidly. Therefore, the graph shifts upward. The value of this shift is designated the roughness index (I_r). Because swelling specimens and paper for inkjet printing used in this experiment absorb liquid extremely quickly at the initial stage, they often display no wetting time.

3. Discussion

The three previously described values of each paper are obtained and their significance is discussed. No wetting time will be accepted if wetting time is not defined.