Flocculation and Formation - the Action and Effect

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ABSTRACT

Formation which is one of the most fundamental characteristic of paper quality is affected by a number of variables. Fiber flocculation in the headbox has been recognized as the most important variable influencing formation. Consistency and crowding number of headbox stock are known to represent the flocculation potential of stocks. The effects of consistency and crowding number on paper formation were studied by measuring the flocculation of fiber suspensions. Increasing consistency increased the degree of fiber flocculation. Especially the consistency of long fiber fraction was the most crucial factor of flocculation. Tensile strength of handsheets was furnish dependent rather than flocculation dependent. Crowding number of a furnish can be used for the characterization of stock flocculation.

Keywords : Flocculation, formation, headbox consistency, long fiber fraction, fibers, sheet, crowding number, flocculation tendency, tensile strength, furnish

INTRODUCTION

Formation is generally the most fundamental characteristic of paper quality because it directly influences most other physical and optical properties of the sheet. Sheet formation is affected by a number of variables. One of the most crucial factors affecting formation is the fiber flocculation in headboxes. The tendency of fibers to flocculate has been known to lead to poor formation of paper. The headbox consistency and fiber crowding number have been recognized as factors that represent flocculation potential of a given furnish (1-3).

The choice of headbox consistency for a paper machine should be maintained at a low level as the dewatering capability of the forming section allows to obtain papers with good formation. For example, linerboard is uaually made with stocks low in headbox consistencies ranging from 0.2-0.3%. On the other hand, ground wood-containing pulps are often run at headbox consistencies of 1% or more (4). Kerekes and Schell introduced the concept of crowding number (5), which is defined to be the expected number of fibers in a spherical volume with diameter of one mean fiber length.

$$N_{crowd} = \pi c \lambda^2 / 6\delta$$

Where c kg/m^3 is the mass of fibers per unit volume, λ m is the length-weighted mean fiber length, δ kg/m is the mean fiber coarseness. Consistency and crowding number of headbox stock are known to represent the potential of flocculation for the stock of interest (5,6).

In this study, the influence of the stock consistency and crowding number on flocculation phenomena of the stocks were evaluated. Also, the effect of flocculation on the paper properties was investigated.

EXPERIMENTAL

Materials

UKP (Unbleached Kraft Pulp), AOCC (American Old Corrugated Container) and KOCC (Korean Old Corrugated Container) were used to investigate the flocculation tendency of stock.

Stock preparation

UKP was refined at 1.57% in a Valley beater. UKP stocks with three different freeness levels (700 mL CSF, 440 mL CSF, and 335 mL CSF) were prepared and used along with the stock consisted of fines only. KOCC was disintegrated in a disintegrator at 5% for 50,000 rev. and fractionated. In general, fractionation means to separate fiber stock into two fractions of long and short fiber lengths. Two different stocks of KOCC with same fiber length (1.13 and 1,15 mm) were employed in this study. Even though the average fiber lengths were the same, the compositions of the fiber stocks were quite different. One stock sample was a whole stock that consisted of long fiber, short fiber and fines while the other stock was obtained by mixing long fiber stock and fines. By adjusting the mixing ratio of the long fiber stock and fines the average fiber length was controlled to have the similar fiber length as the whole stock. AOCC stocks were also prepared following the same method as KOCC. Table 1 illustrates stock properties.

Table 1. Analysis of stocks

	Fiber length (mm)	Coarseness (kg/m)	Fines Contents (%)	Freeness (mL CSF)
UD	2.46	$1.71 * 10^{-7}$	4.4	728
UB440	2.20	$1.82 * 10^{-7}$	14.1	440
UB335	2.21	$1.90 * 10^{-7}$	14.3	335
AD	1.31	$1.80 * 10^{-7}$	28.1	446
AF	1.54	$1.80 * 10^{-7}$	44.0	228
KD	1.13	$2.40 * 10^{-7}$	35.8	307
KF	1.15	$2.40 * 10^{-7}$	51.6	130

* U = UKP, A=AOCC, K=KOCC, D=Disintegrated, B=Beaten, F=Fractionated.

Handsheet forming

The basis weight of handsheets used for testing was 90 g/m^2. To assess the effect of consistency on fiber flocculation, handsheet was made from stock slurries at different consistencies with the used of RDA (Retention and Drainage Analyzer).

Fiber length and Coarseness

Fiber length and coarseness were measured by Kajaani FiberLab Fiber Analyzer.

Flocculation and Formation

Flocculation and formation were measured by 2D-F sensor from Techpop. The details of this procedure are described in Figs. 1-2.

Handsheet properties

The papers were conditioned to reach equilibrium at standard conditions of temperature and relative humidity for at least 24 hours. All paper properties were measured according to TAPPI test methods. Handsheet properties including thickness, basis weight, apparent density, tensile strength and formation were determined.

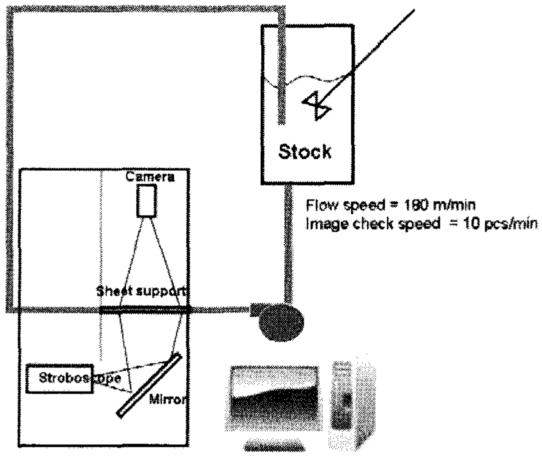


Fig. 1. Schematic of flocculation measuring test.

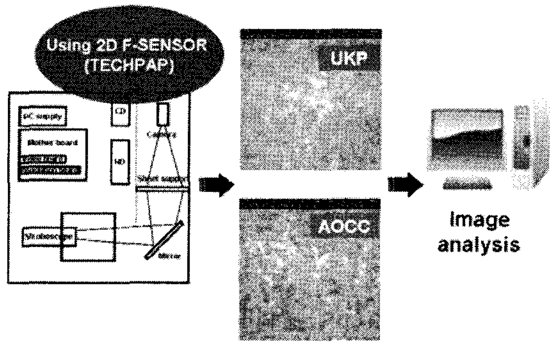


Fig. 2. Diagram of formation test.

RESULTS AND DISCUSSION

Flocculation tendency at different consistencies

Fig. 3 shows the flocculation tendency of stocks at different consistencies. Stocks with higher formation energy value indicate that they show greater tendency to flocculate than those with low formation energy value. Flocculation tendency of UKP increased with increasing the suspension consistencies. Formation energy of recycled pulps also increased with consistency. But it did not show linear relationship with consistency. The formation energy of recycled pulps, AOCC and KOCC, however, was linearly increased with consistency when the consistency was lower than 0.3% after which the increasing rate was decreased. Refining that causes fiber cutting decreased the formation energy. This occurs because the crowding number decreased with refining, which causes a lower propensity to flocculate (6, 7). And this change leads to improved formation (8).

Flocculation tendency of UKP was most substantially increased with the increase of consistency among the fibers tested. There was no difference in formation energy among the fibers tested when the consistency was lower than 0.3%.

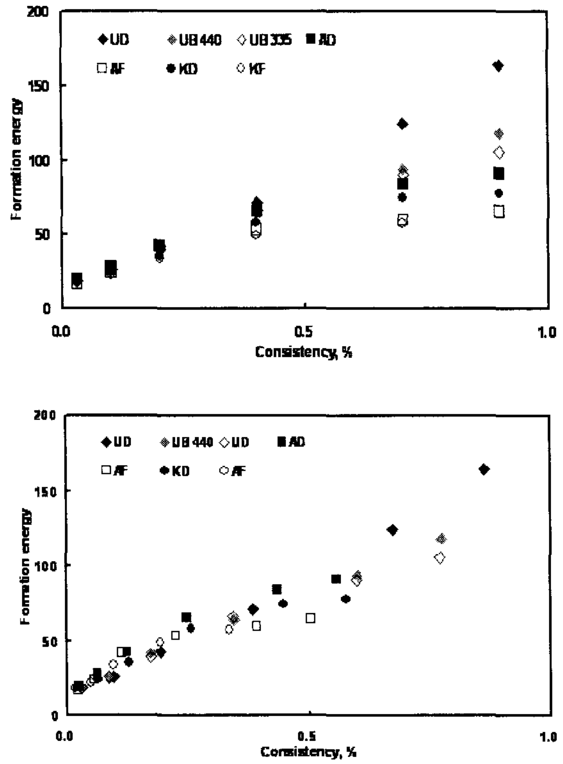


Fig. 3. Flocculation tendency of stocks as a function of entire stock consistency (Upper) & long fiber consistency (lower).

This indicates that flocculation does not occur for these fibers when the consistency is lower than 0.3%. Beating caused reduction of flocculation tendency of UKP.

Flocculation that started to occur at a consistency greater than 0.3% was fiber type dependent. Especially it was strongly affected by long fiber consistency.

Flocculation tendency and crowding number

Fig. 4 shows the formation energy of stocks as a function of crowding number. Kerekes and Schell suggested that the crowding number is a useful tool for characterizing the fiber flocculation. Virgin UKP pulp showed different flocculation trend compare to recycled fibers. Formation energy of UKP was linearly increased with increasing crowding number of the suspension. The linear relationship between formation energy of UKP and crowding number was also observed for beaten UKP fibers. In the case of recycled fibers, however, formation energy increased linearly with crowding number until it reached at 30. But the rate of flocculation tendency rapidly slowed down when the crowding number was greater than 30. This shows that crowding number can be used as a powerful control variable for formation energy if the stock is consisted of UKP fibers only.

Fig. 4. Flocculation tendency of stocks as a function of crowding number calculated entire stock & long fiber.

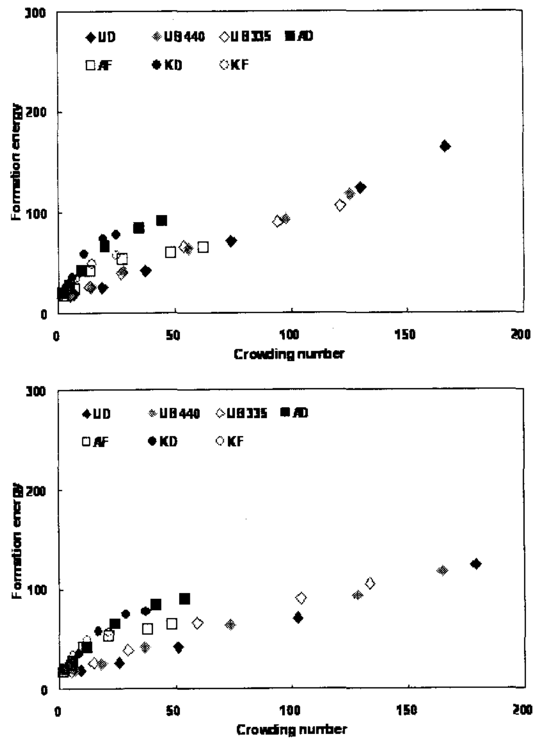
On the other hand, it will not predict the formation energy so well when the stock is made of recycled fibers.

Effect of flocculation tendency on paper properties

Fig. 5 and 6 show the formation energy of handsheets as a function of consistency and crowding number, respectively. Increasing the level of consistency and crowding number significantly deteriorated formation. Deterioration of formation differed depending upon the type of stocks. Fiber consistency showed a clear negative effect on formation. Especially, long fiber consistency appeared to be very important on paper formation.

Formation energy was leveled off when the formation energy value was around 500. This may be the characteristics of the handsheets formed with laboratory forming machine (RDA) or may be due to the fiber characteristics.

Fig. 7 shows the tensile strength of handsheet as a function of formation energy. When the formation deteriorated, tensile strength was decreased. Especially, tensile strength of UKP decreased more significantly with formation than AOCC and KOCC.



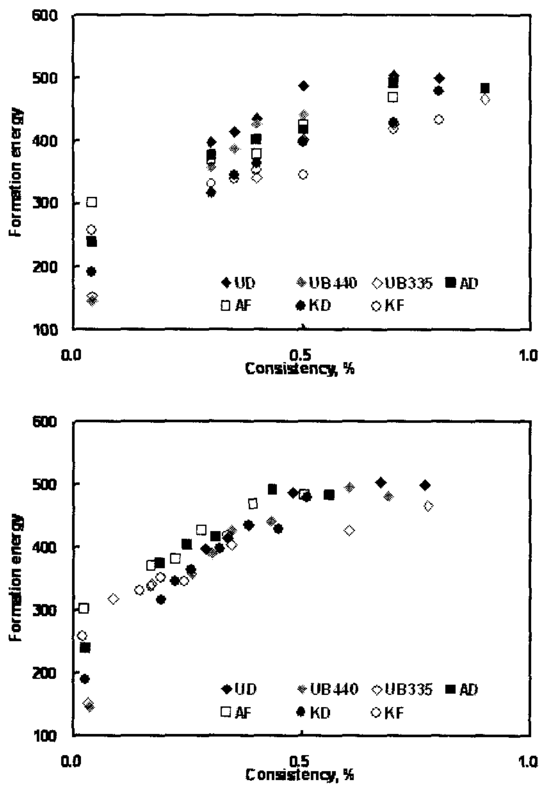


Fig. 5. Formation energy of handsheets as a function of entire stock consistency & long fiber stock consistency.

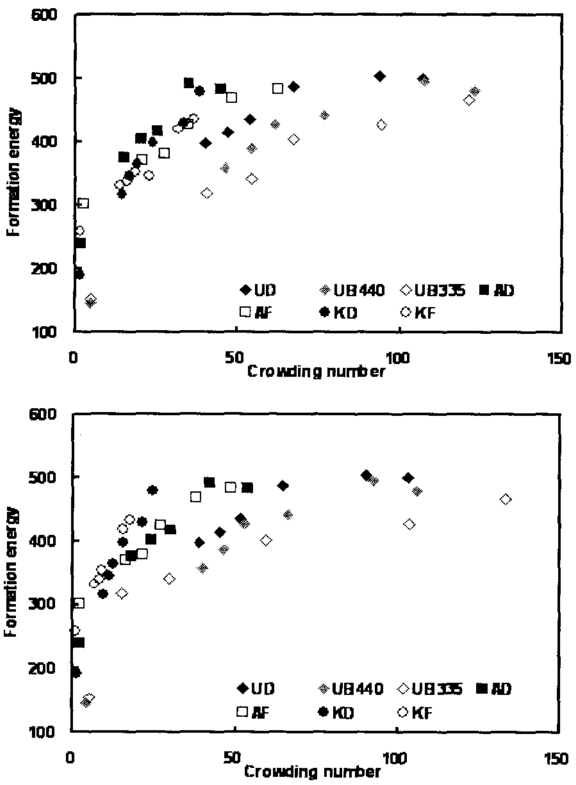


Fig. 6. Formation energy of handsheet as a function of crowding number of entire stock & long fiber stock.

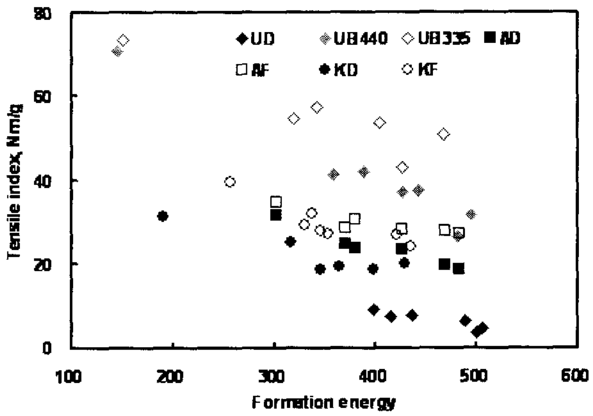


Fig. 7. Tensile index as a function of formation energy of handsheet.

Tensile strength of fractionated stocks was greater than that of disintegrated stocks since fractionated stocks contained more fiber fines.

CONCLUSIONS

Formation energy was dependent upon the consistency, crowding number and furnish type. The consistency of long fiber fraction appeared to have the most significant effect on flocculation tendency of stocks. Crowding number can be used to characterize the flocculation of fibers. But the use of crowding number has a limitation in its use to compare the flocculation tendency of different fibers. It is improper to use the crowding number to analyze the flocculation tendency of different stocks. Tensile strength was affected by formation energy as well as furnish types. Tensile strength of handsheets formed with the same furnish deteriorated as the formation energy of the handsheet increased.

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