Kasetsart J. (Nat. Sci.) 44 : 949 - 955 (2010)

Water Absorptiveness of Handsheets Produced with Various pH Levels of Pulp Suspension, AKD Dosages and Mixing Times

Somwang Khantayanuwong*, Atipong Wattanayingyongkul and Weerapol Mingkwan

ABSTRACT

The objectives of this study were to determine the effects of high pH levels of pulp suspension and high dosages of alkyl ketene dimers (AKD) on the water absorptiveness of handsheets. Various mixing times were applied for the pulp suspension-AKD mixing conditions and analyzed for their effects. Handsheets were produced with various pH levels (pH 8, 9 and 10) of pulp suspension, AKD dosages (0.25, 0.50, 0.75 and 1.00% oven-dry weight (o.d.wt.) of pulp fiber) and mixing times (1, 5 and 10 min). The results indicated that the water absorptiveness of handsheets produced with 0.25% o.d.wt. of pulp fiber of AKD at any pH level of pulp suspension or prepared with any dosage of AKD in the pulp suspension at pH 8 was lower with a mixing time of 5 min, while that of handsheets produced with 0.50% to 1.00 % (o.d.wt. of pulp fiber) of AKD in the pulp suspension at pH 9 and 10 was higher with a mixing time of 5 min. This was possibly because the higher dosages of AKD could ensure sufficient AKD-oligomers were retained in the handsheets to promote good sizing, while the number of β-keto ester bonds established between the AKD and the surfaces of pulp fibers and fines was insufficient after a short mixing time of 1 min. Although some AKD could also be hydrolyzed with a long mixing time of 10 min, the excess amount of AKD could still react with the surfaces of pulp fibers and fines with β-keto ester bonds and the remaining AKD would also be retained in the handsheets as oligomers to promote good sizing. In addition, the stronger basic conditions would favor the formation of ester bonds.
Keywords: alkyl ketene dimers, handsheets, water absorptiveness

INTRODUCTION

Generally, water or fluids can be absorbed into paper sheets. Thus, for some purposes, a practical technique known as sizing is used to enable paper sheets to resist such absorption. Although rosin sizes traditionally have played a major role as internal sizing agents both worldwide and in Thailand, the use of alternative internal sizing agents, such as alkyl ketene dimers (AKD) is being pursued increasingly by papermakers, because of their benefits in the neutral-alkaline papermaking process. AKD consist of synthetic polymers of unsaturated lactones and were initially patented in 1953 and subsequently introduced into the paper industry in the USA in 1956 (Neimo, 1999; Auhorn, 2006). Hubbe (2009) and Neimo (1999) concluded that AKD could possibly react with the hydroxyl groups of cellulose pulp fibers with the formation

Pulp and Paper Technology Program, Department of Forest Products, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand.
* Corresponding author, e-mail: fforsok@ku.ac.th
Received date : 19/02/10 Accepted date : 10/05/10

of a β-keto ester bond and could produce a well-sized surface for the pulp fibers.

Although AKD are usually applied in the neutral-alkaline papermaking process with a pH level of pulp suspension ranging from 6.5 to 8.5 and their dosages are typically varied from 0.05 to 0.20% based on the oven-dry weight of pulp fiber (Neimo, 1999), there is no record of any reports on the effects of high pH levels of pulp suspension and high dosages of AKD on the water absorptiveness of paper sheets. This is probably because most of the previous research reports demonstrated only the typical conditions of the AKD sizing mechanism and relative phenomena (Bottorff, 1994; Hodgson, 1994; Shen *et al*., 2001; Karademir and Hoyland, 2003; Mattsson *et al*., 2003; Champ and Ettl, 2004; Seppanen *et a*l., 2004). Colasurdo and Thorn (1992) showed that the pH level of water in systems containing carbonate ranged from 8.0 to 10.0 and could probably be related to the AKD sizing loss in paper sheets.

Therefore, the purpose of the current research was to determine the effects of high pH levels of pulp suspension and high dosages of AKD on the water absorptiveness of handsheets. Various mixing times were applied for the pulp suspension-AKD mixing conditions and analyzed for their effects.

MATERIALS AND METHODS

Pulp suspension preparation

According to the Tappi T 200 standard, virgin commercial bleached kraft pulps derived from hardwoods and softwoods are separately disintegrated in water and then beaten with a Valley beater (Laurentzen and Wettress, Sweden) to 300 ml and 350 ml of Canadian Standard Freeness (CSF), respectively. For the purposes of comparison with paper mill conditions, a pulp suspension was produced with a mixing ratio of 80:20 between the beaten hardwood bleached kraft pulp and the beaten softwood pulp. The pulp suspension was subsequently used to produce handsheets.

Handsheets production

In accordance with the pH level of water in systems containing carbonate suggested by Colasurdo and Thorn (1992), a set of handsheets was produced by treating a part of the pulp suspension with 1 mol NaOH to attain a pH level of 8 and then mixing it with 0.25 % based on the oven-dry weight of pulp fiber (o.d. wt. of pulp fiber) of alkyl ketene dimers (AKD) for 1 min without using any retention aids. The AKD-mixed pulp suspension was immediately drained through a wire screen for handsheet forming according to the SCAN-C 26:76 standard. Handsheets were then dried at 80°C with an electric drum dryer to ensure the sizing effectiveness of the AKD.

More sets of handsheets were produced using the same procedure as mentioned above but with various pH levels (pH 9 and 10), AKD dosages (0.50, 0.75 and 1.00% o.d. wt. of pulp fiber) and mixing times (5 and 10 min).

Water absorptiveness test

In accordance with the Tappi T 205 standard, all the sets of handsheets were conditioned at 50±2% relative humidity and 23±1°C for 1 week before testing their water absorptiveness. In this study, the water absorptiveness was assessed in accordance with the Tappi T 441 (Cobb test) standard. The Cobb test was performed by applying 100 mL of de-ionized water to a surface area of 100 cm^2 exposed within a metal ring tightly placed on a handsheet. A specified time of 120 sec was assigned for the absorption. The excess de-ionized water was removed with blotter sheets. The result of the water absorptiveness of handsheets was expressed in grams of de-ionized water absorbed onto a square meter of the surface of handsheet (g/m^2). Ten conditioned samples from each set of handsheets were separately analyzed for their water absorptiveness with the Cobb test, with one half tested on the top side and the other half tested on the bottom side.

RESULTS AND DISCUSSION

Tables 1 and 2 show the water absorptiveness of handsheets treated with AKD under various conditions. The water absorptiveness of the top side of the handsheets was slightly lower than on the bottom side, indicating a two-sided sizing effect (Casey, 1961). This was possibly because of the denser surface on the top side with more retention of AKD. Generally, the top side of paper sheets is denser than the bottom side, because many papermaking fibers, fines and other material gradually accumulate on the forming wire screen by filtration (Casey, 1961). As shown in Figures 1 and 2, changes in the water absorptiveness of handsheets could be categorized into two phenomena as follows:

Table 1 Water absorptiveness of the top side of handsheets treated with AKD under various conditions.

		Water absorptiveness (g/m^2)			
pH	Mixing time	AKD (% of o.d. weight of pulp fiber)			
	(min.)	0.25	0.50	0.75	1.00
8	1	23.88 ± 2.62	20.00 ± 0.66	22.10 ± 1.87	22.24 ± 1.63
	5	20.50 ± 0.33	19.50 ± 0.52	19.06 ± 0.43	19.63 ± 0.65
	10	20.93 ± 0.81	19.85 ± 0.74	19.80 ± 1.25	19.66 ± 0.51
9	1	22.42 ± 1.94	19.20 ± 0.78	19.56 ± 1.34	21.10 ± 2.13
	5	22.84 ± 2.42	22.22 ± 2.42	25.30 ± 3.98	20.82 ± 1.50
	10	23.68 ± 0.55	21.80 ± 0.35	18.10 ± 0.30	20.80 ± 0.37
10	1	24.86 ± 1.80	20.48 ± 1.95	20.64 ± 1.66	19.40 ± 1.76
	5	24.26 ± 2.02	22.52 ± 2.54	23.20 ± 2.32	15.63 ± 2.15
	10	25.72 ± 0.39	19.66 ± 0.35	19.66 ± 0.44	18.36 ± 0.40

Mean values are shown with the 95% confidence level range.

Table 2 Water absorptiveness of the bottom side of handsheets treated with AKD under various conditions.

		Water absorptiveness (g/m^2)			
pH	Mixing time	AKD (% of o.d. weight of pulp fiber)			
	(min.)	0.25	0.50	0.75	1.00
8	1	26.03 ± 0.45	20.36 ± 2.79	25.10 ± 1.07	24.22 ± 2.81
	5	20.80 ± 0.08	20.32 ± 0.96	19.82 ± 0.25	19.73 ± 0.70
	10	23.30 ± 1.33	21.64 ± 1.12	21.24 ± 1.26	20.73 ± 0.28
9	1	24.18 ± 1.14	21.90 ± 0.45	20.38 ± 1.22	20.12 ± 1.11
	5	22.16 ± 2.06	23.06 ± 1.05	22.38 ± 1.07	22.42 ± 1.65
	10	25.66 ± 1.64	22.52 ± 0.51	19.76 ± 0.58	20.34 ± 0.24
10	1	22.86 ± 1.76	19.78 ± 1.27	21.74 ± 1.49	20.55 ± 1.88
	5	23.36 ± 1.69	22.90 ± 1.72	22.52 ± 1.18	17.66 ± 1.18
	10	26.43 ± 0.75	21.12 ± 0.23	20.74 ± 0.18	19.62 ± 0.37

Mean values are shown with the 95% confidence level range.

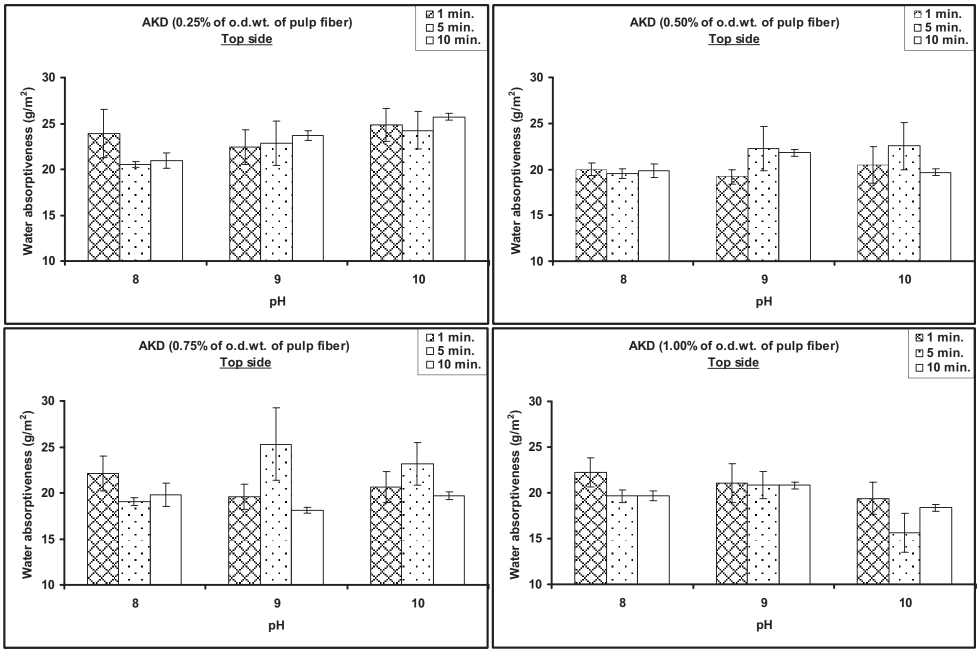

Figure 1 Effect of changes in AKD dosage (as % of o.d. wt. of pulp fiber) on water absorptiveness of the top side of handsheets at various pH levels of pulp suspension, and mixing times (min). Bars = 95% confidence interval.

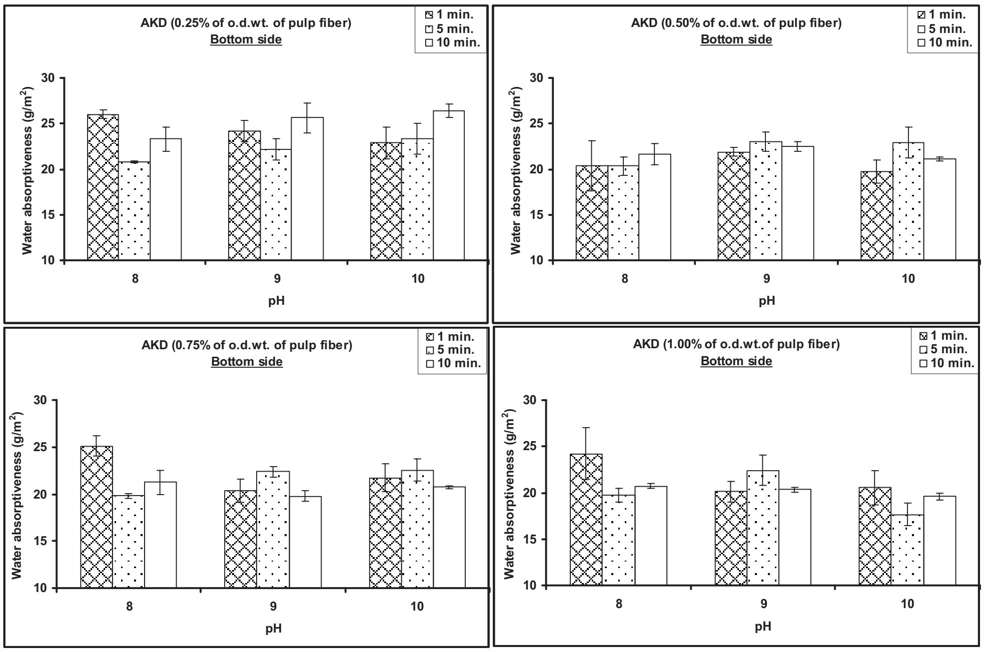

Figure 2 Effect of changes in AKD dosage (as % of o.d. wt. of pulp fiber) on water absorptiveness of the bottom side of handsheets at various pH levels of pulp suspension, and mixing times (min). Bars = 95% confidence interval.

The water absorptiveness of handsheets treated with 0.25 % o.d.wt. of pulp fiber of AKD at any pH level of pulp suspension or prepared with any dosage of AKD in the pulp suspension at pH 8

It was obvious that with 0.25% (o.d.wt. of pulp fiber) of AKD at any pH level of pulp suspension, the water absorptiveness of handsheets prepared with a mixing time of 5 min was lower than that of handsheets prepared with the application of mixing times of 1 and 10 min. According to Hubbe (2009) and as shown in Figure 3, AKD could produce a good sizing effect because of its oligomers and its ability to establish β-keto ester bonds with pulp fibers and fines. However, there was no effective sizing using AKD due to the hydrolysis of the AKD. Therefore, a low dosage of AKD (0.25% o.d.wt. of pulp fiber) could not promote sizing in the handsheets due to insufficient β-keto ester bonds on the surfaces of pulp fibers and fines and the small amount of AKD-oligomers retained in the handsheets after a short mixing time of 1 min. Furthermore, the low dosage of AKD would be insufficient and would be transformed almost completely to an inactive form after a long mixing time of 10 min, due to hydrolysis. This phenomenon was dominant in all the handsheets prepared using any dosage of AKD in the pulp suspension at pH 8 probably because the milder basic conditions would not promote adequate formation of the β-keto ester bonds between the AKD and the surfaces of the pulp fibers and fines (Neimo, 1999; Hubbe, 2009).

The water absorptiveness of handsheets treated with 0.5% to 1.0% o.d.wt. of pulp fiber of AKD in the pulp suspension at pH 9 and 10

The water absorptiveness of handsheets produced with AKD dosages ranging from 0.50 to 1.00% o.d.wt. of pulp fiber and a mixing time of 5 min was higher than that of handsheets prepared with mixing times of 1 and 10 min. This was possibly because, with a short mixing time of 1 min, a high dosage of AKD could produce sufficient AKD-oligomers in the handsheets to promote good sizing, even though the number of β-keto ester bonds between the AKD and the surfaces of the pulp fibers and fines was insufficient. Nevertheless, some AKD could also be hydrolyzed over the long mixing time of 10 min and the excess amount of AKD could still react with the surfaces of the pulp fibers and fines to form β-keto ester bonds, while the remaining AKD would also be retained in handsheets as oligomers to promote good sizing. This phenomenon occurred frequently in all handsheets processed

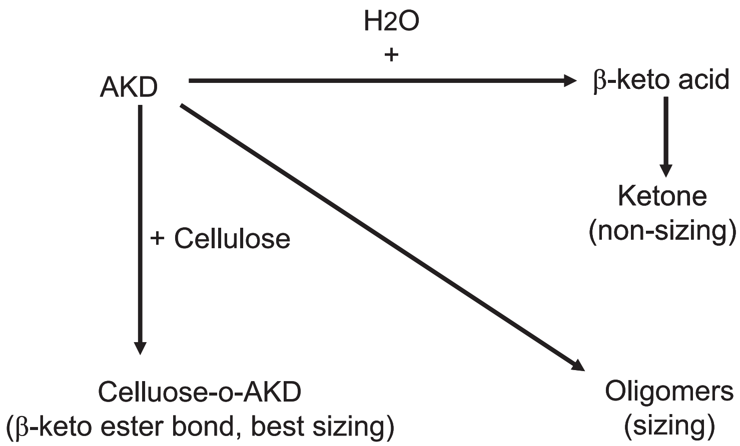

Figure 3 Sizing processes of AKD (Hubbe, 2009).

with 0.50 to 1.00% o.d.wt. of pulp fiber of AKD in the pulp suspension at pH 9 and 10, probably because of the stronger basic conditions favoring the promotion of the ester bonds (Neimo, 1999; Hubbe, 2009).

It is noteworthy that the effects of the high pH levels in the pulp suspension, the high dosages of AKD and the various mixing times on the water absorptiveness of handsheets were consistent with the conventional sizing process and with related known actions of typical AKD applications, as suggested by Neimo (1999) and Hubbe (2009).

CONCLUSIONS

The water absorptiveness of handsheets produced with 0.25% o.d. wt. of pulp fiber of AKD at any pH level of pulp suspension or with any dosage of AKD in the pulp suspension at pH 8 was lower with a mixing time of 5 min. This was possibly because a low dosage of AKD could not promote good sizing in the handsheets due to the lack of β-keto ester bonds with the surfaces of the pulp fibers and fines and the small number of AKD-oligomers retained in the handsheets after a short mixing time (1 min). AKD would also be transformed to an inactive form after a long mixing time (10 min), due to hydrolysis. The mild basic conditions would not promote adequate β-keto ester bonds between AKD and the surfaces of the pulp fibers and fines.

Nevertheless, the water absorptiveness of handsheets produced with 0.50 to 1.00% o.d.wt. of pulp fiber of AKD in the pulp suspension at pH 9 and 10 was higher after a mixing time of 5 min. This was possibly because the high dosage of AKD could allow for sufficient AKD-oligomers to be retained in the handsheets to promote good sizing, even though there were insufficient β-keto ester bonds between the AKD and the surfaces of the pulp fibers and fines after a short mixing time of 1 min. Furthermore, though some AKD could be hydrolyzed after a long mixing time (10 min), the excess amount of AKD could still react with the surfaces of the pulp fibers and fines to form β-keto ester bonds and the remaining AKD could be retained in the handsheets as oligomers to promote good sizing. In addition, the stronger basic conditions would favor the formation of ester bonds.

These results were consistent with conventional sizing processes and with related known actions of typical AKD applications.

ACKNOWLEDGEMENTS

The authors wish to express their sincere gratitude to Mr Krisana Siripaipran, Eka Chemicals (Thailand) Co., Ltd. for providing the AKD materials used in this study.

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