Application of Dual Dry Strength Additives System on Brown Paper Strength Development

Hossein Jalali Torshizi [a,*] and Ahmad Jahan Latibari [b]

Strength development is a prime concern in OCC recycling, which can benefit from the application of different dry strength polymers. Therefore, the combined effect of four levels of cationic starch (0, 1, 2, 3% based on OD weight of pulp) and four levels of guar gum (0, 0.5, 0.75, 1% based on OD weight of pulp) on burst index, tear index, tensile index, folding endurance, and retention rate of paper produced from OCC pulp was investigated. Six 120 g/m^2 handsheets were made and tested for each condition. Individually, the addition of starch increased all assessed properties, especially folding endurance up to 118% compared to the blank. But, the gum addition had an inferior effect on the properties. Also, the results revealed that the combination of two additives will show different effects. Addition of 3% cationic starch combined with 1% gum produced highest strength values, and the strength of paper was increased between 45 to 145% compared to the sheets with no additives. The results also indicated that at the same level of addition, the performance of gum in improving dry strength was superior to cationic starch except for tear strength. However, the cost and availability suggest application of the cationic starch.

Keywords: Guar gum; Cationic starch; Old Corrugated Container (OCC); Recycling; Dry strength

Contact information: a: Cellulose and Paper Technology Dept., Shahid Beheshti University, Tehran, Iran;
b: Wood & Paper Science and Technology Dept., Islamic Azad University, Karaj, Iran;
** Corresponding author: H_Jalali@sbu.ac.ir*

INTRODUCTION

Limitations in cellulosic fiber resources, ever-increasing demands for paper and paperboard, and enforcement of environmental protection regulations and laws to limit the exploitation and harvesting of forest, as well as pollution concerns has forced world communities towards recycling more wastes and also preventing waste generation and discharge. Waste paper is unique, as it is easily recyclable and available; extensive savings in energy can be achieved by recycling it. However, the production, storage, use, and recycling operations will adversely affects the properties of the next generation of paper, especially with regards to strength indices. So those concerned about paper recycling ought to concentrate on ways to prevent strength deterioration or improve strength properties. During paper drying, hornification phenomena make the fiber rigid with irreversible loss of flexibility, even after prolonged soaking or thermo-chemical treatments (Jalali *et al.* 2010). Refining, as a common operation in any paper mill, has been used for strength development in recycled paper. Even though refining improves some of the paper strength properties, it will damage the fibers and therefore reduces tear strength, and it reduces the porosity of the produced paper, which limits the extent of

application of this method (Brouwer and Baas 2002). Also, excessive refining will deteriorate drainage, which is a very important parameter in technical and economic aspects of papermaking (Jalali *et al.* 2014).

On the other hand, application of dry strength additives, without adverse effect on paper properties, will improve the desired strength properties of interest (Brouwer and Baas 2002; Jalali *et al.* 2010). However, the performance of different dry strength additives is not the same. Rojas *et al.* (1995) reported that addition of the cationic gum to pulp slurry decreases the dissolved and suspended carbohydrates, fines, wet-end additives, as well as BOD in the white water, but it increases the yield. Lee *et al.* (2005) investigated the adsorption of cationic gum on fiber in a closed loop recycling system and found that addition of gum to recycled fibers slurry containing anionic trash particles reduces cloudiness of the process water and the effluent loads. Howard (1989) added cationic starch to recycled pulp and studied the fiber bonding in paper and stated that fiber bonding, which is usually deteriorated upon recycling, will improve, and the strength of handsheets from recycled pulp will approach those made from virgin pulp. It has also been expressed that cationic polymers such as cationic starch are more effective than other additives and improve retention and drainage (Brower and Boss 2002). In addition to the paper strength, retention of pulp ingredients onto the wire and resulted in paper sheet will improve the system efficiency, especially in furnish having a relatively high fines content, like OCC (Jalali *et al.* 2016). The higher retention results in cleaner production in any papermaking systems with environmental, technical, and economic benefits (Jalali *et al.* 2014).

Since Iran is faced with a severe shortage of virgin fiber supply, paper recycling will be able to provide considerable of fiber needs. Fiber development and strength improvement of recycled paper is very important. One way will be the application of suitable low-cost additives, which is the subject of this article.

EXPERIMENTAL

Materials and Methods

Additives Preparation

Cationic starch was obtained from Iran Wood and Paper Co. (Chukka) with the following specifications:

Moisture Content: 4.3%	pH: 5.73
Gelation Temperature: 62 – 67^{o}c	Viscosity: 75.7 cp
Cooking Temperature: 79 - 81^{o}c	D.S: 0.035

Cationic starch was received in powder form and was cooked at 80^{o}C for 25 minutes in water at 4% concentration. The solution was gently and uniformly mixed during cooking. At the end of cooking, the solution was diluted to 1% before adding it to the pulp slurry. Cationic starch was used at 4 levels of 0, 1, 2, 3% (based on OD weight of pulp).

Guar gum was obtained from Merck chemical office at 8% moisture content and was dissolved in water. The gum was also used at four levels of 0, 0.5, 0.75, 1% (based on OD weight of pulp).

Pulping and slushing

Uncontaminated and clean corrugated board cuttings were collected randomly from local corrugating board production plants. Attention was paid to be sure that samples were uniform and representative of currently utilized boards.

Pulping was carried out in one 0.5 m^3 laboratory pulper at 6% consistency and 52 ^{o}C for one hour. Then, the pulp slurry was discharged and dewatered on 400 mesh screen to retain as much fines as possible. Dewatered pulp was dried under laboratory conditions for 72 hours to reach 7.5% moisture content. Dried pulp was collected and stored in plastic bags for further use. Drainage and pH of pulp were measured in the ranges of 45 to 48° SR and 8.5 to 9.5, respectively.

Handsheets preparation and testing

Six replicate handsheets with the basis weight of 120 g/m^2 were prepared for each combination of variables, and a total of 96 handsheets were made. Handsheets were prepared in accordance to TAPPI test method no. T205 sp-95, and the wire side was marked. All handsheets were conditioned at 23 ± 1 ^{o}C and 50 ± 2% relative humidity (RH) before testing. All tests were performed according to following TAPPI test methods:

- Basis Weight: T410 om-98
- Tear Index: T412 om-98
- Tensile Index: T404 om-98
- Burst Index: T403 om-97
- Folding Endurance: T511 om-96

Statistical Analysis

A factorial experiment based on completely randomized design was used for analysis of variance to compare the averages of properties. In case of evidence of significant difference between averages, then DMRT was used for classification of averages.

RESULTS AND DISCUSSION

The results of strength measurements of recycled paper produced from OCC before and after adding various combinations of dry strength additives are summarized in Table 1, and are shown in Figs. 1 to 4. DMRT of averages are also shown in Figs. 1 to 4. These results show that the both additives improved strength properties of burst, tensile, and folding endurance in different manner, and the highest values of these properties was reached in the presence of 2 and 3% cationic starch. Except for tear index, at the same level of addition (1%), the influence of gum on these properties was higher. (Figs. 1 to 3).

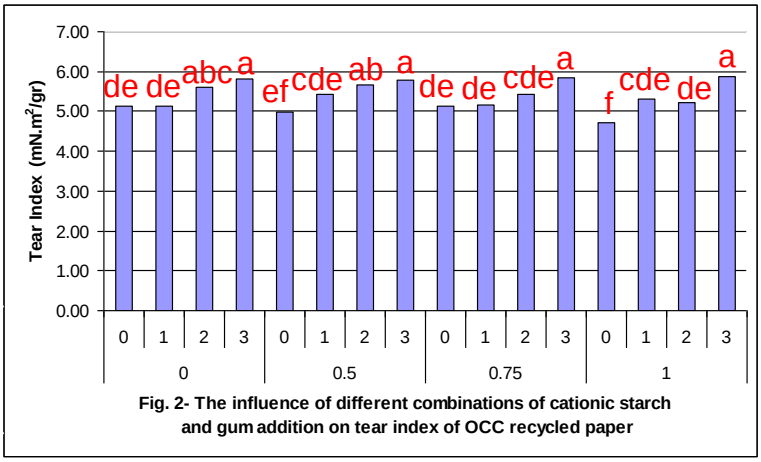

Fig. 1. The influence of different combinations of cationic starch and gum addition on burst index of OCC recycled paper

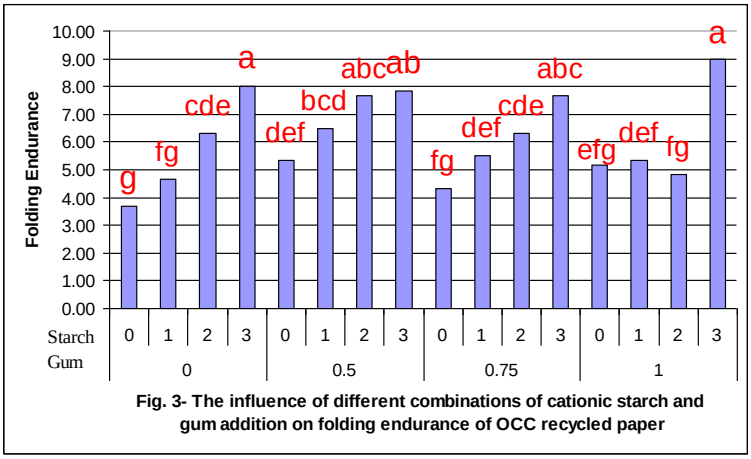

Fig. 2. The influence of different combinations of cationic starch and gum addition on tear index of OCC recycled paper

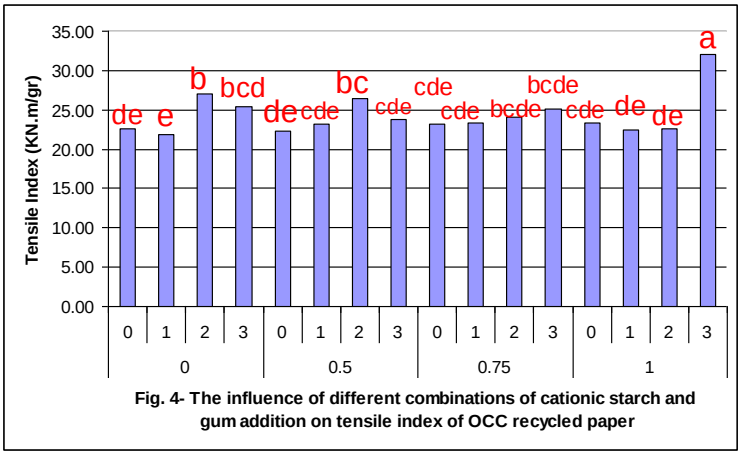

Fig. 3. The influence of different combinations of cationic starch and gum addition on folding endurance of OCC recycled paper

Less effectiveness of the gum on tear index could be attributed to its lubricant effect on the fiber surface, resulted in lesser persistence of the fiber network. However, combined addition of cationic starch and gum on tear strength was more effective and at all levels of gum, tear strength was improved, too (Fig. 2).

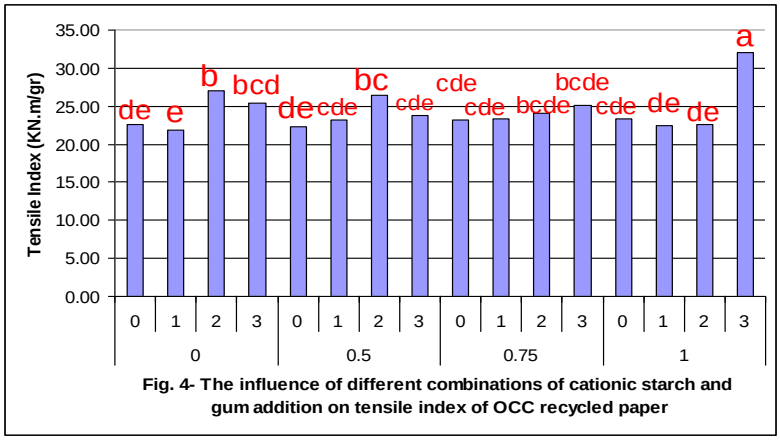

Fig. 4. The influence of different combinations of cationic starch and gum addition on tensile index of OCC recycled paper

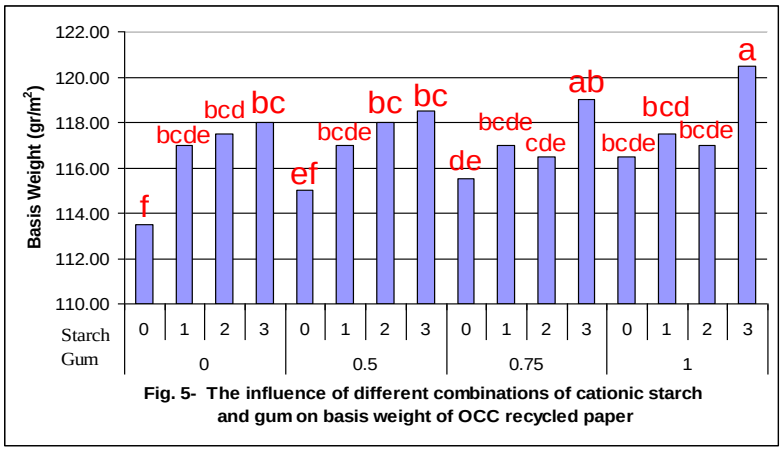

Fig. 5. The influence of different combinations of cationic starch and gum addition on basis weight of OCC recycled paper

As mentioned, the combination of 3% cationic starch and 1% gum produced the highest strength indices in the range of 45 to 145% higher than control sheets made without any additives. However, the performance of either 0.5% or 1% gum was better than 1% cationic starch, except for the retention rate of the pulp. Regarding to application of dry strength agent at 2% addition level, sole addition of cationic starch compared to combined addition of 1% cationic starch and 1% gum yielded markedly greater positive effects on the properties. It should be pointed out that the performance of 1% cationic starch on basis weight of paper was higher at any level of gum, which must be assigned to the positive charge of cationic starch and the anionic charge of the pulp slurry. This phenomenon causes more retention of fines as well as cationic starch and higher basis

weight. However, natural gum will not have such behavior. Since the price of gum is higher than cationic starch, it follows that the efficiency of cationic starch will be advantageous over gum. Of course, some exceptions were noticed as well.

Table 1. Strength Properties and Basis Weight of OCC Recycled Paper and Addition of Dry Strength Additives

Guar Gum	Cationic Starch	Tear Index		Tensile Index		Folding Endurance		Basis Weight		Burst Index	
		Quantity ($mN.m^2/g$)	Increase (%)	Quantity (KN.m/g)	Increase (%)	Number	Increase (%)	Quantity (g/m^2)	Increase (%)	Quantity ($KPa.m^2/g$)	Increase (%)
0	0	4	0	20.607	0	3.667	0	112.5	0	3.633	0
	1	5.124	28.1	21.842	6	4.667	27.2	117	4	3.666	0.9
	2	5.599	39.9	27.039	31.2	6.333	72.7	117.5	4.5	4.368	20.2
	3	5.827	45.6	25.425	23.4	8	118.1	118	4.9	4.352	19.7
0.5	0	4.988	24.7	22.253	8	5.333	45.4	115	2.2	3.705	1.9
	1	5.44	36	23.25	12.8	6.5	77.2	117	4	3.838	5.6
	2	5.669	41.7	26.367	27.9	7.667	109.1	118	4.8	4.532	24.7
	3	5.781	44.5	23.716	15	7.833	113.6	118.5	5.3	4.035	11
0.75	0	5.136	28.4	23.182	12.5	4.333	18.1	115.5	2.6	3.721	2.4
	1	5.168	29.2	23.279	12.9	5.5	50	117	4	3.735	2.8
	2	5.42	35.5	24.029	16.6	6.333	72.7	116.5	3.5	3.967	9.2
	3	5.851	46.2	25.034	21.5	7.667	109	119	5.7	4.14	13.9
1	0	4.727	18.1	23.369	13.4	5.167	40.9	116.5	3.5	3.831	5.4
	1	5.3	32.5	22.407	8.7	5.333	45.4	117.5	4.4	4.043	11.3
	2	5.225	30.6	22.602	9.7	4.833	31.8	117	4	3.656	0.6
	3	5.87	46.7	32.017	55.3	9	145.4	120.5	7.1	5.31	46.1

Based on the present results, application of 0.5% gum will show more beneficial effect on burst index, tensile index and folding endurance compared to 1% cationic starch. However, that difference was not significant at the 1% level. Even though the performance of cationic starch on recycled paper was better than gum, the ability of gum to impart strength improvement should not be ignored. Gum is a highly branched oligomer that is easily absorbed on fibers and therefore will adversely affect the absorption of cationic starch. Then starch will adsorb on fines and anionic particle which do not participate in strength development, especially when be neutralized by the anionic trash which can be present at high concentration in recycled furnish. On the other hand,

the colloidal and dissolved substances (DCSs) will be simply removed from the fiber network and reduce retention, which results in white water and finally waste water pollution.

CONCLUSIONS

Combined addition of cationic starch and guar gum showed contradictory results. Even though addition of both additives improved all strength indices, the performance of gum addition was superior with respect to all strength measures except tear index development. Moreover the higher price of gum and its availability compared to cationic starch suggests the application of cationic starch. This is a better alternative compared to refining to achieve strength development in OCC recycling.

REFERENCES CITED

Brouwer, P. H., and Baas, J. (2002). "Anionic wet-end starch: A wealth of possibilities to improve paper quality and/or reduce paper costs," *Technology Summit Proceedings*.

Howard, R. C., and Jowsay, C. J. (1989). "Effect of cationic starch on the tensile strength of paper," *J. Pulp & Pap Science* 15(6), J225.

Jalali Torshizi, H., Mirshokraie, S. A., Faezipour, M., Hamzeh, Y., and Resalati, H. (2010). "Application of galbanum gum (*Ferula gummosa*) polysaccharide as a natural polymer to improve dry strength properties of recycled papers obtained from old corrugated cartons," *Iranian Journal of Polymer Science and Technology* 23(4), 345-353.

Jalali Torshizi, H., Zare Bidoki, S., Ramezani, O., and Rudi, H. (2014). "Effect of cationic poly acrylamide -nano bentonite system on retention, drainage and properties of recycled paper from OCC," *Iranian Journal of Wood and Paper Science Research* 29(3), 474-483.

Jalali Torshizi, H., Zare Bidoki, S., Ramezani, O., and Rudi, H. (2016). "Effect of nano silica and cationic polyacrylamide on retention, drainage and strength properties of recycled paper from OCC," *Journal of Forest and Wood Products* 68(4), 771-784.

Ketola, H., and Anderson, T. (1998). "Dry strength additives," in: *Papermaking Chemistry*, Chapter 12.

Lee, J. Y., Lee, H. L., and Youn, H. J. (2005). "Adsorption analysis of cationic guar gum on fibers in closed papermaking systems", *TAPPI Journal*, October, Vol. 4(10).

Marton, J. (1996). "Dry strength additives," in: *Paper Chemistry*, J .C. Roberts (ed.), Chapman & Hall, London, p. 83.

Rojas, O., Newman, R., and Mills, R. (1995). "Utilization of guar gum for white water BOD reduction," *Papermakers Conference Proceedings*, TAPPI Press.

Article Submitted: September 15, 2015; Peer review completed: November 10, 2015; Revised version received and accepted: November 25, 2015; Published: December 15, 2015.