EFFECTS OF DIFFERENT FILLER COMBINATION WITH TALC AND CALCIUM CARBONATE ON PAPER PROPERTIES/PRINTABILITY

YUAN-SHING PERNG, EUGENE I-CHEN WANG,[*] YUE-JOE HSIA[**] and SHU-HSUN TSAI[***]

Department of Environmental Engineering, Da Yeh University, 168 Univ. Road, Dacun, Changhua 51591, Taiwan
[*]*Division of Wood Cellulose, Taiwan Forestry Research Institute, 53, Nanhai Road, Taiepi 10066, Taiwan*
[**]*College of Environmental Study, National Dong Hwa Univ., No. 1, Sec. 2, Da Hsueh Rd., Shoufeng, Hualien 97401, Taiwan*
[***]*Chung Hwa Pulp Corp., 100, Kuang Hwa Road, Chi-An, Hualien 97356, Taiwan*
✉ *Corresponding author: Yuan-Shing Perng, ysperng@mail.dyu.edu.tw*

Received July 15, 2013

This paper investigated mainly the effects of talc and ground calcium carbonate (GCC) mixed filler in wet end applications on the handsheet paper properties and printability. Particle sizes of talc and GCC were of 2 grades each: 7.96 and 16.07; and 1.99 and 4.99 µm, respectively. The mix ratios of talc/GCC were as follows: 100/0, 75/25, 50/50, 27/75, and 0/100. The examined paper properties included bulk, sizing degree, air permeability, coarseness, tensile strength, bursting strength, tearing strength, stiffness, printed gloss, print density, ink absorption, and print-through. The results indicated that mixed talc/GCC fillers performed better than either pure talc or GCC with respect to bulk, sizing degree, tensile index, stiffness, printed gloss, ink absorption, and print-through properties. However, smoothness and print density were reduced, while coarseness increased. Pure talc compared favorably to GCC with respect to sizing degree, tensile strength, smoothness, roughness, and printed gloss; but was poorer in bulk and ink absorption.

Keywords: talc, calcium carbonate, filler, printability, paper properties, bulk

INTRODUCTION

Talc is the softest mineral in nature, it can effectively extend the life of doctor blades and slitter knives. Talc has a platy morphology, with an aspect ratio of ca. 30, and has higher aspect ratio than clay and calcium carbonate, which can reduce the surface roughness of paper surface and lead to better printability and ink holdout. The chemical nature of talc is inert and will not react with wet end additives, and it will not affect the charge balance in wet end either. The average particle sizes of talc are 3 to 5 times those of calcium carbonate, hence it is retained easier in the wet end. When mixed with calcium carbonate or clay, talc also contributes to the retention of other fillers. The surface of talc possesses hydrophobic and lipophilic characteristics, which tend to help with web dewatering as well.[1-3] The physical properties of talc and $CaCO_3$ are shown in Table 1.

Lasmarias and Sharma investigated the substitution of a portion of precipitated calcium carbonate (PCC) with talc in both supercalendered and coated base paper formulations. The practice led to increased retention and drainage rates in lab handsheets, but also increased handsheet tensile strength and rotogravure printability. As for the mill test results, they were not published because of secrecy concerns, but the authors claimed that similar results were obtained.[1] Zhang *et al*. utilized $Al_2O_3 \cdot 3H_2O$ and P_2O_5 to modify talc. When both were at 2.5% doses, the first pass retention (FPR) at wet end increased 29.8% compared to the unmodified talc. When the $Al_2O_3 \cdot 3H_2O$ dose was 5%, the increase was 11.4%, however.[4] Sharma *et al*. studied higher filler loading in wheat straw pulp and found that the talc group had higher FPR than the ground calcium carbonate (GCC) group. At the same filler loadings, GCC decreased paper strength properties to a stronger degree than the talc group did. With respect to the addition of amphoteric strengthening agent, the talc group also outperformed GCC.[5] Chauhan *et al*. used a response surface statistics method to investigate the optimal dosages of talc and cationic polyacrylamide (cPAM) in handsheets at certain ash loading. They found both parameters had significant effects and increased the strength of handsheets.[6] Gupta *et al*. added medium molecular weight and low charge density retention polymer at 50 and 100 ppm to a talc containing wet end system and found FPR gains of 9.0 and 14.0%, and ash retention increase of 16% and 28%, respectively.[7] Lasmarias mixed scalenohdral PCC and talc to improve the optical properties and printability of paper. When finer talc and a talc with patented treatment were mixed with PCC, a significant reduction of linting and dusting was observed. In addition, talc helped pitch and stickies control.[8] Ibrahim *et al*. used starch, carboxymethyl cellulose, glycerol, dodecytrimethylammonium bromide, polyacrylamide and polyvinyl alcohol to chemically modify talc. The results indicated that the modified talc could effectively increase mechanical and optical properties. SEM graphs showed that modified talc could improve fiber-fiber-filler bond.[9] The same authors also modified talc using phthalic anhydride and urea, and found that rosin-sized talc-filled paper had improve the mechanical and optical properties.[10] Perng *et al*. investigated wet co-grinding of talc and GCC and found that co-ground fillers had a positive effect on FPR and ash retention; at 10% co-ground substituting of dry ground talc, paper bulk, sizing degree, breaking length, and brightness were all increased, but smoothness and opacity tended to decrease.[11]

Table 1
Talc and GCC properties[3]

Property	Talc	GCC
Morphology	Macrocrystalline	Blocky
Brightness (%GE)	82	95
Refractive index	1.57	1.56
Einlehner abrasion (g/m^2)	9.8	18.2
Aspect ratio	30	1
Particle size, D_{50} (µm)	7	1.5
Hardness (Moh's scale)	1.0-1.5	3.0
Specific surface area (BET, m^2/g)	9-20	2-12
Surface energy (J/cm^2)	35-40	75-80
Slurry pH	9.5	9.0

This study mainly investigated the effects of wet end addition of talc/GCC combinations and their particle sizes on the handsheet physical and printing properties. The particle sizes of talc were 7.96 and 16.07 µm, and those of GCC, 1.99 and 4.99 µm. The mixing ratios of talc/GCC were of 100/0, 75/25, 50/50, 25.75, and 0/100. The handsheet properties, such as paper bulk, sizing degree, air permeability, roughness, tensile, bursting, tearing, stiffness, and printed gloss, print density, ink aborption, print-through of printability were examined and compared.

EXPERIMENTAL

Two grades of each talc and GCC of different average particle sizes (7.96 and 16.07 µm vs. 1.99 and 4.99 µm, referred to as Tf, Tc, Cf, and Cc, respectively), were combined in different mixtures (Tc/Cc, Tc/Cf, Tf/Cc, and Tf/Cf) and in different blend ratios (100/0, 75/25, 50/50, 25/75, and 0/100) and were added at 25% filler loading to a printing and writing paper furnish for a total of 20 sets of samples. There were 3 replications to the experiments for a total of 60 experimental sets.

Materials

A bleached eucalyptus hardwood kraft pulp from Chunghwa Pulp & Paper Co., (Hualien, Taiwan) was used. The pulp was beaten from an original freeness of 605 mL to ca. 430 mL CSF. Pulp brightness was 86.7% ISO and opacity was 73.6%. Both the coarse (4.99 µm) and fine (1.99 µm) GCC were from Jawhwa Mining Co., Hualien, Taiwan. They had a brightness of respectively 94.2% ISO and 94.8% ISO, and solid content of 99.82% and 65.3%. Coarse (16.07 µm) and fine (7.94 µm) talcs were obtained from the same company with solids content respectively of 99.87%, 99.83%; and brightness of 90.0% and 91.6% ISO. The sizing agent used was alkyl ketene dimmer (AKD) TD-15 with 15.5% solids by Hercules, Taiwan. A cationic retention aid, cPAM powder, K-850 was from Pujia Co., Taiwan. An anionic retention aid, bentonite powder, was also from Pujia Co. Tapioca starch was converted to a cationic charge of 500-600 μeq/g by Chunghwa Pulp and Paper Co.

The instruments used in the study included a 4-digit balance, AB204-S, Mettler Toledo, accurate to ± 0.1 mg; a laser particle sizer, Cilas 1064, France; an oven, Web Binder, Tuttlingen, Germany; an analytical balance, XS 225A, Precisa, Switzerland; a blender, Kika Homodizer, Tokushu, Japan; a standard handsheet mould, KRK, Tokyo, Japan; a sheet press, Messmer, England; a calliper, Messmer, England; an air permeability meter, Gurley 4110, Teledyne, USA; a tensile tester, 50dN, Adamel Lhomargy, France; an Elmendorf tear tester, Digi-Tear M454, Messmer, England; a bursting meter, Seisaku-Sho, Tokyo, Japan; a model ME 90 Parker Print-Surf (PPS) roughness tester from Messmer (Gravesend,, Kent, UK) ; a brightness meter, Model 577, Photovolt, USA; an opacity meter, Model 575, Photovolt, USA; a Taber stiffness meter, Model 150-D, Teledyne Taber, USA; a scanning electron microscope (SEM), Vega II, Tescan, Czech Republic; a printability tester, AIC2-5, IGT, Neatherland; a high speed inking unit Model 4, IGT, Neatherland; a gloss meter, Novo-Gloss, Gardco, France; a concentration meter, R410e, Technon, Germany; a muffle furnace, HTC 1500, Carbolite, England; a fibre analyzer, Morfi Compact, Techpap, France; an abrasion meter, FP-2250, Thwing Albert, USA; and a coarseness meter, M-590, PMI, England.

Methods

The aforementioned 20 combinations were added to 0.3% consistency pulp at 25% filler loading. After homogenizing, 1% cationic starch, 0.12% AKD sizing agent, 100 ppm cationic retention aid and 2000 ppm bentonite were added sequentially with stirring. Then the pulp stock was formed into standard handsheets of 60 g/m^2. After conditioning overnight, the handsheets were tested for grammage, calliper, bulk, ash retention, sizing degree, air permeability, roughness, tensile, bursting, tearing strengths, stiffness; and printability properties of printed gloss, print density, ink absorption, and print-through etc.

RESULTS AND DISCUSSION

Bulk

The effects of different filler combinations on the bulk of handsheets are shown in Fig. 1. Among the 4 filler size groups, the pure GCC groups showed higher bulk than the pure talc groups; 100% pure fine talc produced paper with higher bulk than the pure coarse talc group. Particle sizes, however, had indistinct effects on the bulk of pure GCC papers. Blended talc/GCC groups generally had higher bulks than either pure GCC or talc groups. Among them Tc/Cf at 25/75 ratio produced the highest bulk. This was probably explained by the intermingling of platy talc with granular GCC, which took up more steric spaces and made the paper bulkier.

Sizing degree

Figure 2 shows the effects of different filler sizes and blend ratios on the sizing degrees of the resulting papers. Pure talc groups had higher size than pure GCC groups; and coarser fillers conferred higher size. Blended fillers generally had higher sizing degrees than either pure talc or GCC. Among these, Tc/Cc at 75/25 ratio produced the highest sizing degree. The phenomena might arise from the specific surface area of the minerals, the higher the specific surface, the more AKD particles are adsorbed onto them, the generally poorer retention of finer fillers leads to higher AKD loss. In addition, the retained AKD on fine filler particles might tend to age slower, leading to degraded sizing. Along with delayed reaction time, AKD lost capacity to react with fibres and hydrolyzed instead, reducing sizing degree.

Tensile strength

The effects of different filler size and blend combinations on the tensile strengths of the resulting papers are shown in Fig. 3. Among the 4 filler size groups, the pure talc groups tended to have higher tensile strengths than the pure GCC groups. The pure coarse talc group in turn had higher tensile strengths than the fine group. Particle sizes, however, had insignificant effects on the tensile performances of the pure GCC groups. The talc/GCC blends had higher tensile strengths than either pure minerals groups. Among these, Tc/Cc at 75/25 blend showed the highest strengths. The probable causes could be that a lesser number of coarse filler particles at the same filler loading causes less interference with fiber-fiber bonding.

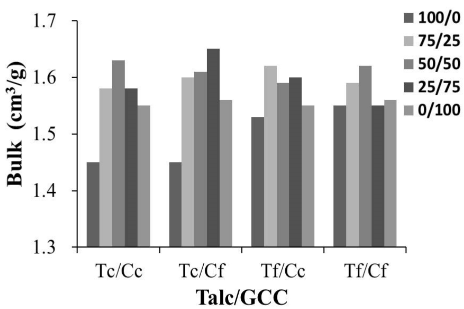

Figure 1: Effects of different talc/GCC size combinations and blend ratios on the bulk of paper; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

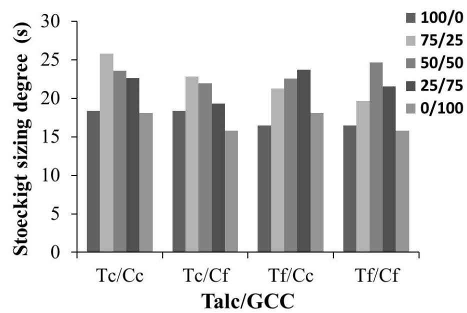

Figure 2: Effects of different talc/GCC size combinations and blend ratios on the sizing degree of paper; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

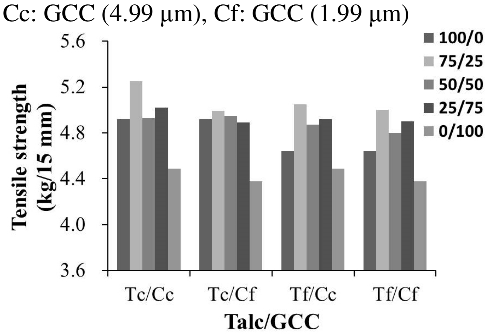

Figure 3: Effects of different talc/GCC size combinations and blend ratios on the tensile strength of paper; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

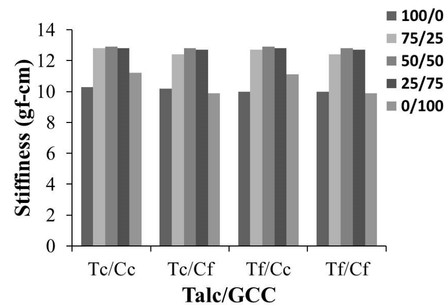

Figure 4: Effects of different talc/GCC size combinations and blend ratios on the stiffness of paper; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

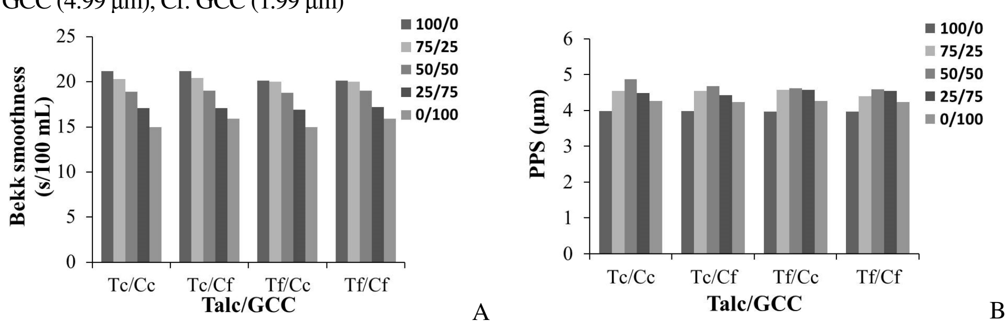

Figure 5: Effects of different talc/GCC size combinations and blend ratios on the smoothness (A) and roughness (B) of paper; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

In addition, the coarser filler groups had a more even sizing distribution, and might form a 3-D microstructure within fiber layers thus increasing the breaking length of paper. The results are congruent with those of Lasmarias and Sharma,[1] and Perng *et al.*,[11] as they also noted that adding talc to GCC filler improved the tensile strengths of handsheets.

Stiffness

The effects of different filler sizes and blend combinations on the stiffness of the resulting papers are shown in Fig. 4. Of the 4 filler groups, pure talc of different particle sizes and the pure Cf produced similar paper stiffness; pure Cc, however, produced paper with higher stiffness.

Blended talc/GCC groups generally had higher stiffness than the pure filler groups and the blend ratios showed no significant effect to paper stiffness. Filler size appeared to have no notable effect on stiffness regarding blended-filler papers. Based on well-known empirical observations, the stiffness of paper varies at the cube exponent of its bulk,[12] thus a formulation resulting in higher bulk should also produce paper of greater stiffness. The trend was not very distinct in the present case.

Smoothness and roughness

Figure 5 shows the effects of different filler size and blend ratio on the smoothness and roughness of the resulting papers. For the 4 filler size groups, paper smoothness decreased with increasing GCC ratios. Probably the flat platy surfaces of talc particles tended to lie preferentially along the fiber surface and pure Tc had slightly better surface covering capacity than pure Tf; while granular GCC caused surface micro-bumps, and pure Cc had greater bumpiness than pure Cf on the fiber surface, leading to the observed smoothness differences. Particle size generally showed a lesser effect on paper smoothness. As for the roughness of paper, pure talc produced lower roughness than pure GCC groups. Particle sizes of the pure filler groups showed no apparent difference in roughness. The blended talc/GCC groups tended to have higher roughness than either mineral alone. The Tc/Cc group had the highest roughness result. The phenomena might relate to the platy structure of talc, while the intermingling of granular GCC at higher ratios might cause irregular stacking and increased roughness.

Printed gloss

The effects of different filler size and blend combinations on the printed gloss of the resulting papers are shown in Fig. 6. It indicates that among the 4 filler size groups, pure talc groups tended to have higher printed gloss than the GCC groups; and pure Tc had a higher value than Tf. Particle size appeared to have little effect on the GCC printed gloss, however. The printed gloss of talc/GCC blends had no discernible trend, among these, the Tc/Cf at 75/25 ratio produced the highest printed gloss.

Print density

Figure 7 shows the effects of different filler size and blend combinations on the print intensity of the resulting papers. Of the 4 size grades, the pure Tf resulted in the highest print density. The densities decreased with increasing GCC ratios in the blend, however. For Tc, regardless of the Cc and Cf combinations, lower print densities resulted.

Ink absorptivity

The effects of different filler size and blend combinations on the ink absorptivity of the resulting paper are shown in Fig. 8. Of the 4 size grades, the pure talc groups showed lower ink absorptivity than the pure GCC groups. Pure Tc and pure Cc groups tended to have slightly higher ink absorptivity associated with their coarser particle sizes. Talc/GCC blends generally had higher ink absorptivity than either pure filler; and the Tc/Cc at 25/75 ratio produced the highest ink absorptivity.

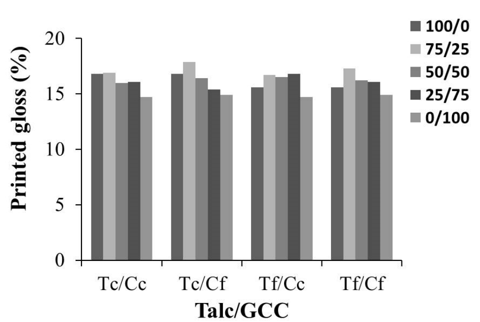

Figure 6: Effects of different talc/GCC size combinations and blend ratios on the printed gloss of paper; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

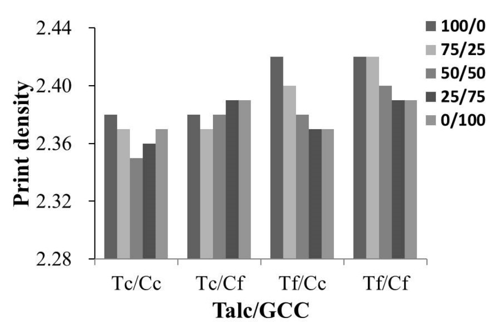

Figure 7: Effects of different talc/GCC size combinations and blend ratios on the print density of papers; Tc: talc (16.07 µm), Tf: talc (7.96 µm), Cc: GCC (4.99 µm), Cf: GCC (1.99 µm)

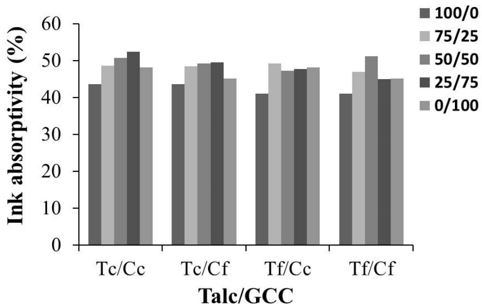

Figure 8: Effects of different talc/GCC size combinations and blend ratios on the ink absorptivity of paper; Tc: talc (16.07 μm), Tf: talc (7.96 μm), Cc: GCC (4.99 μm), Cf: GCC (1.99 μm)

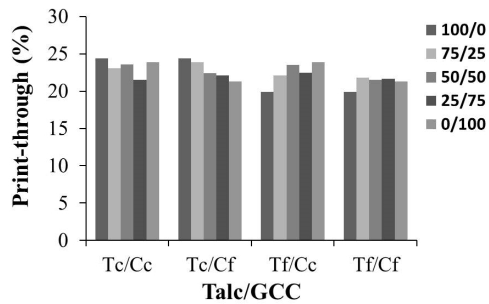

Figure 9: Effects of different talc/GCC size combinations and blend ratios on the print-through of papers; Tc: talc (16.07 μm), Tf: talc (7.96 μm), Cc: GCC (4.99 μm), Cf: GCC (1.99 μm)

Print-through

Figure 9 shows the effects of different filler sizes and blend combinations on the print-through occurrences of the resulting papers. Among the 4 filler size grades, pure fillers of coarser particles showed higher rates of print-through than the finer ones. Among the blends, the rates of print-through were irregular compared to the pure filler groups. In a Tc/Cc blend, lower print-through was observed, however, in the Tc/Cf blend, with increased GCC, print-through decreased. For Tf, regardless of blending with Cc or Cf, the mixed filler tended to have higher rates of print-through.

CONCLUSION

Blending talc with GCC appeared to perform well compared to either pure filler alone in paper bulk, sizing degree, tensile strength, stiffness, printed gloss, ink absorptivity, and print-through properties. However, the smoothness and print density decreased and roughness increased. The pure talc groups tended to have higher sizing degree, tensile strength, smoothness, printed gloss and print density than the pure GCC groups did, however, at the costs of lower bulk and ink absorptivity.

ACKNOWLEDGEMENT: The authors wish to acknowledge the financial support from National Science Counselor (NSC 95-2313-B-212-012-MY3). Jawhwa Mining Co. Ltd (Hualien) provided the filler minerals for the experiment. The authors are thankful to their help.

REFERENCES

[1] V. B. Lasmarias and S. Sharma, *Tappi J.*, **3**, 31 (2004).
[2] S. Sharma and W. Bash, in *Procs. TAPPI Coating Conference*, Atlanta, GA, USA, 1998, pp. 695-707.
[3] M. C. Withiam, *Tappi J.*, **74**, 249 (1991).
[4] H. Zhang, Y. H. Zhang and R. Yang, *Tianjin University of Sci. Tech.*, **19**, 349 (2004).
[5] A. Sharma, S. Kumar, V. S. Chauhan, S. K. Chakrabarti and R. Varadhan, *IPPTA J.*, **24**, 87 (2012).
[6] V. S. Chauhan, S. K. Chakrabarti and N. K. Bhardwaj, *IPPTA J.*, **24**, 171 (2012).
[7] C. Gupta, P. Sridhar and M. K. Gupta MK, *IPPTA J.*, **24**, 191 (2012).
[8] V. Lasmarias, in *Procs. TAPPI PaperCon 2010 Conference*, Atlanta, GA, USA, TAPPI Press, 2010, pp. 90-117.
[9] M. M. Ibrahim, F. Mobarak, E. I. Salah El-Din, A. E. H. E. Ebaid and M. A. Yussef, *Tappi J.*, **8**, 15 (2009).
[10] M. M. Ibrahim, F. Mobarak, E. I. Salah El-Din, A. E. H. E. Ebaid and M. A. Yussef, *Carbohyd. Polym.*, **75**, 130 (2009).
[11] Y. S. Perng, I. C. Wang, W. C. Yang and M. H. Lai, *Taiwan J. For. Sci.*, **23**, 1 (2008).
[12] W. E. Scott, J. C. Abbott, S. Trosset, "Properties of Paper: An Introduction", 2nd ed., TAPPI Press, Atlanta, 1995, pp. 83-86.