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Difference of Calendering and Dochim Effects on Paper Surface Properties

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ABSTRACT

Hanji is a traditional Korean handmade paper, which has been known in ancient Far East as excellent quality calligraphic paper for more than 1,500 year. Hanji is mostly made of Korean paper mulberry bast fibers, and if properly processed, normally lasts for more than 1,000 years with significant strength and still recognizable calligraphic writings or drawings on it. Dochim is a special way of Hanji calendering process, but is turned out to be quite different from modern calendering (machine calendering) in several aspects. In Dochim process, mechanical impacts were applied vertically to the surface of papers. Compared to the modern calendering, Dochim increased paper gloss much more, but paper smoothness a little less. By the Dochim process, densification occurred and the degree of densification was more sensitive to the fiber type in the Dochim process than in the calendering method.

Keywords *: Hanji, Dochim, calendering, smoothness, gloss, opacity*

1. Introduction

Hanji is Korean traditional handmade paper, which mostly consists of Korean paper mulberry bast fibers (also called "Dak" in Korea). Dak has long length (8-12mm) and narrow width (~20 ㎛). Its Runkel ratio is around 0.77 (1). Hanji was well known in ancient Far East as an excellent quality paper by its high brightness, whiteness, high strength, high gloss, smooth feel in writing and drawing, and proper ink-paper interaction. Furthermore, it lasts more than thousand years with still significant strength and with recognizable calligraphic writings on it. Korean archaeologist found old Hanji documents printed by wooden press in 751 AD. They were kept under the pagoda in a Buddhist temple (2). The letters were still clearly recognizable.

In this study, we tried to compare the paper smoothing process, which is done by the machine calenders in modern paper machine, to Dochim, which is a traditional way of Hanji smoothing process. In Dochim, a heavy wooden block falls repetitively on the Hanjis, normally ten to twenty sheets of which are treated together. From time to time, very small amount

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Table 1. Physical properties of the samples

Physical properties	Linerboard	White paper	Hwang-dae-ji(Hanji)	Hwa-sun-ji(Hanji)	Chang-ho-ji(Hanji)
Basis weight(g/m^2)	183.9	101.7	27.7	28.0	53.8
Density(g/cc)	0.694	0.779	0.229	0.341	0.304
Smoothness(sec.)	1.7	6.5	1.1	1.6	0.6
Breaking Length(km)	3.86	4.52	8.60	7.79	6.71
Tear index(mN·m^2/g)	93.5	137.6	881.5	625.0	900.3
Burst index(kPa·m^2/g)	0.021	0.019	0.056	0.058	0.080
Stiffness(g·cm)	15.2	5.8	-	-	-
Gloss(%)	8.5	9.9	13.6	12.3	12.9
Opacity(%)	99.9	88.3	49.7	55.2	75.6

of water is sprayed on the Hanji, but drying process is not needed after Dochim. The wooden block has flat bottom. The Hanji- makers who have life-long experiences in Hanji making usually decides the amount of impact and the degree of Dochim. If we can find any unique and profitable quality of Dochim process besides paper smoothness improvement, we may apply the same mechanism to modern paper machine someday. The dochim process is shown in Fig.1. Hanji-making is briefly described in ref. 3 and 4.

2. Materials and Methods

Three kinds of Hanjis as well as a linerboard and a white paper were used in Dochim treatment. The general physical properties of samples were summarized in Table 1. Linerboard from Asia Paper Co. in Korea and white paper (reprographicpaper) from Shinho Paper Co. in Korea were hard nip calendered in the paper machine and in lab. by hard nip pilot calender. Linerboard and white paper before machine calendering were obtained for the application of Dochim. Dochim process was applied to all five samples, and their physical and mechanical properties were compared to one another. Wooden block, which was used in Dochim process, was about 20 kg in weight, and the free-fall distance to the paper was around 70 cm. Frequency of the impact was 15 to 20 times per a minute.

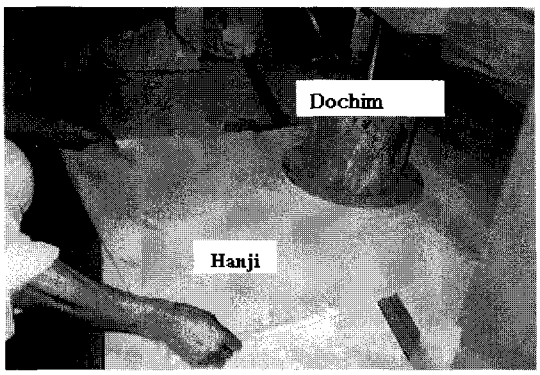

Fig. 1. Dochim process.

3. Results and Discussion

The density profiles of linerboard and white paper were shown in Figs. 2 and 3. Machine and pilot calendering, and Dochim process increased density of the linerboard in proportion to the amount of treatments. In white paper, Dochim increased paper density greatly even at the lowest level of Dochim (higher than 0.9 g/cc) while the machine or the pilot calendering increased paper density not as much as Dochim did. In linerboard, the density of PC200-1 treatment (Pilot calender 200 kN/m^2, 1 time pass) was

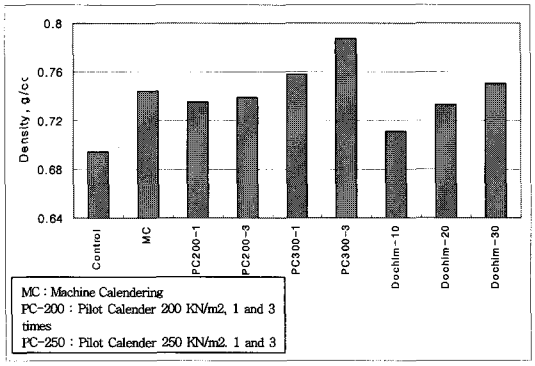

Fig.2. Linerboard density profile after surface mechanical treatment.

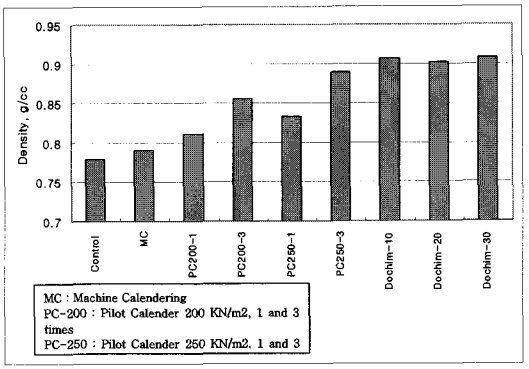

Fig. 3. White paper density profile after surface mechanical treatment.

higher than that of Dochim-10 treatment (Dochim 10 minutes), but in white paper, Dochim-10 treatment gave much higher density than PC200-1 treatment did. For the Hanjis, we could not use on-line machine calender. From the results of pilot calendering and Dochim, it can be said that the densities of the Hanjis were proportional to the amount of the treatment. The more Dochim application there was, the higher the density (Fig. 4).

The glosses of linerboard and white paper were shown in Fig. 5. Only Dochim process increased gloss of the samples remarkably. For example, the final density of PC300-3 in linerboard (Pilot calender 300 kN/m^2, 3 times pass) was much higher than that of Dochim-10 (Fig. 1), but the gloss of Dochim-10 of the linerboard in Fig. 4 was more than two times higher than that of PC300-3. So, high gloss at low density was achieved in linerboard by Dochim process. In white paper, high gloss at high density was achieved. In Hanji, paper gloss was proportional to its density change (Fig. 6).

Paper smoothness was measured with Bekk type smoothness tester. The pattern of the linerboard smoothness resembled exactly that of linerboard gloss as shown in Fig. 7. One surprising result was that there was very little smoothness improvement in white paper by the Dochim process, but very high improvement of smoothness (Fig. 7) by calendering. By Dochim process, the density of the white paper went up very quickly to 0.9 g/cc. It seems that the fibers in the white paper were collapsed by the impact of the Dochim process, and no recovery to the original

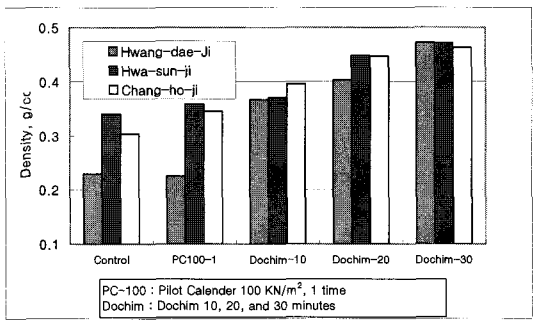

Fig. 4. Hanji's density profile after surface mechanical treatment.

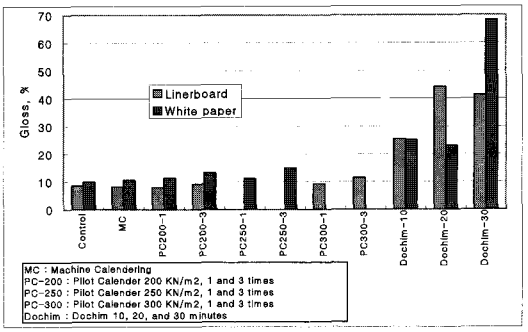

Fig. 5. Gloss change (%) of linerboard and white paper after surface mechanical treatment.

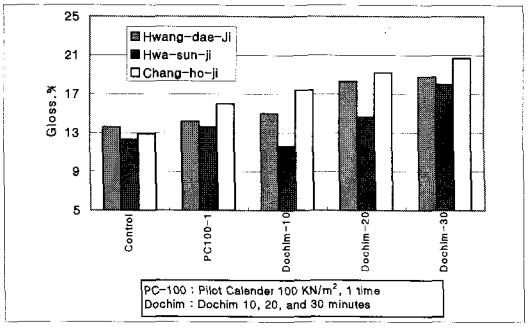

Fig. 6. Gloss change (%) of Hanjis after surface mechanical treatment.

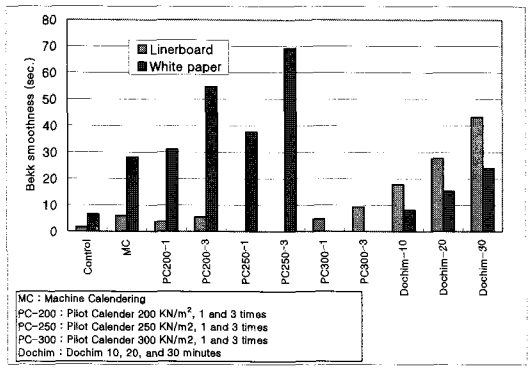

Fig. 7. Smoothness improvement of linerboard and white paper after surface mechanical treatment.

thickness occurred. Every impact of the wood block in Dochim process might have shaped the surface contour of the white paper, which could be the replica of the bottom surface of the wood block. Actually, the surface of the wood block was not very smooth. The smoothness of the Hanjis were increased in proportion to their density (Fig. 7).

White paper and linerboard did not show significant changes in opacity by calendering, but all the Hanjis increased their opacities by calendering and Dochim (Fig.8). Especially, Hwang-dae-ji and Chang-ho-ji increased their opacities more than 10 points by the Dochim treatment. This trend was not well known to Hanji-makers and should be recognized from now on. Initial density of the white paper and the linerboard before the treatments were more than 0.7 g/cc, and the density of the Hanjis were close to 0.3 g/cc.

Hanjis usually have very low basis weight and very low density. Densification of Hanjis by calendering and Dochim could lower see- throughness or increase opacity according to this experiment (Fig. 8).

The changes of tensile properties of the samples were shown in Figs. 9 and 10. Breaking length of white paper and linerboard were generally increased by calendering and Dochim. Hwang-dae-ji and Hwa-sun-ji, which had high breaking length initially, decreased their breaking length significantly, but

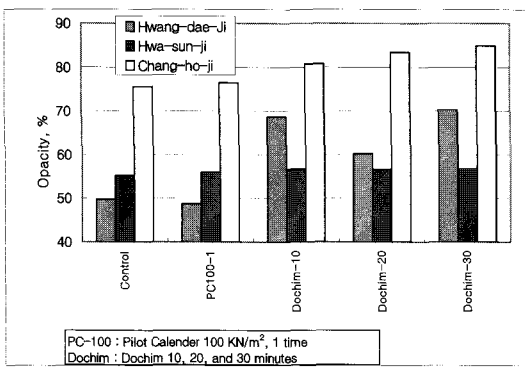

Fig. 8. Opacity change (%) of Hanjis after surface mechanical treatment.

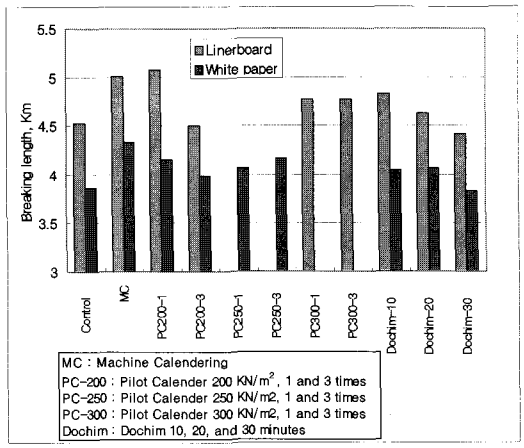

Fig. 9. Breaking length change of linerboard and white paper after surface mechanical treatment

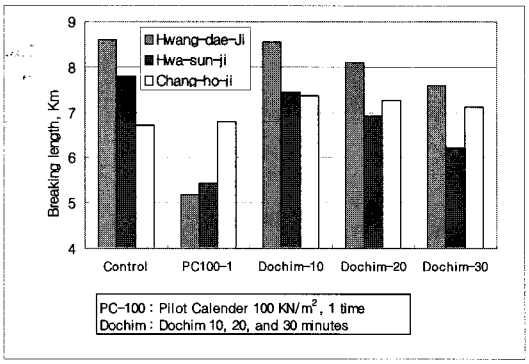

Fig. 10. Breaking length changes of Hanjis by various surface mechanical treatment.

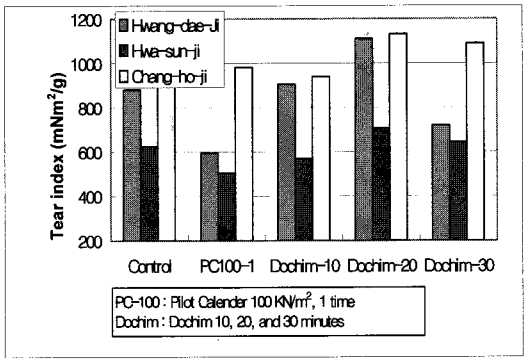

Fig. 12. Tear index changes of Hanjis by the surface mechanical treatment.

Chang- ho-ji, which had low breaking length initially, increased its breaking length by Dochim and pilot calendering (Fig. 10). For the Hanjis, pilot calendering did not increase smoothness significantly as much as Dochim (Fig. 7), and only decreased the breaking length considerably (Fig. 10). Tear index of white paper was not changed much by calendering and Dochim, but that of linerboard was generally decreased as shown in Fig. 11. Tear indexes of Hanjis were 5 to 10 times higher than those of white paper and linerboard (Fig. 12). Except pilot calendering, tear index of Hanjis were generally increased by Dochim.

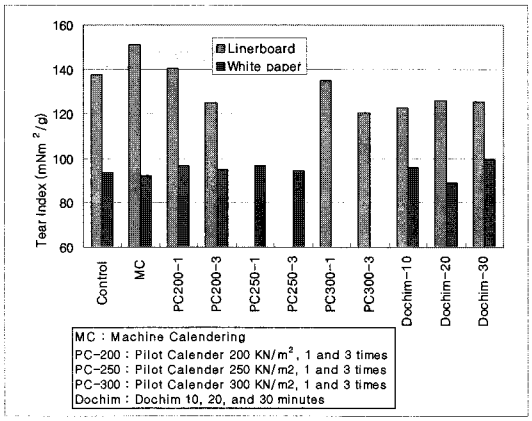

Fig. 11. Tear index changes of linerboard and white paper by surface mechanical treatment

4. Conclusions

In Dochim, repetitive mechanical impacts were applied to the paper surface. The gloss of every paper in the experiment was increased significantly by the Dochim process. However, it seems that the fibers in white paper were totally collapsed by the Dochim process. A few conclusions were made in the followings.

⊙ Dochim was an excellent gloss improving process for all the paper samples. Its effect on paper gloss was much better than machine and pilot calendering.

⊙ By Dochim, smoothness of all the paper samples were increased significantly except white paper. It seems that fibers of white paper were very sensitive to mechanical impact, and its surface contour only reflected the surface of the Dochim wooden block.

⊙ Opacity of Hanjis were increased by Dochim process because their initial densities were too small to block the see-through.

⊙ For Hanjis, machine and pilot calendering were not effective to improve smoothness and gloss, but only decreased breaking length significantly.

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