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Studies on the Printability of Hanji by Sizing and Calendering

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ABSTRACT

The development of printable Hanji is regarded as an important work to create a new demand of Hanji in information-oriented era. Hanji has rougher surface, huger absorption of ink and lower optical properties and printabilities than common printing papers. Improving those shortcomings of Hanji is required to be printable Hanji. Sizing and calendering have known as a way to make properties of paper good. Accordingly, this research was performed to find out useful sizing agents for reforming its drawbacks. Four sizing agents (CMC, corn starch, PVA, AKD) were used in this research. The optical properties and the printabilities of sized Hanji were tested. The obtained results were as follows. Based on concentration, each sizing agent was prepared. These were CMC (0.5, 1, 1.5%), corn starch (1, 2, 3%), PVA (1, 5, 10%), AKD (0.05, 0.1, 0.15%) respectively. After sizing, we performed calendering treatment with pressure of 0.5, 1 kgf/㎠. All the sizing agents and calendering treatment improved the properties of Hanji to some extent. Particularly, corn starch was good for gloss. In case of printability, 0.1% AKD with 1 kgf/㎠ was recommendable for typography ink density, 3% corn starch with 0.5 kgf/㎠, inkjet ink density, 2% corn starch with 0.5 kgf/㎠, inkjet ink girth. PVA and AKD without calendering were counter-effective agents for inkjet ink density. Printable Hanji is required to have not only better surface strength enough to appear non-picking, higher ink density and lower show-through than base paper but also the lowest ink girth in comparison with base paper. When referring to them, efficient sizing agents were regarded as 0.1% AKD with 1 kgf/㎠, calender pressure, for typography printing and 2% corn starch with 0.5 kgf/㎠, calender pressure, for inkjet printing.

Keywords : CMC, corn starch, PVA, AKD, sizing, calendering, printability

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1. Introduction

Hanji is a presentative paper with Korean tradition and has been recognized as an important vehicle for long preservation of Korean historical and informative media. In spite of the native fact, recognition on Hanji as a cultural paper has been recently reduced due to a lack of its essential understanding and industrially economical output. Hanji has many good properties such as air-penetration, flexibility, soundproof, heatproof and humidity control. Hanji has been traditionally used as a painting paper. In recent, it was also developed for a variety of applications such as changphanji (1), wrapping paper (2), business card paper (3), lightproof paper (4), wall paper (5,6) and industrial art paper (7). Although use of Hanji was extended, the limitation of industrial demands and high price are still disturbing the promotion of Hanji industry. Development of a new capital field, which can meet a large demand rather than multi-usage, is necessarily required to reduce an economical burden in Hanji industry. Meanwhile, increasing a preservation period of an informative document has attracted strong attention due to the limit of general printing papers. Hanji is suitable to meet the needs due to the excellent durability (8). Moreover, as the use of printing paper is increased, development of printable Hanji can be one of the substantial demands. However, Hanji has shortcomings such as rough surface, huge ink absorption and low properties itself. Therefore, this study aims to estimate the possibility by measuring the properties and the printability of Hanji by sizing and calendering processes.

2. Materials and Methods

2.1 Materials

Machine-made Hanji (100 g/m^2) was obtained from Jirisan Hanji company. Carboxymethyl cellulose (CMC, HAYASHI), corn starch (DAE SANG), Polyvinyl alcohol (PVA, YAKURI) and Alkylketenedimer (AKD, 20%, HE-201) as sizing agents were used to improve the surface properties and printabilities of Hanji.

2.2 Methods

2.2.1 Preparation of sizing agents

The four agents were dissolved with distilled water. Particularly, PVA was dissolved at 80℃ for 1 hr, and corn starch was gelatinized at 95℃ for 30 min to increase dissolution of these sizing agents. The concentration of dissolved sizing agents was adjusted as shown Table 1. Sizing on the surface of Hanji was performed using a coater (PI-1210, Sangyo, Japan) and the speed was 13 mm/sec with RDS 16, bar used. The sized Hanji was dried in a convection dryer at 50℃ for 10 min and employed for estimation of various optical properties and printabilities.

Table 1. Concentration of sizing agents

Sizing agents	Concentration (%)
CMC	0.5, 1, 1.5
Corn starch	1, 2, 3
PVA	1, 5, 10
AKD	0.05, 0.1, 0.15

2.2.2 Measurement of optical properties and ink printabilities of sized and/or calendered Hanji

The sized Hanji was treated at 20±1℃ and 65.5%(RH) for over 24 hr. The optical and

surface properties such as sized weight, sized thickness, brightness, density, gloss, smoothness, air permeability, roughness, opacity, sizing degree, and ink printabilities (surface strength, typography ink density and its show-through, inkjet ink density and its show-through, inkjet ink girth) were investigated to estimate the effect of the sizing agents. The sized Hanji was also calendered using the calender (Beloit wheeler). The condition was: pressure, 0.5 and 1.0 kgf/㎠, operation speed, 7.16 cm/sec; temperature, 45℃. And then, optical and surface properties were measured to observe the impact of calendering. The measurement of inkjet ink girth was made using an image analyzer (BMI pus). Two types of ink (typography ink, inkjet ink) were applied to evaluate ink printabilities of sized and/or calendered Hanji.

3. Results and Discussion

3.1 Optical properties of sized Hanji

The optical properties of sized Hanji were investigated without calendering treatment, The sized weight (4.6-7.3 g/㎡), sized thickness (1-14 ㎛) and density (0.42-0.46 g/㎤) were increased with increase in concentration of the applied sizing agents. In most case of the sizing agents, a slight increasing trend in brightness with increase in its concentration was observed. AKD, well-known as a neutral sizing agent which has replaced the acidic sizing agent (9,10), showed maximum brightness. The degree of gloss was improved by corn starch. It might mean that corn starch can be a good agent for improvement of gloss of Hanji. CMC (optimum concentration: 1%) was superior to the other agents in smoothness. Sizing resulted in reduction of air permeability owing to a narrow space among fibers. The roughness of sized Hanji was a little better than base paper. AKD showed the most improved sizing degree. It was considered to be due to good penetration

Table 2. Optical properties of sized Hanji without calendering

Properties / Sizing agents	Sized Weight (g/㎡)	Sized Thickness (㎛)	Density (g/㎤)	Bright-ness (%)	Opacity (%)	75° Gloss (%)	Smooth-ness (sec.)	Rough-ness (㎛)	Air perme-ability (ml/min.)	Stöckigt sizing degree (sec.)
Base paper	0	0	0.43	75.8	88.61	6.6	1.6	3458	367.0	0
0.5% CMC	5.3	1	0.45	75.4	89.64	7.1	2.0	3385	342.0	2
1% CMC	6.6	1	0.43	74.3	89.47	7.3	2.7	2540	268.0	3
1.5% CMC	6.9	9	0.46	74.6	87.75	7.8	2.8	1963	226.2	4
1% Starch	6.0	1	0.44	75.7	89.65	8.1	1.6	2766	370.4	1
2% Starch	6.9	11	0.45	74.8	89.24	8.4	1.9	2834	348.7	1
3% Starch	7.2	13	0.46	74.8	89.02	8.4	2.4	2611	301.5	2
1% PVA	6.1	5	0.43	77.3	89.13	6.8	1.5	2378	369.1	1
5% PVA	6.9	7	0.45	76.7	88.29	7.3	1.5	2184	367.6	2
10% PVA	7.3	8	0.46	76.2	88.33	7.7	1.9	1616	365.0	2
0.05% AKD	4.6	6	0.43	76.2	89.50	7.1	1.5	2104	371.1	29
0.1% AKD	6.9	7	0.43	77.5	89.06	7.0	1.5	2137	374.5	111
0.15% AKD	7.3	14	0.42	77.5	90.91	6.8	1.4	2211	372.6	124

of AKD with relatively low molecular mass into an empty space among fibers and partly due to high hydrophobic property (11). Therefore, AKD seems to be recommendable as an agent for improvement of sizing degree and brightness of Hanji.

3.2 Optical properties of calendered Hanji after sizing

The optical properties of Hanji after stepwise process of sizing and calendering were estimated. In general, calendering treatment improves the optical properties of paper by

Table 3. Optical properties of calendered Hanji after sizing

Properties / Sizing agents	Pressure of calendering (kgf/㎠)	Sized Weight (g/㎡)	Sized Thickness (㎛)	Density (g/㎤)	Bright-ness (%)	Opacity (%)	75° Gloss (%)	Smooth-ness (sec.)	Rough-ness (㎛)	Air perme-ability (ml/min.)	Stöckigt sizing degree (sec.)
Base paper	—	0	0	0.43	75.8	88.61	6.6	1.6	3458	367.0	0
0.5% CMC	0.5	—	-76	0.70	76.5	88.71	11.4	16.1	364	273.8	1.6
	1	—	-91	0.74	76.2	88.73	13.7	23.0	217	246.4	1.5
1% CMC	0.5	—	-81	0.66	76.8	88.32	11.9	17.3	298	220.8	3.3
	1	—	-93	0.76	74.3	88.88	13.1	29.3	131	205.8	2.5
1.5% CMC	0.5	—	-80	0.65	75.1	88.13	12.1	18.7	254	137.8	2.7
	1	—	-93	0.72	75.3	87.84	13.9	31.7	134	137.7	2.8
1% Starch	0.5	—	-79	0.65	75.2	89.23	13.4	14.7	367	339.8	1.1
	1	—	-93	0.71	75.5	89.54	15.5	24.3	145	300.8	1.5
2% Starch	0.5	—	-69	0.68	75.4	88.77	12.6	14.2	223	281.0	1
	1	—	-87	0.73	75.4	88.62	14.7	25.6	143	244.0	1.6
3% Starch	0.5	—	-85	0.67	75.0	88.12	12.8	16.9	348	229.4	1.2
	1	—	-95	0.68	75.3	89.11	15.5	21.1	157	210.8	1.1
1% PVA	0.5	—	-75	0.66	75.5	89.73	11.4	9.6	371	352.0	1.1
	1	—	-88	0.73	75.2	88.75	13.4	17.3	298	313.4	1.5
5% PVA	0.5	—	-75	0.66	75.2	88.66	11.3	8.1	400	346.6	1.8
	1	—	-95	0.74	75.1	88.31	13.4	16.1	365	308.2	1.5
10% PVA	0.5	—	-85	0.64	75.3	88.67	11.5	8.5	393	356.6	1.2
	1	—	-97	0.72	75.0	87.06	13.0	16.4	360	314.4	1.4
0.05% AKD	0.5	—	-71	0.65	75.1	88.86	10.6	8.1	409	358.6	7.7
	1	—	-88	0.70	74.8	89.42	12.5	17.0	302	325.4	10.9
0.1% AKD	0.5	—	-77	0.66	74.9	89.09	10.9	7.4	427	369.0	22.8
	1	—	-93	0.70	74.8	89.36	12.9	16.0	360	350.2	67.0
0.15% AKD	0.5	—	-71	0.63	76.3	89.57	10.7	7.9	412	368.2	59.0
	1	—	-97	0.70	74.7	88.54	12.7	15.9	377	351.8	74.1

balancing the thickness and surface properties (12,13). As calender pressure was increased, thickness was significantly decreased, but the density increased as an expectable result. The slight increase of brightness and opacity and the predominant rise of gloss were observed. Corn starch contributed to improvement of gloss degree of Hanji. It represents, from the results of sizing and calendering, that corn starch can be recognized as a gloss-improving agent for printable Hanji. Expectedly, the reduction of roughness and air permeability were considered to be due to the relative increase of density. AKD (0.1%) is likely to be desirable for an optimized sizing degree. As a result, sizing and calendering were effective treatments to reform the properties of Hanji to some extent.

3.3 Printability of sized and/or calendered Hanji

The surface strength is given in Table 4. CMC and corn starch improved the surface strength as concentration was increased. PVA indicated the most effective agent for surface strength. AKD was counter-effective agent for surface strength. It can be considered that AKD which is a reactive agent needs heating treatment to promote its reaction with the fiber based on cellulose (14). Calendering after AKD sizing showed the improving effect on picking. When printing, surface strength was required to protect the fiber of surface from picking. Accordingly, appropriate surface strength which can endure picking was required for printable paper.

Table 4. Surface strength of sized and/or calendered Hanji (Unit : cm)

Pressure(kgf/cm²) / Sizing agents	No calendering	0.5	1
0.5% CMC	8.4	0.2	0.1
1.0% CMC	N	N	N
1.5% CMC	N	N	N
1% starch	7.5	N	N
2% starch	N	N	N
3% starch	N	N	N
1% PVA	N	N	N
5% PVA	N	N	N
10% PVA	N	N	N
0.05% AKD	1.7	N	N
0.1% AKD	0	N	N
0.15% AKD	0	N	N

0 : All picked, N : no picked
※ Base paper : 0 (All picked)

Fig. 1 presents typography ink density and its show-through. The typography ink density was improved with increase of calender

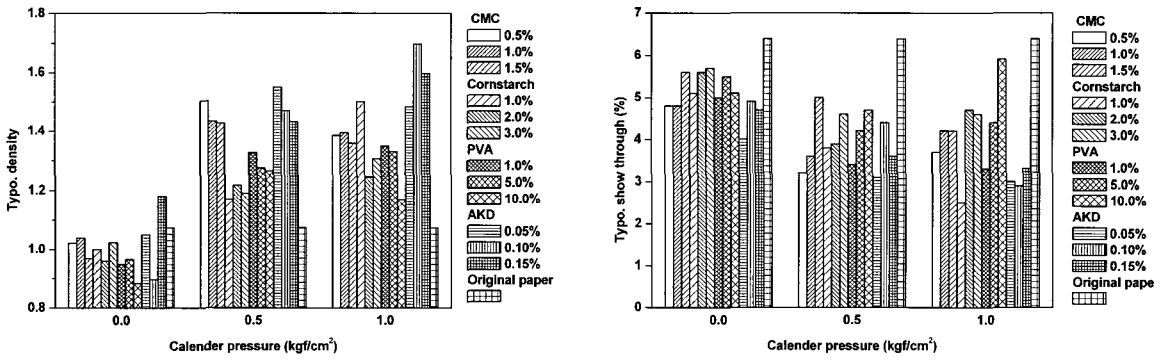

Fig. 1 . Effect of typography ink density and its show-through.

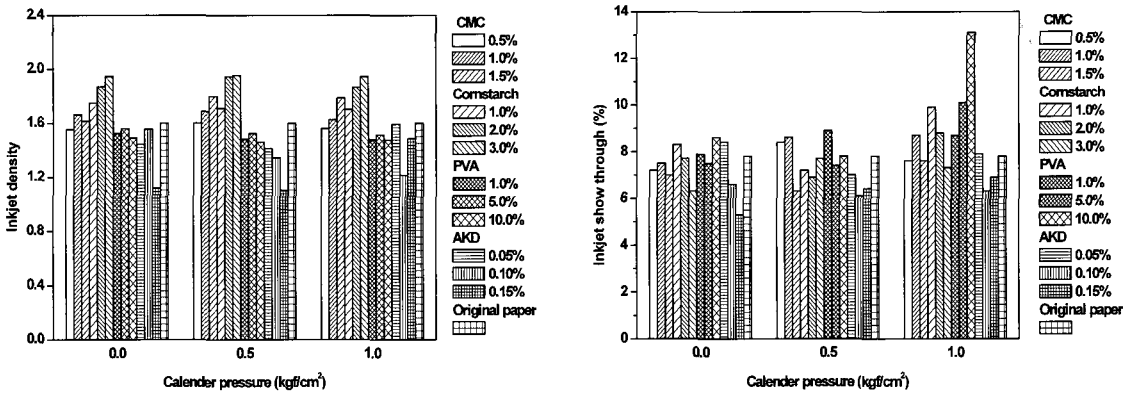

Fig. 2. Effect of inkjet ink density and its show-through.

pressure. The maximum ink density of typography and its minimum ink show-through were observed as 1.7 and 2.9%, respectively, when 0.1% AKD was applied under 1 kgf/㎠ of calender pressure. In typography printing, AKD (0.1%) with 1 kgf/㎠ can be recommendable as a sizing agent for improvement of printability of Hanji.

Inkjet ink density and its show-through are given in Fig. 2. In ink density, Hanji sized with 3% corn starch with 0.5 kgf/㎠, calender pressure, showed maximum ink density and minimum its show-through was by 3% corn starch without calendering. The value was 1.955 and 6.3%, respectively. In all concentration of corn starch, inkjet ink density was improved. When considering ink show-through with ink density together, appropriate ink density and low show-through can make high receptivity. As mentioned Fig. 2, ink density of 3% corn starch showed a similar trend. Hanji sized with PVA and AKD indicated lower inkjet ink density than base paper. Therefore, corn starch (3%) without calendering seems to be a suitable sizing agent to improve printability of inkjet ink.

Inkjet ink girth is illustrated in Fig. 3. In most case, the sizing agents tend to increase ink girth, when calendered. Accordingly, calendering process in inkjet printing is desirable to be avoided due to a significant increase of ink girth. On the one hand, Hanji sized with 0.1% AKD and 5% PVA showed highly improved ink girth but it is due to lower ink density than base paper. By way of it, sizing with PVA and AKD should be avoided. On the other hand, 2% corn starch with 0.5 kgf/㎠ showed the lowest ink girth with 3.64 cm. As mentioned above, 3% corn starch was a adequate agent related to ink density and ink show-through. However, the lowest spreading was by 2% corn starch with 0.5 kgf/㎠. Higher ink density, lower show-through and the

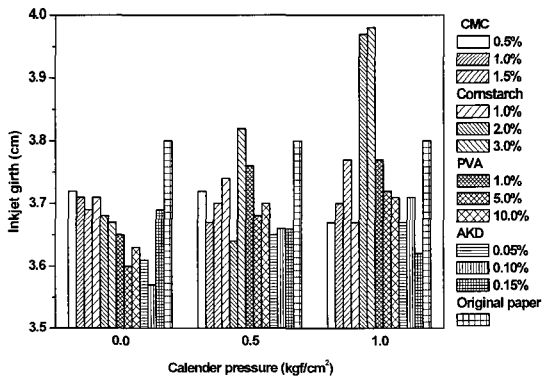

Fig. 3. Effect of inkjet ink girth.

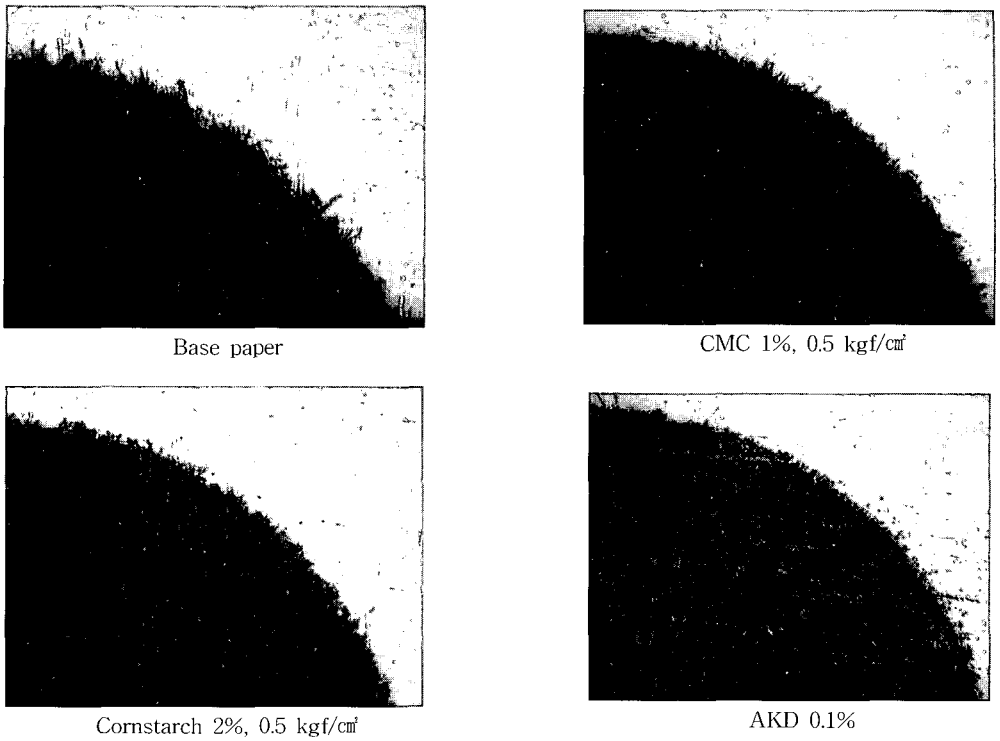

Fig. 4. Inkjet ink image analysis of sized and/or calendered Hanji.

lowest ink girth comparing to base paper can be pursued in case of printability. As a result, 2% corn starch with 0.5 kgf/㎠ of calender pressure can be considered as an appropriate sizing agent to improve inkjet ink printability of Hanji.

As shown above, 3 kinds of agents were effective agents on inkjet ink girth. Among them, 2% corn starch with 0.5 kgf/㎠ can be recommended for inkjet printing.

4. Conclusions

All the sizing agents improved the properties of Hanji to some extent through sizing without calendering. AKD increased sizing degree outstandingly. In case of printability, only AKD didn't improve surface strength called picking because of non-heating treatment. Nevertheless, AKD (0.1%) increased typography ink density and decreased its show-through. Corn starch (3%) improved inkjet ink density and its show-through. Ink girth was decreased by all the agents, particularly, PVA and AKD. But ink density of Hanji sized with PVA and AKD was lower than base paper.

As a calendering effect, low thickness, low air permeability and high density were observed. In addition, gloss, smoothness and roughness were improved. In case of printability, surface strength was completely improved by all the agents. Typography ink density and its show-through were highly revised by 0.1% AKD with 1 kgf/㎠, calender pressure. Corn starch (3%) with 0.5 kgf/㎠,

calender pressure, was maximum inkjet ink density. It also increased inkjet ink girth. Minimum of inkjet ink girth was by 0.1% AKD without calendering. But AKD made lower inkjet ink density than base paper and induced a low surface strength.

Printable Hanji is required to have not only better surface strength enough to appear non-picking, higher ink density and lower show-through than base paper but also the lowest ink girth in comparison with base paper. When referring to them, efficient sizing agents for printable Hanji were regarded as 0.1% AKD with 1 kgf/㎠ for typography printing and 2% corn starch with 0.5 kgf/㎠ for inkjet printing.

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