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Studies on the Printability Improvement of Hanji by Surface Sizing with Mixed Agents

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ABSTRACT

Many researches for extensive uses of Hanji have been performed. With the advent of an information-oriented age, the development of Hanji which is printable has been considered as a new field of study. Since Hanji has many drawbacks in comparison with common printing papers, that is, rougher surface, huger absorption of ink and lower physical properties and printabilities. Improving the properties and printabilities of Hanji is therefore the most important work to deal with. This study was conducted to find out useful mixed agents for surface sizing suitable for printable Hanji. Four surface sizing agents (CMC, corn starch, PVA, AKD) were applied for mixture in this study. The physical properties of surface sized Hanji were measured. Results obtained were as follows.

Based on designated agents according to concentration, each of the mixed agents was prepared. The kinds of mixture were corn starch (3%) and PVA (5%), corn starch (3%) and AKD (0.1%), corn starch (3%) and CMC (1%), AKD (0.1%) and CMC (1%), AKD (0.1%) and PVA (5%), CMC (1%) and PVA (5%). Each mixed surface sizing agents was included with these ratios (100:0, 90:10, 70:30, 50:50, 30:70, 10:90, 0:100) respectively. All the mixed agents improved the physical properties and printabilities of Hanji. Among them, mixed agent of CMC (1%) and corn starch (3%) with 90:10 ratio is superior to the others for not only smoothness but also ink printability. In view of the result achieved, it is regarded that it can be fit for using Hanji as a printing paper and turned out to be a good contribution to Hanji industry.

Keywords : Hanji, CMC, corn starch, PVA, AKD, surface sizing, printability

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1. Introduction

Hanji, Korean traditional paper, has been progressed with Korean history for a long time as a elegant paper. Hanji is known for its excellent quality, such as strength, whiteness and smoothness (1). In addition, its neutrium character induces a long periods of preservation properties (2). That was the most important part of recognizing Hanji as a world's paper. Moreover, Hanji has been used as painting paper, umbrella, and folding screen because it can represent a various quality and color in accordance with material, the method of manufacturing and usage. Based on its quality, beauty, rigidity and superiority, various useful researches have been performed (3~6).

Nevertheless, as Hanji industry is fallen into a depression with limiting demands, creating a new direction for use of Hanji is required to be suggested. The secondary processing is necessary for extensive use and high added value of Hanji to overcome the recent recession. And it is time for us to look around the world in order to find a new demand for Hanji industry. With appearance of world wide web, so much information was on the internet. It made papers more able to be printed from the computer. In the long run, printing papers are getting active. Accordingly, printable Hanji can be recognized as an new important demand to revive Hanji industry. For printable Hanji, properties of Hanji is required to be improved. Surface sizing can be an efficient way to improve paper's properties (7). Mixing one agent in the other can be considered as adapting to acquire complementary and increasing effect on properties of Hanji. It means when the agents are mixed, each agents form a continuous phase by inducing reaction (8). This reaction can lead an good effect on the improvement of the properties and the printability of Hanji. Accordingly, mixing one agent in the other can be considered as adapting to acquire a complementary effect in stead of calendering.

In this study, based on the previous results, with selected four agents by percent in prior paper (9) which is estimated to be effective on printable Hanji, six mixture of agents by four agents were applied to improve the low physical properties and the printabilities of Hanji by sizing on the surface of machine-made Hanji. Moreover, the possibility of printable Hanji was estimated.

2. Materials and Methods

2.1 Materials

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

2.2 Methods

2.2.1 Preparation of surface sizing agents and making mixed agents

The six mixed agents were dissolved with distilled water. Particularly, PVA was dissolved at 80℃ for 1 h, and corn starch was gelatinized at 95℃ for 30 h to increase its dissolution. The concentration of dissolved surface sizing agents was given in Table 1. Sizing on the surface of Hanji was performed using a coater (PI-1210, Sangyo, Japan) and its speed was 13 mm/sec. The sized Hanji was dried in a convection dryer at 50℃ for 10 min and utilized for estimation of

Table 1. Surface sizing agents and mixing ratios for making the mixed surface sizing agents

Surface sizing agents	Mixing ratios
CMC(1%) + Cornstarch(3%), (C/S) CMC(1%) + PVA(5%), (C/P) CMC(1%) + AKD(0.1%), (C/A) Corn starch(3%) + PVA(5%), (S/P) Corn starch(3%) + AKD(0.1%), (S/A) PVA(5%) + AKD(0.1%), (P/A)	100/0, 90/10, 70/30, 50/50, 30/70, 10/90, 0/100

various physical properties. And then, mixing ratios of the surface sizing agents are presented in Table 1.

2.2.2 Physical properties and printabilities of sized Hanji

The sized Hanji was put into a thermo-hygrostat (20±1℃, RH: 65.5%) for over 24 h. The physical properties such as pickup weight, sized thickness, brightness, density, gloss, smoothness, air permeability, roughness, opacity, surface sizing degree, color degree ($L^*a^*b^*$), surface strength and ink printabilities (typography ink density and its show-through, inkjet ink density and its show-through, and inkjet ink girth) were investigated to estimate the impact of the surface sizing agents. The measurement of ink girth was conducted using an image analyzer (BMI pus). Viscosity was measured by Viscometer (DV-II ++, Brookfield).

3. Results and Discussion

3.1 Physical properties of surface sized Hanji with mixed agents in CMC

CMC is a natural surface sizing agent and highly biodegradable. It is presently used as a paper modifying agent for water retention, gel formation, emulsifying and aroma retention (10). Accordingly, the physical properties of Hanji can be expected to be improved with the agent. Table 2 shows the results of physical properties of sized Hanji with the mixed agents (PVA (5%), AKD (0.1%) and corn starch (3%) in CMC (1%)).

3.1.1 Surface sizing agent mixing PVA in CMC

Viscosity of surface sizing agent with each ratios was reduced as PVA was added. Pickup weight, sized thickness were increased in these ranges, 3.6~4.0 g/m^2, 16.0~20.3 μm respectively. Density and brightness tend to be decreased slightly. Since calendering treatment was not applied, reduction of thickness wasn't observed. In case of gloss, it increased with increase in PVA ratio to some extent. Smoothness, known as an important factor for ink printability showed a good effect on 90:10 (C:P). Roughness and air permeability were reduced highly in 90:10 (C:P). Surface sizing degree was increased comparing with base Hanji but when the agents were mixed, the values were dropped. Values($L^*a^*b^*$) in color were rarely changed. In the long run, without changed color, the effective ratio for improvement of the physical properties of Hanji was considered as 90:10 (C:P). By mixing PVA in CMC, smoothness and roughness were improved relatively. Accordingly, PVA can be a effective agent for improvement of smoothness, roughness and air permeability in CMC.

3.1.2 Surface sizing agent mixing AKD in CMC

Viscosity of mixed agent was decreased because AKD had a very low viscosity. Pickup

weight and sized thickness were relatively uniform with 3.2~4.0 g/m^2 and 15.5~18.5 g/m^2. This mixed agent made the opacity low. Gloss and smoothness were good in the ratio of 70:30 (C:A). Roughness had the lowest value in that ratio like smoothness. Air permeability was also good on 70:30 (C:A) ratio. As reported paper (11) shows, AKD had a good impact on surface sizing degree. AKD can be considered as an important factor for surface sizing degree. L*a*b* values in color is little different from base Hanji. As a result, superior ratio of surface sizing agent with the mixture of AKD and CMC was estimated to be 70:30 (C:A).

3.1.3 Surface sizing agent mixed corn starch in CMC

Viscosity got increased in corn starch addition. Pickup weight was 3.6~4.0 g/m^2 and sized thickness was 16.2~19.4 μm in a similar trend. Density was slightly increased. Brightness was maintained without a huge difference from base one. Opacity was good in 90:10 (C:S) ratio. Gloss tends to be increased and maximum smoothness in 90:10 (C:S) ratio was expected to show a good printability. The ratio of 90:10 (C:S) ratio was considered to be a good agent for air permeability. Surface sizing degree was slightly increased. L*a*b* values was little altered. The results support that properties of Hanji were expected to be improved in the ratio of 90:10 (C:S) in case of mixing corn starch in CMC. Because adding corn starch to CMC brought a conspicuous smoothness and gloss, mixing cornstarch in CMC at the ratio of 90:10 (C:S) is suitable for improving smoothness and gloss.

3.2 Physical properties of surface sized Hanji with mixed agents in corn starch

Table 2. Properties of surface sized Hanji mixed PVA, AKD and corn starch in CMC

Properties / Surface sizing agents	Ratio (%)	Viscosity	Pickup weight (g/m^2)	Sized Thickness (μm)	Density (g/cm^3)	Brightness (%)	Opacity (%)	75° Gloss (%)	Smoothness (sec.)	Roughness (mℓ/min)	Air permeability (sec.)	Stöckigt sizing degree (sec.)	Color Degree L	a	b
Base Hanji	—	0	0	0	0.41	80.2	90.13	6.60	1.10	3458	5.4	0	93.95	1.19	4.22
CMC(1%) /PVA(5%)	100/0	8.4	3.4	16.6	0.41	80.2	92.04	6.75	1.43	1747	8.3	2.6	93.85	1.25	4.05
	90/10	7.9	3.8	18.5	0.40	80.1	91.12	6.89	1.46	1487	8.3	1.8	93.80	1.28	4.09
	70/30	8.2	4.0	20.8	0.40	80.2	91.59	6.98	1.35	2386	7.8	1.8	93.88	1.24	3.92
	50/50	8.6	3.5	16.0	0.40	80.5	91.32	7.13	1.36	2239	6.9	1.8	93.87	1.25	4.06
	30/70	8.5	3.6	18.2	0.40	80.2	90.80	6.94	1.29	2440	6.2	1.4	93.80	1.29	4.33
	10/90	7.1	4.1	20.6	0.41	79.8	91.90	6.69	1.28	2578	8.0	1.5	93.83	1.25	4.04
	0/100	5.1	3.6	17.6	0.40	79.8	91.35	6.83	1.20	2911	8.2	2.4	93.74	1.26	4.19
CMC(1%) /AKD(0.1%)	90/10	6.1	3.2	15.5	0.41	79.6	90.83	7.13	1.47	1705	8.5	3.0	93.70	1.16	4.37
	70/30	3.6	3.4	16.2	0.39	80.4	92.02	7.19	1.48	1649	11.3	5.4	93.84	1.33	3.88
	50/50	2.0	3.5	17.3	0.41	80.2	91.53	6.84	1.24	2715	7.4	15.8	93.77	1.22	3.93
	30/70	0.9	3.7	17.2	0.38	80.4	90.76	6.84	1.33	2408	6.3	16.3	93.84	1.29	3.88
	10/90	0.5	3.8	18.5	0.41	79.9	91.42	6.85	1.28	2519	8.1	25.9	93.81	1.18	4.28
	0/100	0.1	3.4	16.8	0.40	80.8	92.49	6.48	1.16	3223	6.9	70.6	93.88	1.15	4.28
CMC(1%) /Corn starch(3%)	90/10	8.6	3.6	16.5	0.43	80.0	92.91	6.98	1.68	1205	12.5	3.5	93.70	1.20	3.96
	70/30	8.1	3.6	16.2	0.42	79.6	92.24	6.88	1.45	1740	8.5	2.6	93.55	1.14	4.01
	50/50	165	4.0	18.8	0.41	80.5	91.15	6.94	1.50	1522	8.4	2.9	93.67	1.26	3.52
	30/70	225	3.6	16.1	0.42	79.8	91.01	7.21	1.59	1324	7.2	2.4	93.58	1.19	3.94
	10/90	300	3.9	19.0	0.41	80.0	91.09	7.34	1.55	1433	8.7	2.9	93.58	1.23	3.78
	0/100	9.4	4.0	19.4	0.42	79.9	92.08	7.64	1.45	1716	8.6	1.6	93.69	1.17	4.09

Corn starch is renowned for increasing paper strength and erasibility, ink hold out as well as a natural biodegradable agent (12~14).

Accordingly, corn starch can be treated as a effective agent for improving the physical properties of Hanji when mixing with other agents. The result of physical properties of sized Hanji with mixed agents is given Table 3.

3.2.1 Surface sizing agent mixed PVA in starch

Viscosity was decreased as PVA has a low concentration. Pickup weight in 3.6~4.5 g/m^2 describes that it is sized uniformly. Sized thickness was 17.6~19.8 μm. Density was slightly decreased by PVA addition. Brightness has little different from base Hanji. Opacity was highly increased in 90:10 (S:P) ratio. Smoothness in the ratio of 90:10 (S:P) was supreme with 1.52 value. Since roughness is related to smoothness, the ratio of 90:10 (S:P) was the lowest value. Air permeability was showed highly in 70:30 (S:P) mixing ratio. As a result, the ratio of 90:10 (S:P) can improve the physical properties of Hanji superiorly.

3.2.2 Surface sizing agent mixed AKD in corn starch

Viscosity decreased as AKD is added. Pickup weight and surface sizing thickness were 3.4~4.1 g/m^2 and 15.3~19.4 μm. Density was 0.41 g/cm^3 without a huge difference. Brightness was increased when the ratio of AKD was multiplied. Opacity tends to be increased slightly. In case of gloss, its value was reduced with increase of the ratio of AKD. Good result of smoothness was appeared in the ratio of 50:50 (S:A). Roughness was the same influence with smoothness. AKD was a main agent to increase surface sizing degree. L*a*b* values showed a similar trend to base Hanji. As a result, 50:50 (S:A) ratio of mixing AKD in corn starch is expected to improve the physical properties of Hanji. When AKD is added to corn starch with 50:50 (S:A) ratio, good effect can be estimated. On the other hand, in case of AKD and CMC mixture, 70:30 (C:A) mixing ratio offered similar results to AKD and corn starch mixture (50:50). Accordingly, AKD can be an useful agent with CMC for improvement of the physical properties of Hanji.

Table 3. Properties of surface sized Hanji mixing PVA and AKD in corn starch

Properties / Surface sizing agents	Ratio (%)	Viscosity	Pickup weight (g/m^2)	Sized Thickness (μm)	Density (g/cm^3)	Brightness (%)	Opacity (%)	75° Gloss (%)	Smoothness (sec.)	Roughness (mℓ/min)	Air permeability (sec.)	Stöckigt sizing degree (sec.)	Color Degree		
													L	a	b
Base Hanji	—	0	0	0	0.41	80.2	90.13	6.60	1.10	3458	5.4	0	93.95	1.19	4.22
Corn starch(3%) /PVA(5%)	100/0	9.4	4.0	19.4	0.42	79.9	92.08	7.64	1.45	1716	8.6	1.6	93.69	1.17	4.09
	90/10	6.3	4.6	19.8	0.42	79.8	92.45	7.46	1.52	1505	10.2	2.0	93.65	1.29	4.16
	70/30	2.7	4.5	19.5	0.42	79.8	92.42	7.29	1.43	1714	13.3	1.8	93.68	1.23	4.11
	50/50	2.3	4.1	18.6	0.40	80.6	90.37	6.73	1.33	2435	5.8	3.5	93.80	1.44	3.63
	30/70	2.3	4.0	18.2	0.39	80.8	91.24	6.64	1.29	2502	6.3	3.6	93.86	1.40	3.72
	10/90	3.0	3.8	17.8	0.41	80.7	91.26	6.73	1.15	3286	6.7	1.9	93.76	1.33	3.85
	0/100	5.1	3.6	17.6	0.40	79.8	91.35	6.83	1.23	2840	8.2	2.4	93.74	1.26	4.19
Corn starch(3%) /AKD(0.1%)	90/10	7.4	3.8	16.4	0.42	80.3	92.07	7.55	1.45	1714	9.9	6.3	93.88	1.15	4.07
	70/30	2.3	3.4	15.3	0.41	80.4	91.70	7.43	1.47	1709	8.6	8.1	93.79	1.21	3.88
	50/50	2.9	4.0	17.2	0.40	80.3	91.52	6.76	1.50	1535	7.3	9.6	93.78	1.29	3.90
	30/70	0.8	3.4	15.8	0.41	80.4	91.65	6.75	1.39	2018	8.5	24.8	93.90	1.22	4.06
	10/90	0.2	4.1	17.5	0.40	80.8	92.04	6.26	1.26	2691	7.2	29.0	93.99	1.16	3.90
	0/100	0.1	3.4	16.8	0.40	80.8	92.49	6.48	1.16	3223	6.9	70.6	93.88	1.15	4.28

Table 4. Properties of surface sized Hanji mixing AKD in PVA

Properties / Surface sizing agents	Ratio (%)	Viscosity	Pickup weight (g/m²)	Sized Thickness (μm)	Density (g/cm³)	Brightness (%)	Opacity (%)	75° Gloss (%)	Smoothness (sec.)	Roughness (mℓ/min)	Air permeability (sec.)	Stöckigt sizing degree (sec.)	Color Degree L	a	b
Base Hanji	—	0	0	0	0.41	80.2	90.13	6.60	1.10	3458	5.4	0	93.95	1.19	4.22
PVA(5%) /AKD(0.1%)	100/0	5.1	3.6	17.6	0.40	79.8	91.35	6.83	1.23	2840	8.2	2.4	93.74	1.26	4.19
	90/10	3.0	3.6	17.4	0.42	80.2	91.43	6.83	1.23	2862	5.7	2.8	93.68	1.37	3.78
	70/30	1.6	3.9	19.4	0.39	80.4	90.90	6.55	1.27	2685	6.4	3.6	93.78	1.37	3.81
	50/50	0.9	3.6	17.6	0.42	80.6	90.91	6.50	1.16	3231	6.8	6.1	93.76	1.35	3.59
	30/70	0.6	4.1	19.6	0.41	80.8	91.63	6.40	1.20	2989	7.0	7.9	93.96	1.30	3.79
	10/90	0.3	3.4	16.5	0.39	80.5	90.87	6.58	1.19	3103	5.7	28.4	93.87	1.29	3.84
	0/100	0.1	3.4	16.8	0.40	80.8	92.49	6.48	1.16	3223	6.9	70.6	93.88	1.15	4.28

3.3 Surface sizing agent mixing AKD in PVA

Viscosity was decreased with increase in AKD. Pickup weight and sized thickness were 3.4~4.1 g/m², 16.5~19.6 μm respectively. Density and brightness had a same result with base Hanji. Opacity was increased slightly and gloss tend to be reduced except for the ratio of 90:10 (P:A). Smoothness is superior to the other agents in the ratio of 70:30 (P:A). Roughness was same trend with smoothness. Air permeability was best in the ratio of 90:10 (P:A), 10:90 (P:A). In case of surface sizing degree, as amount of AKD was increased, the values were elevated. Any improvements of $L^*a^*b^*$ value in color couldn't be expected. Although smoothness was high in the ratio 70:30 (P:A), the value was low comparing to the result by other agents. As a result, the small revision of the physical properties of Hanji through mixing AKD in PVA with 70:30 (P:A) can be anticipated. But when considering the economical efficiency, comparing with other agents, it is not desirous to mix AKD in PVA because of their low improvement.

3.4 Printability of surface sized Hanji with mixed agents

Typography ink density is given in Fig. 1. The majority of mixed agents showed a low density in comparison with base Hanji because all surface sizing agents revealed surface sizing effect. Since AKD mixing is superior to other mixed agents, it is estimated to show the lowest ink density. Furthermore, CMC and corn starch revealed the

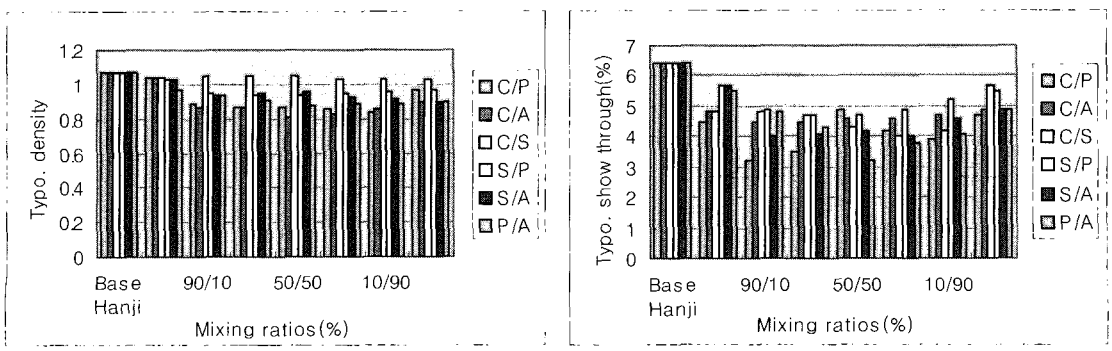

Fig. 1. Effect of typography ink density and its show-through.

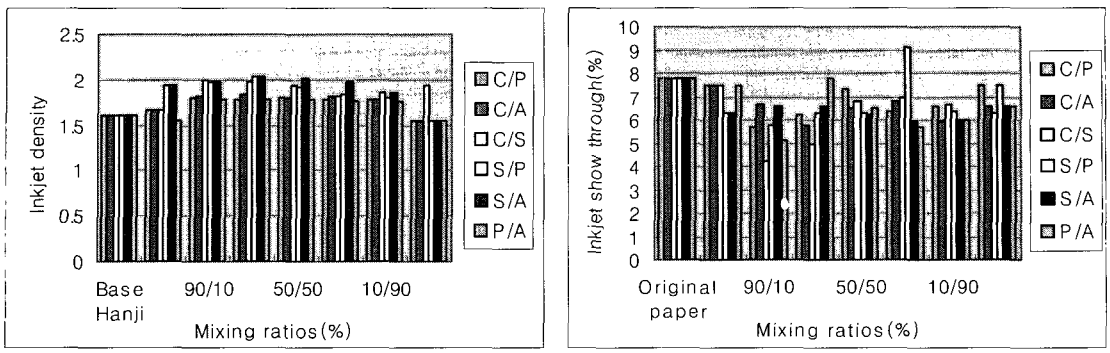

Fig. 2. Effect of inkjet ink density and its show-through.

low surface sizing effect as a natural surface sizing agents. In spite of the low ink density values, the agents mixing corn starch in CMC were higher than other agents. Accordingly, adequate mixing ratio is required to be adapted based on mixing corn starch in CMC. Fig. 1 also shows also typography ink show-through. Show-through is generally affected by thickness. Thickness was uniform in the range of 0.21 ~ 0.25 mm because machined-Hanji was used in this study. The agent mixing PVA in CMC in the ratio of 90:10 (P:C) indicates a good result in show-through. As a result, Hanji with those surface sizing agents is not considered suitable for typography printing paper because typography ink is made up of vehicles including oil and the oily components disturb the combination between surface sizing agents and Hanji (15).

Inkjet ink density is shown in Fig. 2. All mixed surface sizing agents improved the ink density of Hanji. Unlike typography ink, inkjet ink which increases water-soluble vehicle increases ink density during sizing treatment on the surface of Hanji (16). As Fig. 2 is represented, C/S, S/P, S/A among all agents are on high values in comparison with base Hanji. Corn starch is involved in them respectively. Accordingly, corn starch is estimated to be a good agent to improve the inkjet ink density of Hanji. Mixture of corn starch in CMC with the ratio of 70:30 (C:S) made inkjet ink density higher than any other mixed agents with 2.030 value. Inkjet ink show-through is given in Fig. 4. In case of show-through, mixing corn starch in CMC with the ratio of 90:10 (C:S) was a excellent result. Ink density and ink show-through are related to ink receptibity. When ink density is high and ink show-through is low, ink receptibity is investigated high. Appropriate ink density more than base Hanji and low show-through are necessary to improve the printability of Hanji. Therefore, mixture of corn starch in CMC with the ratio of 90:10 (C:S) is regarded as a forceful mixed agent to revise the printability of Hanji. That is, inkjet printing paper is estimated to be necessary for surface sizing

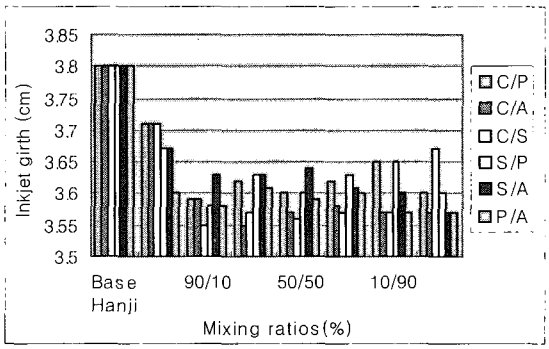

Fig. 3. Effect of Inkjet ink girth.

treatment with corn starch.

Fig. 3 indicates inkjet ink girth through inkjet printing. Girth which represents ink spreading is estimated to be good when the value is low. All kinds of surface sizing agents had a good result on the girth comparing to base Hanji. The lower ink spreading than any other agents was shown at the agent mixing corn starch in CMC. Especially, the value was the highest at the ratio of 90:10 (C:S). AKD gave counter-effect on inkjet ink density but a good effect on ink girth. When the method which can increase ink density is investigated, AKD can be estimated to be a good agent for inkjet ink girth. To make ink girth lowered, a proper coordination of corn starch and CMC is needed. Mixing corn starch in CMC with the ratio of 90:10 (C:S) can be considered as an effective agent for improving the ink girth of Hanji. In case of inkjet printing, because smoothness and gloss is important factor to impact on printability, mixing corn starch in CMC is assessed to be appropriate mixed agents for printable Hanji.

3.5 Image analysis of surface sized Hanji with mixed agents

Designated points were printed by inkjet printer. The printed point was measured by image analyzer to investigate the trend of ink spreading effect by surface sizing. The results were followed to Fig. 4.

As shown above, the agent mixing corn starch in CMC with the ratio of 90:10 (C:S) can be recommended for inkjet printing.

4. Conclusions

The physical properties and the printabilities of machine-made Hanji were evaluated and applied, in accordance with typography ink and inkjet ink. The results can be summarized below.

All kinds of mixed surface sizing agents improved the physical properties of Hanji to

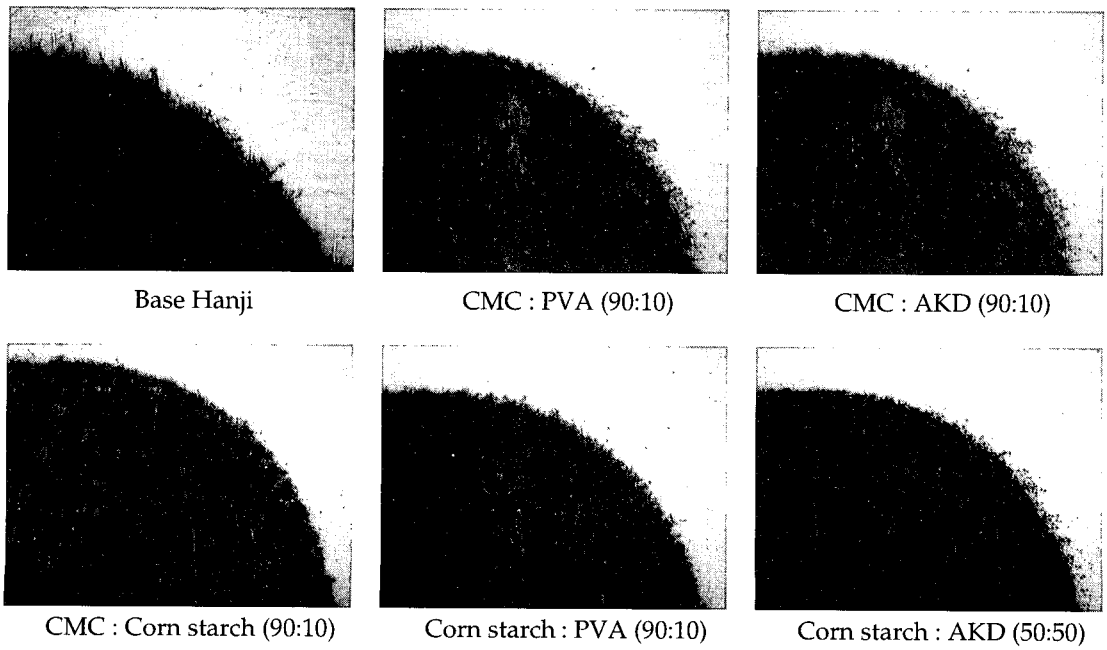

Fig. 4. Inkjet ink image analysis.

some extent. Among them, smoothness and roughness was showed at mixing corn starch in CMC and mixing AKD in corn starch separately. Surface sizing degree improved by AKD was a outstanding result. When checking ink printabilities out, in case of typography ink, ink density was reduced comparing with the base Hanji. Although show-through was good in that case, with the reason that ink density was low, typography ink can be taken into account affected by mixed agents. In case of inkjet ink, mixing corn starch in CMC with the ratio of 90:10 (C:S) showed maximum ink density and show-through. Besides, the same ratio of mixing corn starch in CMC also made an excellent result on ink girth. In conclusion, because proper ink density, low show-through and low girth including improved physical properties are necessarily required for printable Hanji, the agent mixing corn starch in CMC with the ratio of 90:10 (C:S) can be recommendable to promote the physical properties and the printability of Hanji.

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