Development of Wet-on-Wet Coating Method for Paper Coating

Akira Eguchi[*1] **Hiroto Jakunen**[*1]
Masahiro Sugihara[*1] **Mitsuo Yamamoto**[*2]
Yasuhisa Kodoi[*2]

The Wet-on-Wet double coating method for paper coating, in which the top coating layer is coated on the wet undercoating layer, has been developed. In this development, coating devices for each layer and the interval between under- and top-coating have been optimized. These optimizations enable two coater heads on one backup roll. Wet-on-Wet coating paper, which has employed the results of this research in its coating, shows qualities equal to those of conventional Wet-on-Dry coating paper. It has also been verified that this Wet-on-Wet method has reduced not only coater machine size but also its running costs.

1. Introduction

The paper coater is an apparatus for applying a water suspension whose solids are mainly composed of pigments (clay, calcium carbonate, etc.) to both surfaces of base paper for the purpose of improving the printing quality and appearance of paper.

To meet the recent need for high quality printing, double coating method is being established as a standard process[(1)], in which an undercoat layer (hereafter "underlayer") responsible for smoothing the base paper surface and bonding the coated layer to the base paper, and a topcoat layer (hereafter "top layer") responsible for improving the appearance and printability are applied four times in total on both surfaces of base paper. The conventional double coating is a so-called wet-on-dry process[(1)(2)], in which the underlayer is first applied and dried, and then the top layer is applied. This method requires four coating stations and dryers for both surfaces and involves increased costs and a troublesome operation, so it is hard to enhance the productivity and drying efficiency.

To solve the problems of such double coating, the top layer is applied directly on the underlayer in wet state, and both layers are dried at the same time. This is known as the wet-on-wet coating method. Hitherto, this method was believed to be unsuitable for high-speed coating of coated paper and the like, because the top layer cannot be applied until the solids content in the undercoat layer is raised by penetration to achieve complete immobilization[(2)].

We made clear from the elementary and pilot tests that prevention of mixing between the top- and undercoat layers, which is a major technical problem with the wet-on-wet coating method, is possible by optimizing the coating method of both layers and the time interval of forming the two layers[(3)]. It was also confirmed that the wet-on-wet coating method produces the paper that is equivalent to or better than that from conventional wet-on-dry coating at 1 200 m/min with simple equipment and easier operation.

2. Wet-on-wet coating method

Fig. 1 shows an outline of a single-side coating apparatus by the wet-on-wet coating method developed in this study. Two sets of short-time dwell coater (SDC) heads are installed along a backup roll. The coater head in the upper stream of the paper path is used for underlayer coating, and the downstream coater head for top layer coating.

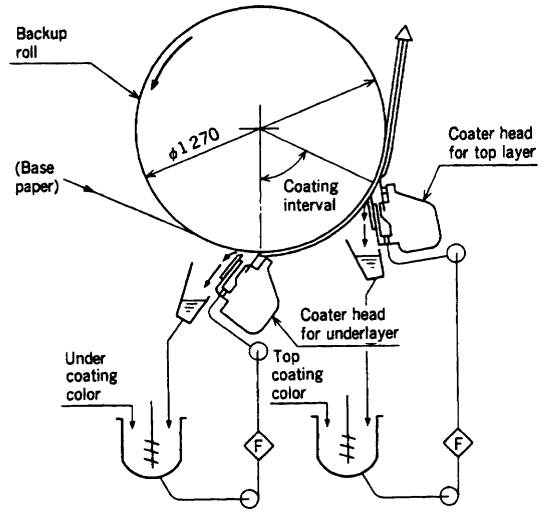

Fig. 1 Wet-on-wet coater station
One backup roll comprises two coater heads for the underlayer and top layer respectively.

Fig. 2 shows the specification of the blades mounted on the coater heads and an outline of the coating method. In the diagram, α denotes the blade angle, and β is the loading angle. In this coating method, the beveled blade method is employed for coating the underlayer, and the bent blade method for coating the top layer. According to the hydrodynamic lubrication theory, the following effects are expected in high-speed coating with individually chosen blade methods for the under and top layer coating[(4)].

(1) In the beveled blade, high fluid lubrication pressure occurs at the leading edge, and the coating color penetrates into the base paper sufficiently. Accordingly, the solids content and apparent viscosity of underlayer coating color increase after passing the blade, which suppresses the mixing between the top and under layers in the top layer coating process[(5)].

(2) The bent blade in the top layer coating allows smooth flow, which also supress the mixing.

Coating weight can be controlled in the same manner as in the conventional blade coating operation[(4)]. That is,

Beveled blade (for underlayer) :

Loading force applied to the blade tip W is controlled by changing the loading angle β.

*1 Hiroshima Research & Development Center, Technical Headquarters
*2 Mihara Machinery Works

Table 1 Experimental conditions

Condition	Test apparatus	Coating method	Coating speed (m/min)	Coating interval (ms)	Blade condition (top/under)		
					Thickness (mm)	Blade angle α (°)	Stick out (mm)
F 1	Elementary	Wet-on-wet	150	160	0.3/0.5	30/30	10/5
F 2	Elementary	Wet-on-wet	150	80	0.3/0.5	30/30	10/5
F 3	Elementary	Wet-on-dry	150		0.3/0.5	30/30	10/5
F 4	Elementary	Single	150		0.3/0.5	30/30	10/5
P 1	Pilot	Wet-on-wet	515	80	0.38/0.5	90/40	20/16
P 2	Pilot	Wet-on-wet	670	62	0.38/0.5	90/40	20/16
P 3	Pilot	Wet-on-wet	1 200	50	0.38/0.5	90/40	20/16
P 4	Pilot	Wet-on-wet	1 070	45	0.38/0.5	90/40	20/16
P 5	Pilot	Wet-on-dry	1 070		0.38/0.5	90/40	20/16

Note: The blade length in the pilot test is 86 mm for the top and 55 mm for the underlayer; in elementary test, 55 mm for both.

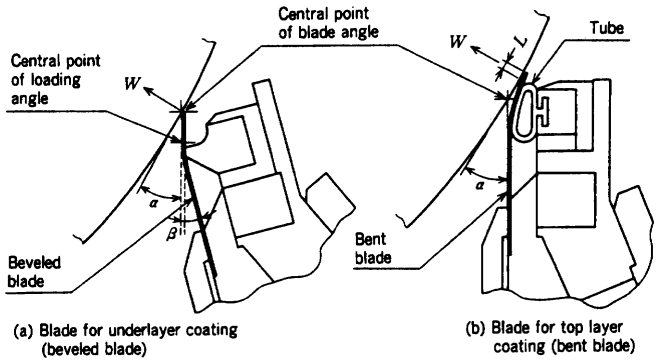

Fig. 2 Specification of coater blade
Beveled blade (a) is used for the underlayer, and bent blade (b) for the top layer.

Bent blade (for top layer) :

Contact length L of the blade tip region is controlled by changing the blade angle α or tube pressure.

3. Apparatus and experimental method

3.1 Experimental apparatus

Major specifications of the experimental apparatus used in this study (elementary test machine, pilot test machine) are as follows:

- Elementary test machine
  - Coating speed : up to 150 m/min
  - Coating width : 0.2 m
  - Coating time intervals : 80 to 160 ms
- Pilot test machine
  - Coating speed : up to 1 800 m/min
  - Max. coating width : 1.2 m
  - Coating time intervals : 40 to 80 ms

3.2 Test conditions

The experimental conditions are shown in **Table 1**. The dry coating weight is 7 g/m² for the underlayer and 8 g/m² for the top layer in both the elementary test and the pilot test.

The specifications of the base paper test were a basis weight of 64.7 g/m², caliper of 0.078 mm, Bekk smoothness of 18 s, and St kigt size of 15 s.

3.3 Experimental method

The coating procedure of the wet-on-wet coating is described below. In ordinary coating, the blade contacts the base paper first and then the coating color is applied. This order is employed in the wet-on-wet coating. In addition, at the start up of coating , the top layers has to be coated first and then underlayer. This start-up order prevents such as "scratch" or "streak" phenomenon that may be caused by the "over rubbing" and "shear thickening" of underlayer.

In this experiment, the proper underlayer coating conditions were determined by some preliminary tests. Additionally, on the pilot coater, it is possible to monitor the coating weight of underlayer with the BM type β-ray absorption coat weight meter.

Table 2 Evaluation items and methods

Evaluation method	Evaluation item	Method	Test conditions	
			Elementary	Pilot
Cross sectional view	Mixing between layers	Microscope observation of cross-section of paper embedded in resin	○	○
Bekk smoothness	Surface smoothness of coated paper	Passing time of specific air volume between surface of coated paper and mirror-surface polished plane metal plate under a certain pressure	○	○
Dry pick	Adhesion strength of coated paper surface	Degree of surface picking of coated paper when printing ink is applied by rubber roller to a dry surface of coated paper.		○
Wet pick	Adhesion strength of coated paper in offset printing	Degree of surface picking of coated paper when printing ink is applied by rubber roller to the surface of coated paper damper with a specific volume of water.		○
Printing quality	Printability of coated paper	Visual evaluation of actual color printing		○

3.4 Methods of evaluation

Table 2 shows the evaluation methods of coated samples [6]. All samples presented for evaluation were calendered by a soft nip calender.

4. Experimental results

4.1 Mixing of coated layers

Fig. 3 shows a cross-section micrograph of the wet-on-wet coated sample obtained in this experiment. Mixing of the top layer is hardly observed. This results may be caused by both the increase in underlayer color concentration during the underlayer coating and smooth flow of the coating color in the top layer with bent blade. In addition, the surface of wet-on-

Fig. 3 Cross-sectional view of the wet-on-wet coated layer
Mixing of underlayer and top layer is hardly observed.

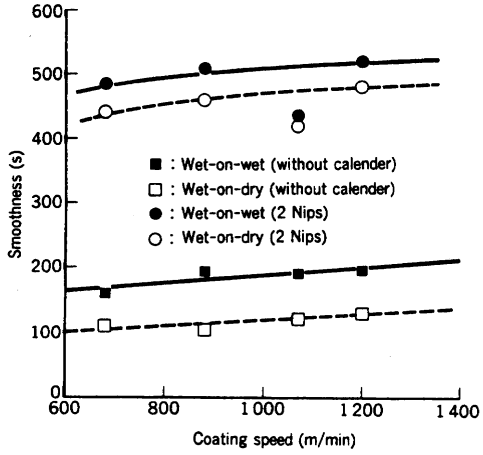

Fig. 4 Smoothness of coated paper surface
Smoothness of surface of paper coated by wet-on-wet method is equivalent or superior to that by the wet-on-dry method.

wet coated paper was free of coating defects, such as exposure of base paper fiber.

4.2 Smoothness of the coated paper surface

Fig. 4 shows the smoothness of the coated paper surface measured by the Bekk smoothness meter. In the figure, the vertical axis represents the required time for a specific volume of air to flow between the surface of the coated paper and the highly polished plane metal plate under a certain pressure. In this figure, a larger value means a higher smoothness.

The experimental results showed the smoothness of the samples coated by the wet-on-wet method to be equivalent or higher than that of the samples coated by the wet-on-dry method.

4.3 Surface strength

Fig. 5 shows the dry pick. The vertical axis represents the degree of picking (peeling-off) of the coated paper surface when the ink is applied to the dry surface using RI tester. Large value of vertical axis means easier peel off. In Fig. 5, there was no apparent difference between the wet-on-wet method and the wet-on-dry method, but in the wet-on-wet coating. Best dry pick value can be seen at a coating interval of 62×10^{-3} s between the underlayer to top layer. As a result, the optimum interval between the underlayer coating and top layer coating is around 50 to 62×10^{-3} s.

Fig. 6 shows the wet pick. In this measurement, the coated paper surface is damped. The meaning of the vertical axis is

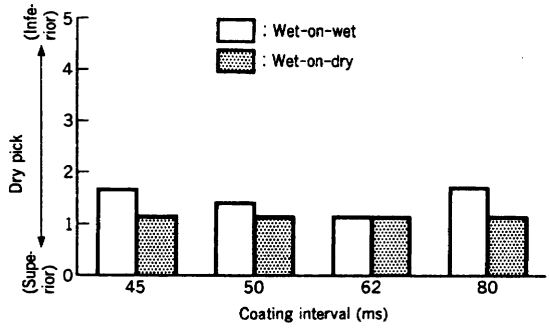

Fig. 5 Evaluation of dry pick
Both coating methods are similar in dry pick.

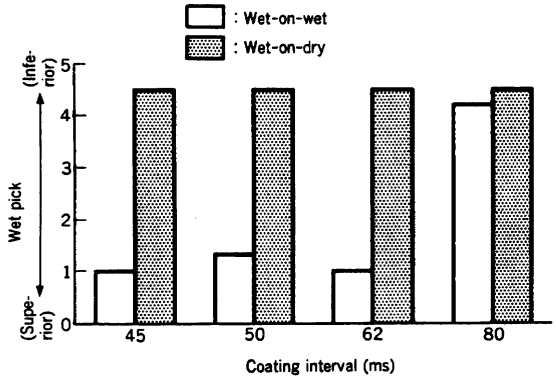

Fig. 6 Evaluation of wet pick
Wet-on-wet method is superior in wet pick.

Table 3 Evaluation of printing qualities

Evaluation item	Wet-on-wet	Wet-on-dry
Dot reproduction	4.3	4.4
Contrast	4.4	4.4
Trapping in multi color printing	4.4	4.4
Unevenness of ink receptivity	4.3	4.4
Gloss	4.3	4.3
Evenness of solid, difference between sides, etc.	4.4	4.5
Overall evaluation	4.4	4.4

(Tested at Printing Engineering Center)

the same as that of Fig. 5. The wet-on-wet method is obviously better in wet pick than the wet-on-dry method.

4.4 Printing quality

Table 3 shows the evaluation of the print quality in actual printing. Among the evaluation items, "trapping in multi color printing" is evaluated from the tone of picture after two different color inks are overlayed. "Evenness of solid" is measured from the density in the solid area. In the table, the highest score is 5.0.

As a result of the evaluation, the printing quality of the coated paper by the wet-on-wet method was confirmed to be equivalent to or better than that by the wet-on-dry method.

5. Machine layout

The layout of a typical wet-on-wet coater is shown in **Fig. 7** in comparison with a conventional wet-on-dry coater (four-station system).

In the layout of wet-on-dry method, two units of a backup roll and a coater head (coating unit) are provided for each