A European view of the use of pigments at the size press

David F. Bailey and Richard Bown

Pigment addition at the size press can reduce porosity, and specialty pigments can improve brightness and opacity, but improvements in smoothness, paper gloss, and print gloss are relatively poor.

The size press has been used to apply pigment to the surface of paper for many years. In reviewing size press coating in 1970, Grant (*1*) indicated that much of the coated paper in Europe was produced using either standard size presses or coaters developed from the size press. Now the use of more sophisticated coaters and the demand for higher quality have restricted the use of the size press in the production of conventional coated papers to the precoating of woodfree papers. The size press or modified size press, however, is being used in some woodfree paper mills to produce lightly coated matte papers for offset printing, or simply to add pigment to improve certain properties of conventional uncoated woodfree paper.

Some major limitations of the size press for conventional coating are that the coating speed is limited, coatweights greater than about 15 g/m^2 total (i.e., about 8 g/m^2 per side) are difficult to apply, and it is impossible to control independently the amount of pigment added to each side of the paper. Film-split marking is a common problem. Also, for a given coatweight applied, the actual amount of pigment forming a coating on the paper surface is much less than that obtained, for example, by using a blade coater.

Recent developments of the conventional two-roll size press (*2*), such as large-diameter rolls, allow speeds up to 900 m/min. In practice, speeds below 700 m/min are more typical for pigment addition. New bar and blade metering systems for size presses (*3*, *4*) allow higher speeds and, like the multiple-roll systems for pigment application, potentially allow better control of coatweight and somewhat higher solids content of coating color. This improves coverage of the paper surface by the pigment, but the total coatweight is still limited.

For the addition of pigments in amounts up to 10 g/m^2 total, the size press still has many advantages. Most woodfree paper machines are fitted with size presses to add starch or other chemicals. Pigments may be added to the size press solution with relatively little modification of the formulation. The solids content of the coating color for a size press is low compared with that used for conventional blade coating, for example, and the rheology is controlled by properties of the binders present. While this is a disadvantage for coating coverage, it is an advantage in that the pigment-water rheology is relatively unimportant, allowing practically any pigment to be added.

In this paper the practical aspects of pigment addition at the size press are briefly discussed, and results from pilot-scale and commercial-scale trials are given to illustrate the improvements in paper quality that may be obtained. The emphasis is on the use of the size press as a sole means of adding pigment, rather than on the use for precoating.

Practical aspects

Base paper

In any coating operation, the quality of the base paper is very important. This also applies for pigment addition at the size press. Even formation and uniformity of water-absorption properties across the sheet are essential. The base paper must be evenly sized and preferably hard sized to reduce fluid uptake. The moisture content to give maximum pickup at the size press is about 7-8% by weight, but lower moisture contents of about 3% by weight are preferred to reduce wet-streaking (*5*).

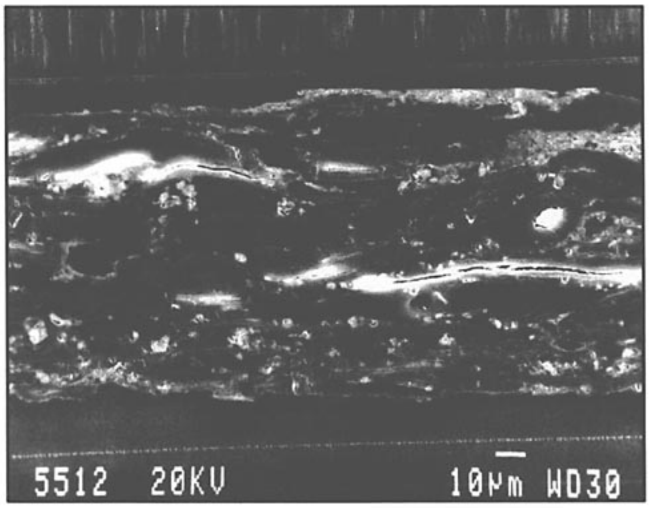
Finally, the paper should have an even filler distribution. It is impossible to control pickup independently on each side of the paper, and frequently the two-sidedness caused by uneven filler distribution is increased, rather than reduced, by pigment addition at the size press.

Layout

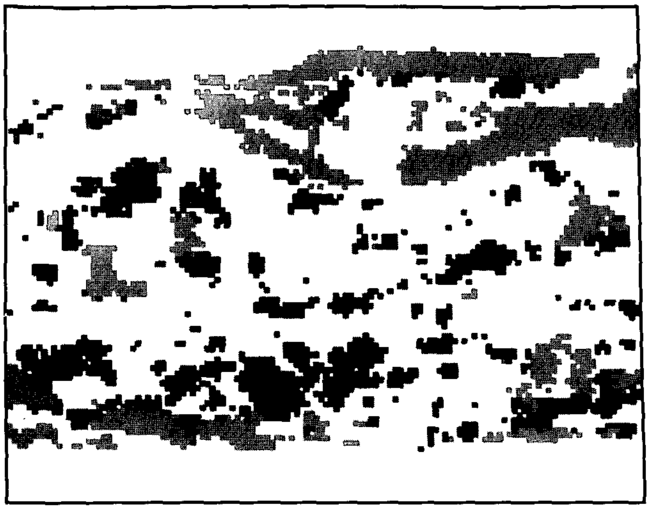
The size press itself should be set up so that the paper passes through with minimal roll-wrap (i.e., minimum contact with the rollers). This reduces film-split marking and turbulence problems. The distance between the size press and the dryer rollers should be such as to allow the coating to set sufficiently to prevent pigment sticking to the rollers. This is a major cause of dusting. Ideally, an infrared dryer after the size press should be used, particularly at higher speeds. Lower temperatures on the

Bailey is regional technical service manager and Bown is deputy research manager for the research department, ECC International Ltd., John Keay House, St. Austell, Cornwall PL25 4DJ, United Kingdom.

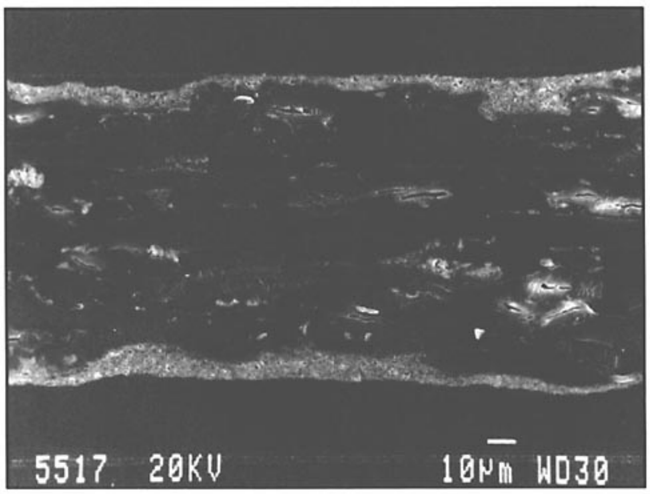
1. Electron micrograph of a cross section from a commercial sheet coated with kaolin at the size press and containing a calcium carbonate filler



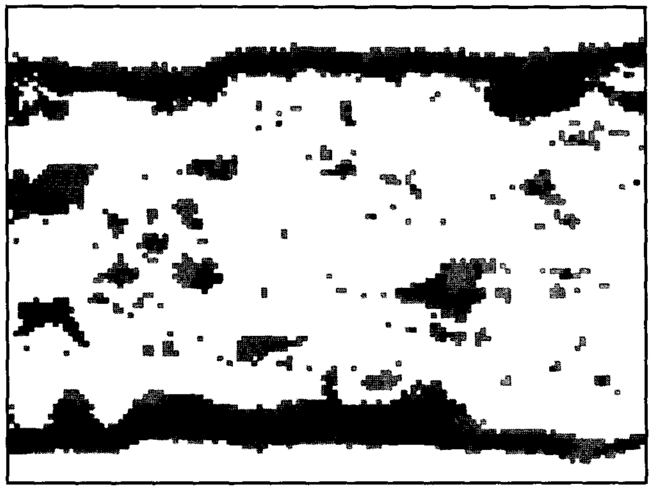
2. Mineralogical map through thickness of paper for cross section shown in Fig. 1. Light gray areas indicate predominantly kaolin and dark gray areas indicate predominantly calcium carbonate



3. Electron micrograph of a cross section from a sheet coated with a trailing blade coater



4. Mineralogical map through thickness of paper for cross section shown in Fig. 3. Light gray areas indicate predominantly kaolin and dark gray areas indicate predominantly calcium carbonate



first and second dryer rolls (e.g., 70° and 85°C, respectively) may also be required.

Coating colors

Size press coating colors generally have a pigment-to-binder ratio of less than 3:1 and a solids content of less than 50% by weight. Rheological properties are important for general runnability. Film-split marking is probably the most serious problem.

Film-split marking has been studied in detail (*6–10*). The major conclusions are that the problem is reduced by using thixotropic binders. The leveling index, or ratio of degree of thixotropy to high-shear viscosity, must be as great as possible. This is generally achieved by using starch ethers or esters and by adding flow modifiers, such as alginates, hydroxethyl cellulose, or carboxymethyl cellulose.

A typical coating color would be 100 parts pigment, 40 parts medium-viscosity starch ether or ester, 1 part cross linker, and 0.5 part calcium stearate.

As shown by various studies (*11, 12*), the coatweight achieved is dependent on the base paper, machine speed, viscosity, and pigment content. For a given base paper and speed, the pigment content of the coating color usually determines the coatweight. For example, a pigment content of about 20% by weight gives a total coatweight of 6–8 g/m^2, whereas a pigment content of 40% by weight is required for a total coatweight of about 15 g/m^2.

Discussion of paper properties

Distribution of coating through the sheet

Figure 1 shows an electron micrograph of a cross section from a commercial sheet coated with kaolin at the size press and containing a calcium carbonate filler. **Figure 2**, showing the distribution of kaolin and calcium carbonate over the same cross section, was obtained by energy-dispersive X-ray analysis in the microscope (*13*). It can be seen that the kaolin added at the size press has penetrated deep into the body of the sheet.

For this sheet, the amount of kaolin added was about

16 g/m^2 total or 8 g/m^2 per side, and the machine speed was about 300 m/min. Similar pigment distributions are seen for all papers coated at the size press. The penetration of the pigment is a result of pressure in the nip and the relatively low solids content of the coating color.

Figures 3 and 4 by contrast show a similar analysis of a sheet coated using a trailing blade coater at 1000 m/min. In this case, the coating pigment is calcium carbonate and the filler is a mixture of calcium carbonate from coating broke and kaolin. The coating can be clearly seen on the paper surface, and penetration into the sheet is limited. This is typical of coatings applied by a blade coater and is primarily due to the higher solids content of the coating color.

The penetration of the pigment into the sheet obviously reduces any effect that pigment addition at the size press may have on surface properties of the paper. Surface roughening, reduction in light-scattering coefficient, and other effects caused by the relatively large amounts of water and binder used at the size press also can have a deleterious effect.

Smoothness and printing properties

Table I gives results from pilot trials in which a typical starch solution with and without pigment was applied at a conventional size press to a standard woodfree paper.

The starch solution alone roughens the sheet. The addition of a pigment marginally reduces the roughness, but the roughening caused by absorption of water by the fibers dominates any effect of the pigment. In this trial, calcined clay appeared to give the greatest reduction in roughness. An addition of about 5 g/m^2 was sufficient to reduce the roughness to that of the sheet before any size press treatment.

Table II gives some data from commercial-scale trials. Direct comparisons between various size press additions are limited, but the results are in general agreement with those from the pilot trials.

Pigment addition reduces roughness marginally compared with that for sheets treated with a starch solution only, but in general the sheets remain rougher than the sheet before any size press treatment.

Similarly, pigment added at the size press gives only marginal improvements either in paper gloss or in print gloss.

Table III shows a typical commercial-scale comparison between similar woodfree papers coated either by size press or by a blade coater to give about 8 g/m^2 coating per side (total about 16 g/m^2) and machine finished. The blade-coated paper has a smoother surface and gives a much higher print gloss. This again is indicative of the poor surface coverage of the sheet achieved by size press coating.

Despite the relatively poor improvements in surface properties achieved by size press pigment addition, the improvements coupled with the reduction in sheet porosity are sufficient to enhance greatly the visual appearance of the printed sheet (contrast, image definition, etc.). This adds value to the paper.

Porosity

Pigment addition at the size press reduces sheet porosity (see Table I). The effect is marginally greater for platy pigments, such as European kaolin, than for blocky pigments, such as calcium carbonate or titanium dioxide. However, the dominant effect is the amount of pigment added. Although not given here, the results for commercial sheets confirm those for the pilot sheets.

Paper strength

The size press without pigment is generally used to increase the burst and tensile strength of woodfree papers. The addition of pigment in amounts up to a total of 6 g/m^2 has little detrimental effect on strength properties per unit fiber weight, but marginally reduces strength properties per unit sheet weight. **Table IV** gives the results for burst strength from the pilot trial. Similar results are seen for tensile strength.

The size press is therefore a convenient technique for adding small amounts of pigment to increase the ash content of papers without serious effects on sheet strength. This is particularly relevant for specialty pigments such as calcined clay or titanium dioxide, which may be added for optical properties but which are known to be detrimental to sheet strength when used as a filler.

In subsequent trials, strength properties such as rigidity and IGT pick have been measured. Again, there were no serious reductions in strength at pigment additions below 6 g/m^2.

Optical properties

Pigments are frequently used, either as fillers or components in a coating, to improve sheet brightness or opacity. The effect of the pigment can be described in terms of a light-scattering coefficient and an absorption coefficient for the pigment in the sheet. The light-scattering coefficient in a woodfree paper system is normally greatest if the pigment is added at the wet end as a filler. In this case, the pigment particles disrupt fiber bonds and interact with fibrils (*14*). This increases the overall light-scattering coefficient of the system, and the increase is generally attributed to the pigment. The light-scattering coefficient is least when the pigment is present in a separate coating layer embedded in a binder.

Pigments added at the size press generally show light-scattering coefficients lying between those obtained for pigments applied by blade coating, for example, and those obtained for pigments added as fillers. This assumes that the light-scattering coefficient of pigment at the size press is assessed by comparison with a sheet treated in the normal way at the size press but without pigment addition. There is, of course, some variation in results depending on the amount and type of binder or fiber conditions in the sheet. **Table V** gives the range of light-scattering coefficients obtained for typical pigments in woodfree paper systems.

The light-absorption coefficient is not affected by the method of pigment addition.

Table I includes the brightness and opacity results for the pilot trials. The addition of starch alone reduces the light-scattering coefficient of the sheet and hence the brightness and opacity. Compared with the addition of starch alone, addition of 6 g/m^2 of a filler kaolin at the size press has no effect on brightness but increases opacity by 2 points. Addition of a coating kaolin at the same level improves brightness by 1 point but gives no further

I. Data for pilot trails

Pigment added at size press	Total pigment added at size press, g/m²	Parker print smoothness (10 kg), µm	Bendtsen porosity, mL/min	Brightness	Opacity (60 g/m²)	Burst index
European coating kaolin	6	6.6	270	80.4	84.5	22
European filler kaolin	6	6.6	210	79.5	84.3	22
U.S. calcined kaolin	1.5	6.5	570	80.4	83.4	24
	3.0	6.3	460	81.1	84.5	23
	4.5	6.2	300	82.1	85.7	24
Titanium dioxide (anatase)	1.5	6.7	750	81.5	84.8	25
	3.0	6.7	770	82.6	86.4	24
	4.5	6.5	690	83.7	86.9	24
Fine ground marble	6	6.7	400	81.4	83.8	23
Size press starch solution only	...	6.8	910	79.5	82.4	25
No size press	...	6.2	1030	80.7	85.1	12

II. Smoothness data for commercial-scale trials with fine papers, starch-based formulations, and machine speeds of approximately 300 m/min

Pigment added at size press	Total pigment added at size press, g/m²	Parker print smoothness (10 kg), µm
Series 1 (no calendering, 100 g/m²)		
European kaolin	15	7.3
None (starch only)	0	7.6
Series 2 (machine calendered, hard rolls, 90 g/m²)		
European kaolin	14	5.3
	18	5.3
Fine ground marble	15	5.3
None (starch only)	0	5.7
Series 3 (machine calendered, soft roll, g/m²)		
European kaolin	6	3.2
No size press	...	2.6

III. Comparison of commercial-scale trials for size press and blade-coated papers with total coatweight of approximately 16 g/m² of European kaolin. Paper was machine calendered (hard rolls)

	Size press	Blade coated
Parker print smoothness (10 kg), µm	5.4	4.0
Paper gloss (75° TAPPI)	10	12
Print gloss (75° TAPPI)	18	40
Print density	1.14	1.36

increase in opacity. Addition of a high-brightness marble gives a greater increase in brightness, but the increase in opacity is not as great because the brightness increase is a result of a reduction in the light-absorption coefficient of the sheet.

The addition of conventional filler and coating pigments, therefore, gives some improvement in optical properties and compensates for the detrimental effects of the addition of a binder alone at the size press.

The addition of specialty pigments obviously gives much greater improvements in brightness and opacity. Compared with the sheet after starch addition alone, the addition of 4.5 g/m² of a calcined kaolin increases brightness and opacity by 2.5 points and 3 points, respectively. A similar addition of titanium dioxide (anatase) increases brightness and opacity by 4 points and 4.5 points, respectively.

Table VI shows data from two commercial-scale trials. The improvements in brightness and opacity compared with an untreated sheet (in the first series) and a sheet treated with starch only (in the second series) are in general agreement with data from the pilot trials.

Experimental details of pilot trials

Pigments used in the pilot trials are listed in **Table VII**

The standard size press color was 8% by weight oxidized starch solution, with a pigment-to-starch ratio of 0.5–2.0:1.

The base paper was typical woodfree paper: 60% hardwood kraft and 40% softwood kraft (alkaline sized,

IV. Burst strength data from pilot trials

Pigment	*Total pigment added to sheet at size press, g/m²*	*Burst index (per gram fiber weight)*	*Burst index (per gram sheet weight)*
European kaolin	6	33	22
U.S. calcined kaolin	4.5	35	24
Titanium dioxide	4.5	35	24
Fine ground marble	6	34	23
Size press	Starch solution only	33	25
No size press		15	12

V. Light-scattering coefficients (457 nm) for typical pigments

	Uncalendered coating film,[a] m²/kg	*Size press addition,[b] m²/kg*	*Filler,[c] m²/kg*
European coating kaolin	120-150	130-160	180-220
European filler kaolin	80-100	90-120	120-160
Calcined U.S. clay	200-240	270-290	310-360

[a]More than 12% by weight (on pigment) binder, film dried on nonporous substrate.
[b]Size press addition to fine paper of 40% by weight (on pigment) binder.
[c]Filler addition to fine paper.

VI. Brightness and opacity data from commercial-scale trials

Pigment added at size press	*Total pigment added at size press, g/m³*	*Brightness*	*Opacity*
Series 1 (no calendering, 70 g/m² fine paper)			
European coating kaolin	5	84.6	80.0
U.S. calcined kaolin	5	85.6	82.5
No size press addition	...	84.6	79.5
Series 2 (machine calendered, 90 g/m² fine paper)			
European coating kaolin	15	82.4	93.5
Size press starch addition only	...	80.3	92.5

VII. Properties of pigments used in pilot trials

	ISO brightness	*Percentage by weight (<2 μm)*	*Percentage by weight (<1 μm)*	*Surface area, m²/g*
European coating kaolin	85.5	80	60	13
European filler kaolin	81.0	50	35	9
Fine ground marble	93.5	90	65	12
U.S. calcined kaolin	90.5	...	...	17
Titanium dioxide (anatase)	95.0	...	...	16

Cobb about 25 g/m²), filled with 20% by weight kaolin filler. Nominal basis weight was 60 g/m².

The paper machine was a 10 m/min pilot fourdrinier machine, at the University of Manchester Institute of Science and Technology in the United Kingdom.

Summary

The addition of pigment at the size press provides a convenient method for improving paper quality, precoating, or simply increasing ash content without substantial capital investment.

In Europe, the size press is commonly used as a simple precoating technique for conventionally coated woodfree papers. Pigment addition at the size press is also used to improve the printing characteristics of normally uncoated papers to produce a form of matte paper for offset printing. Pigment is added at the size press in some mills to reduce porosity and generally to increase the pigment content of conventional uncoated fine papers.

The amount of pigment added is limited to a total of about 16 g/m² or about 8 g/m² per side of the paper. However, for amounts greater than about 5 g/m² per side, the binder system must be chosen to prevent serious film-split marking on the surface of the paper, and the drying conditions must be controlled to prevent dust buildup on the drying cylinders.

As a general coating technique, one major limitation of pigment addition at the size press is that the pigment penetrates into the body of the sheet rather than covering the surface, as would be expected, for example, for pigment applied with a blade coater. As a sole means of coating, therefore, pigment addition at the size press does not significantly improve surface properties such as smoothness or gloss.

The visual appearance of the printed paper is, however, improved and an acceptable lightly coated, matte printing paper can be produced by size press pigment addition. As a precoating technique, size press pigment addition is used simply to fill larger pores in the base paper and prevent penetration of subsequent coatings.

As a method of modifying the properties of conventional uncoated papers, amounts up to a total of about 6 g/m^2 of practically any pigment may be added at the size press with no seriously detrimental effects to properties such as paper strength or surface dusting. An addition of 3 g/m^2 of a typical coating kaolin will, for example, reduce porosity by about 50%, but will have little effect on other sheet properties. An addition of 3 g/m^2 of a calcined clay, however, also will reduce porosity, increase sheet brightness by 1.5-2.0 points, and increase opacity by 1.5 points for a 60-g/m^2 sheet.

In fact, the addition of a specialty pigment at the size press for either coated or uncoated woodfree papers is a simple method of improving optical properties. Problems such as poor retention or loss of sheet strength are avoided by adding the pigment at the size press.

Interest in pigment addition at the size press remains strong in Europe. Future developments will probably include the use of bar and blade metering units for higher-speed operation, the use of infrared dryers to improve surface coverage of the paper by the pigment, and the use of on-line soft-nip calenders to improve the surface of the finished paper.□

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