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THE DEVELOPMENT OF PAPER GLOSS IN HOT CALENDERING AND BRUSHING

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ABSTRACT

In bleached, white top and coated packaging paper and board, paper gloss is a desirable property, whereas in printing papers print gloss is most desirable. One section of this paper deals with gloss development of uncoated paper and board and another section deals with coated paper. A final section addresses print gloss.

The enhanced effect of hot calendering on paper gloss and print gloss, as compared to "air leak" smoothness, is illustrated. This enhancement is due to a thermal softening concentrated at the outermost layer of the paper in contact with the highly polished hot steel roll acting preferentially on the topographical irregularities up to a few microns.

Brushing of coated papers produces some densification of the outermost coating layer, thereby filling the surface voids. Brushing improves both paper gloss and print gloss, as well as the gloss uniformity with no significant effect on the "air leak" smoothness.

INTRODUCTION

This work deals mainly with paper gloss but has a short final section on print gloss. Also it only refers to 75° specular gloss, Hunterlab gloss (1).

A theoretical analysis of specular gloss usually divides the effect into that due to" micro"-roughness less than the 0.7 µm wavelength of visible light causing light diffraction and "macro"-roughness greater than this wavelength (2). The wavelength limit is about equal to the thickness of clay platens used as coating pigments. The macro-roughness thus defined includes a size range of amplitudes and wavelengths, from small filler particles to large single fibres and up to the very large structures of fibre flocks. It appears that already in the microroughness range of 0.1 to 0.5 µm specular gloss falls off considerably (3). The same is true when pigments in paint films increase in size above 1.0 to 2.0 µm, thereby causing irregularities protruding out from the surface creatomg surface irregularities smaller than their size (4) and significant to gloss.

Thus, specular gloss is due primarily to the surface irregularities in the micro- and the medium-roughness level, whereas standard "air-leak" smoothness values are more affected by fibre flocs and by occasional fibre bundles. Changes at the micro-roughness level can thus change the gloss even if the air leak smoothness is unchanged. For example a brush which adapts to the surface topography is one tool for improving gloss of coated papers without affecting the standard surface roughness values evaluated by the PPS or Bendtsen method. A calendering nip can simultaneously affect both gloss and roughness to different extents. When specular gloss and paper roughness are compared over a range of calendering conditions, there is therefore usually no sensitive correlation.

This paper discusses separately the gloss of uncoated papers, of coated papers and the relation of print gloss to paper gloss.

From a fundamental point of view, the term hot calendering can be said to refer to conditions where, within a layer of the paper the temperature is rapidly raised by the heated polished steel roll above the glass transition temperature of its wood polymers at the moisture content prevailing, and then rapidly cooled by evaporation, as is exemplified in Figure 1. This thermal softening in a limited layer of the paper or board permits permanent densification including some lateral deformation to take place under conditions where the interior of the paper is cooler and more elastic and can recover from compression when leaving the nip, see Figure 2. Consequently hot calender nips require less linear load for an equal smoothness with increased paper gloss and print gloss. The hot nip also permits some shear displacement of fibre and clay surfaces into the sheet surface plane within the heated layers at the nip exit although these forces are small. These displaced fibre surfaces can be rebonded in this slope on the rapid cooling (quenching) down to about 90 °C at the nip exit, caused by evaporation.

In this context it might be of interest to note the considerable heat that can develop in a cold calendering nip by

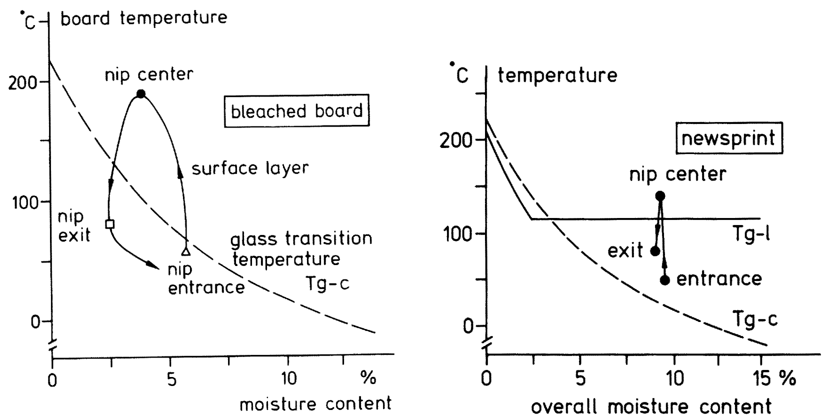


Figure 1 Surface temperature and moisture during a hot calender nip. Left a bleached board or paper - Right newsprint. As a background the glass transition temperature of the corresponding wood polymers, Tg-1 for lignin and Tg-c for cellulose. The one for native hemicellulose is parallel to Tg-c but about 20° to 30°C lower.

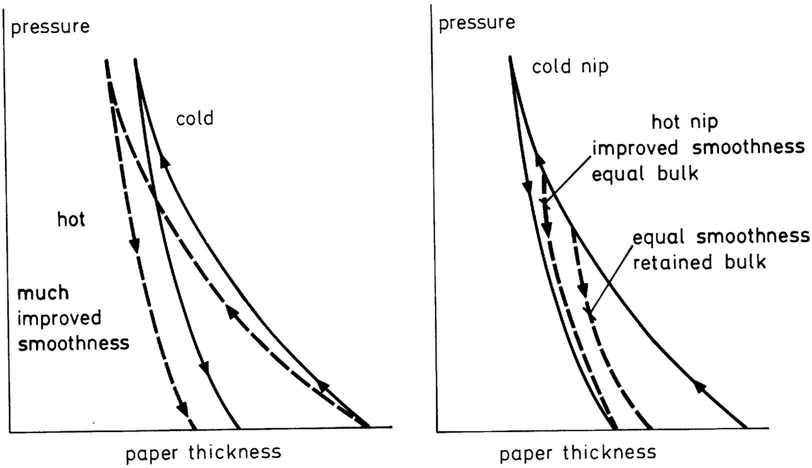


Figure 2 Means of using the softening effects of hot calendering. To the left: With the same press pulse as in cold calendering, thereby improving smoothness but with increased paper density. To the right when reducing the hot nip maximum pressure e.g. by lowering the impulse and/or using a softer roll against the hot steel roll. In this case either improved gloss at equal thickness or equal smoothness at a higher bulk is achieved.

the dynamic compression of the air within the porous structure to more than 300 °C within a nip, an effect which has been experimentally measured (5).

EXPERIMENTAL

Laboratory studies of hot calendering have employed a hammer and anvil platen calender nip simulator, modified with a preheated steel hammer and a steel or rubber anvil at 23 °C, upon which a prethermopstated (23 °C, 50 % RH) paper sample has been placed. (6, 7). Dwell times from 1.3 ms to 5 ms were used. Calendering conditions are denoted in the figures by the order and number of nips in which a paper side faces the polished hot steel surface. Thus T_3W_5 represents three nips with the steel surface against the top side followed by five nips against the wire side of the paper. The same notation is used for both mill supercalendering and laboratory hot calendering. The nip impulse is the integral of nip pressure over nip dwell time and is numerically equal to the linear load divided by the web speed.

For laboratory brushing the sheets were fed 5 to 8 times at 4 m/min through a 27 mm wide brushing zone at a differential speed of about 200 m/min. The brush is made up by ordinary horse tail hairs of about 200 μ diameter and rotates with 450 rpm.

The uncoated 60 g/m^2 rotogravure paper (containing 63 % TMP, 12 % bleached kraft and 25 % clay filler) used in several of the experiments had a "raw" density i.e. before supercalandering of 490 kg/m^3. This Fourdrinier paper had a clay content of 34 % by weight in the top third of the paper and about 14 % in the lower (wire- side) third of the paper (7).

UNCOATED PAPERS

The development of specular gloss and surface smoothness by calendering is thought to be due to two effects. One is the microsmoothening, a minor displacement of material in the surface due to shear forces developed at the entrance and exit of a calendering nip of rolls of different hardness. The other more important one is densification which brings more material into the same plane from below and above and flattens out this material sidewise, by fibre collaps, etc. as a result of the pressure pulse in the calender nip. A sufficiently high temperature to cause thermal softening in this surface layer, concentrates the densification to this layer and facilitates the smoothening action of shear forces in the nip exit. At the nip entrance the paper is still cold and the shear displacement therefore thought to be less. The flattening of large fibre flocs may require densification over a larger depth or even the entire paper thickness.

Fibres and fillers

In calendering, the first nip is applied to the paper when it has its lowest density and is thus most receptible to densification and flattening. If equally smooth sides are the goal of the calendering operation, the first nip should therefore be applied on the rougher side of the "raw" paper. Under isothermal conditions a nip also produces the larger relative densification within the filler-richer layers, i.e. the top side of the fourdrinier paper, with its lower bond strength. The first nip also has the greater effect on specular gloss development, as is illustrated in Figure 3. If additional nips are applied with the hot steel surface against the wire side, its gloss can eventually exceed that of the filler-rich top side, even though the top side actually has a lower PPS-roughness value. Although these results refer to hot steel-paper-cold steel nips in a press simulator, which produces only a minor if any shearing per se, a fibre collapse increases the apparent fibre width and thereby the web CD width of a web or sample having a preferential MD fibre orientation - as pointed out by Baumgarten (8). Some shearing forces might therefore be produced in CD even here. The CD expansion as compared to MD was quite pronounced in the press simulator experiments as well.

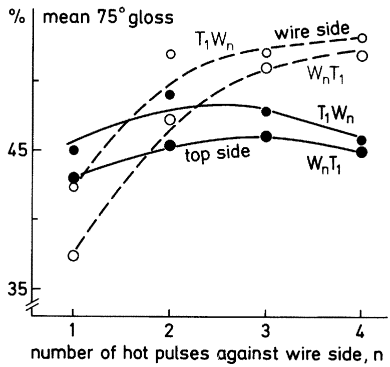


Figure 3 Comparison of wire side and top side gloss developments. T = top side, W = wire side, subscript refers to number of nips for that side. Steel-steel nips. Hammer temperature 250 °C, nip dwell time 1.3 ms, nip impulse 52 kPa•s; and Pmax = 60 MPa. Gloss, measured as average of MD and CD. The raw paper specular gloss was T = 5 %, W = 4 %.

Effect of calender pulse

Generally, specular gloss is developmed more than standard "air leak" smoothness by increasing the number of nips as shown in Figure 4 (9). In this case, fewer, high impulse (high linear load) nips develop much less gloss at the same PPS roughness level than a larger number of lower impulse nips. Few high impulse nips also develop slightly less gloss at equal rotogravure printability, evaluated as speckle index. These data seem to support that the shearing action of a calender nip (e.g. between a harder steel roll and a softer roll) is more important in the development of gloss than in the development of macro-smoothness. The effect on printability lies somewhat between.

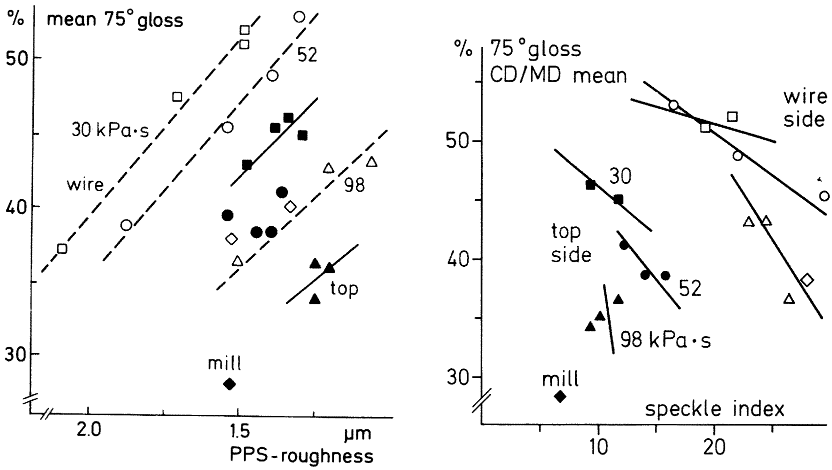


Figure 4 Relation of gloss to air leak (PPS_{10}) roughness and speckle index when using lower and higher impact steel-steel pulses with 250 °C steel hammer. Speckle index is a measure of missing dots after rotogravure printing. [TMP based 60 g/m² rotogravure paper].

Effect of Temperature

The effect of steel roll temperature is illustrated in Figure 5, where data for the two sides of the rotogravure paper are compared. The gloss was somewhat higher on the top side at surface temperatures up to 100 °C, becomes about equal for the two sides at about 150 °C, and higher than on the rougher wire side above 200 °C. The thermal softening of the wood polymers above 150 °C promotes gloss development in the hot wire side which although rougher is richer in lignocellulose fibres. When only one hot nip was applied on each side of the paper, little gloss difference was noted although the top side had a lower PPS-value. Compared at equal PPS-smoothness the fibre-rich wire side exhibited a higher gloss for all these data. The electron microscope pictures of Figure 6 illustrate these effects. The mill-supercalendered papers subjected to a T_3W_5 nips had 10 % higher specular gloss on the PPS-rougher wire side than on the smoother, filler-rich top side. Here, the wire sides had received a larger number of nips against SHW Äquitherm heated steel rolls with a surface temperature of about 75 °C.

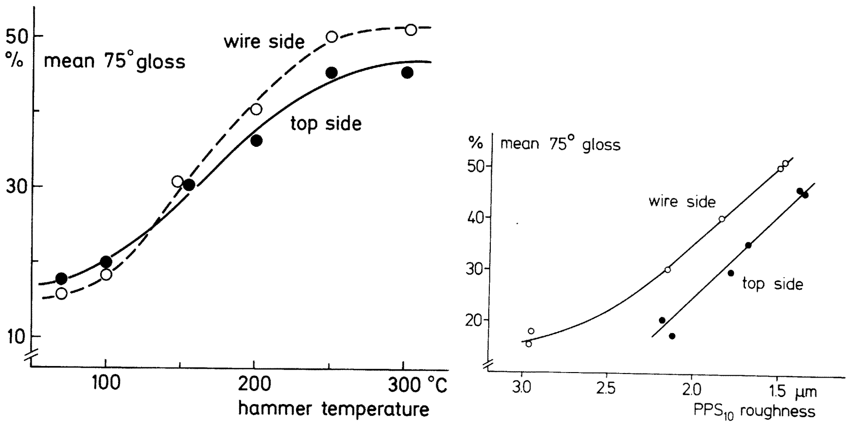


Figure 5 Effect of hammer temperature on paper properties when using the nip sequences W_3T_1 with the lowest impulse 30 kPa • s and a maximum pressure of 35 MPa in steel-steel nips. To the right the mean gloss plotted versus the corresponding PPS-roughness.

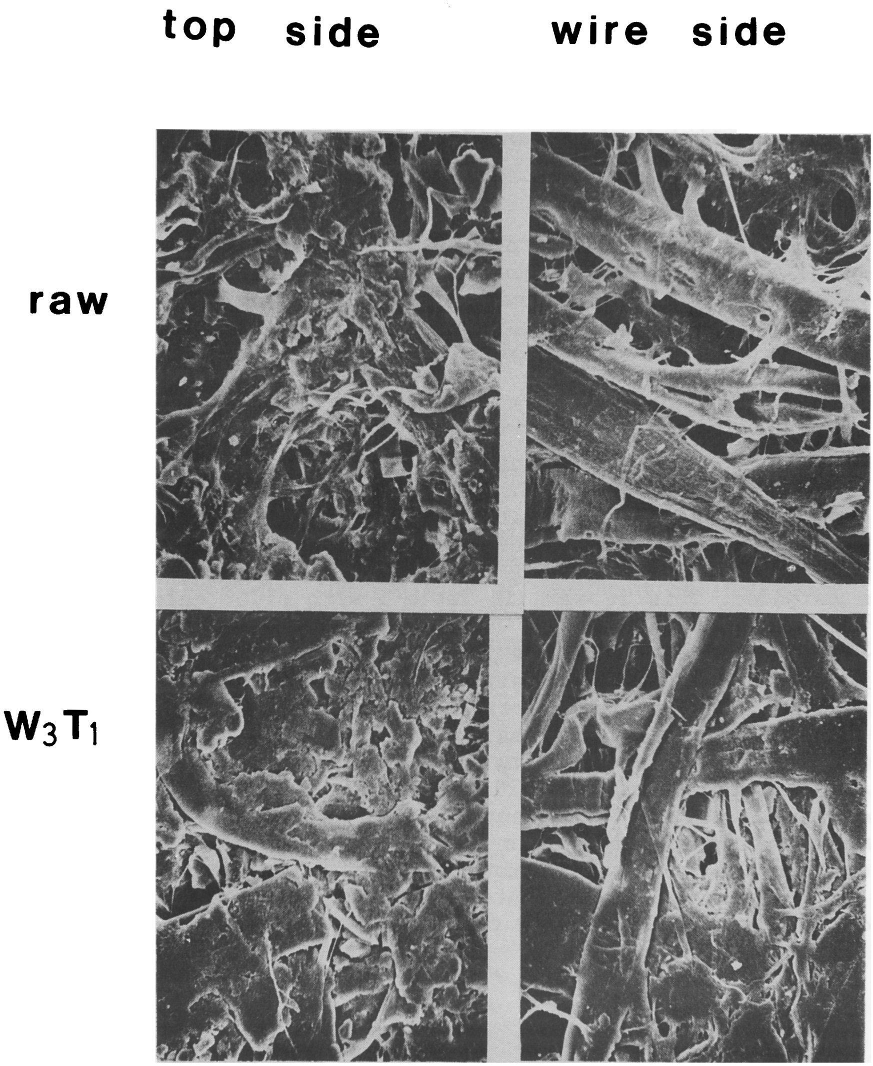


Figure 6 SEM micrographs of top and wire side of "raw" paper before calendering and after W_3T_1 hot calendering at 250 °C with 52 kPA•s impulse with 60 MPa maximum pressure. Photographs courtesy Yoshihiro Mataki, Univ. of Kyushi, Fokuoka, Japan.

Published pilot data from the hot-soft calendering of newsprint (10) (12) (13) also show more specular gloss at a given smoothness than cold-soft nips. Some of these are reproduced in Figure 7. Together with data for coated papers (cf Figure 9) they support the view that shearing deformation at the nip exit must be important for gloss development.

Effect of steel roll polish

Obviously, the polish of the hot metal surface or metal roll is of great importance both for gloss and smoothness development as is illustrated in Figure 8. Here the effect of the hammer polish was highest on the filler-rich top side of this paper.

Effect of fibre orientation

The importance of optical coherence and the size distribution of discrete reflecting areas contributing to specular gloss (2) is easily illustrated by the effect of fibre orientation. The gloss of a sheet is slightly but significantly higher in the MD independent of the feeding direction through the calender. This is seen in Table 1 with pilot calendering of commercial papers of A:4 size fed into a single hot soft-roll nip in CD and MD in a pilot calender running 20 m/min with 100 kN/m linear load between the heated steel roll and a Nomex roll. Feeding the sheets in CD still resulted in higher MD as compared to CD gloss,but it generally reduced PPS-smoothness. In this case both feeding direction and preferential fibre orientation contribute to specular gloss. Even in the non-directional treatment by the hammer-anvil calender simulator, the specular gloss was higher in the machine direction than in the cross machine direction. The difference was up to 10 % on the more oriented fibre-rich wire side but only about 3 % on the filler-rich top side.

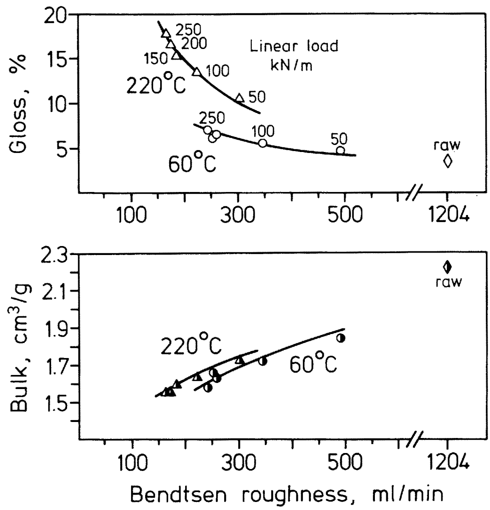
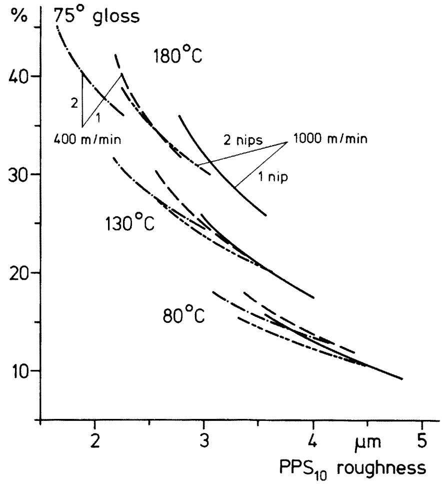


Figure 7 Temperature develops higher gloss at equal "air leak" smoothness. Above, a single Nipco-Mat nip against the top side of newsprint at 1050 m/min (10). Below, one or two Soft Compact nips against newsprint at twø machine speeds and pressure range of 20 to 40 N/mm² (11).



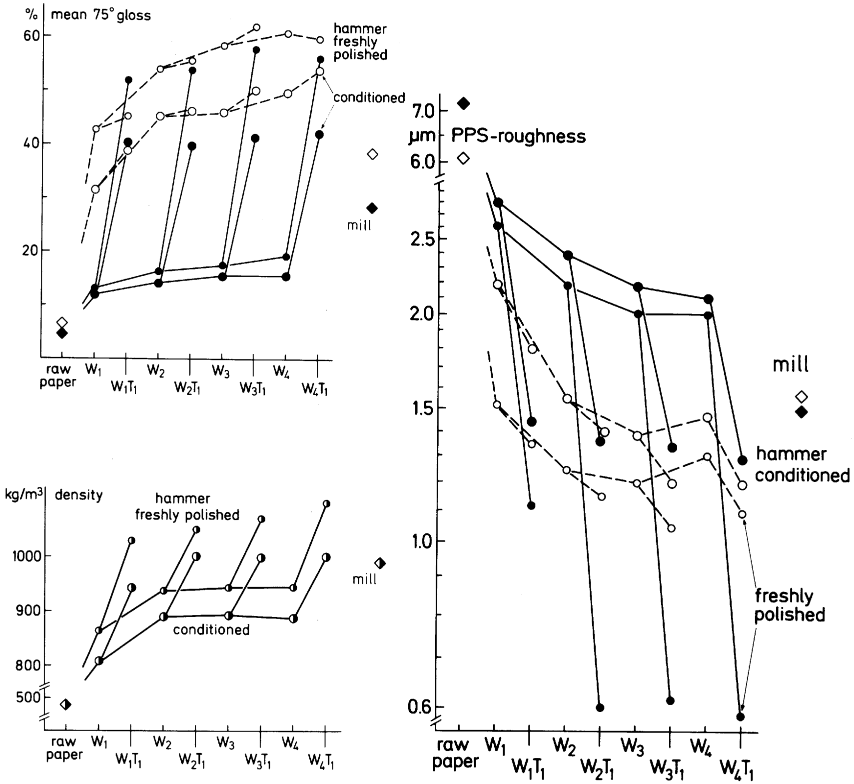


Figure 8 The effect of hammer polish. Results for various sequences of steel-steel pulses with the final one against the top side using a 52 kPa•s impulse, 60 MPa maximum pressure and 250 °C hammer temperature. Open symbols and dashed lines refer to wire side, filled symbols and solid lines to top side and half filled symbols to top/wire side mean. Smaller circles freshly polished, larger circles after 50 calender hammer pulses.

Condition-ing and side against hot roll	Hot roll tempera-ture	Feeding direction	75° Hunter-lab gloss in MD	CD	PPS_{10}
50% RH wire	150 °C	MD	32.6	30.2	1.23
		CD	30.3	27.2	1.30
30% RH wire		MD	26.4	26.7	1.25
		CD	26.5	23.3	1.49
30% RH wire	200 °C	MD	40.3	37.0	1.09
		CD	37.3	37.4	1.09
50% RH wire	150°	MD	31.5	29.4	1.28
		CD	31.6	29.9	1.32
50% RH top	papers	MD	33.9	32.4	1.14
		CD	33.8	33.4	1.07
30% RH	extracted	MD	26.7	25.0	1.43
		CD	27.0	23.8	1.50

Table 1 Effect of feeding direction in hot calendering for normal and pre-extracted rotogravure paper sheets.

Conditions	Property	Standard A	Standard B	Extracted A	Extracted B
150 °C 50% RH	PPS	1.46	1.69	1.56	1.62
	gloss MD	29.9	26.6	30.0	28.0
	gloss CD	24.8	22.9	26.1	24.1
150 °C 30% RH	PPS	1.60	2.00	1.66	1.99
	gloss MD	26.3	22.3	26.8	22.4
	gloss CD	21.3	18.8	22.6	21.3

Table 2 Single nip hot calendering of standard and extracted newsprint against side A or B.

Effect of brushing

While brushing develops considerable gloss in many coated papers, on uncoated papers, it has little effect. For example five times laboratory brushinhg in MD of the uncalandered, rotogravure paper improved the 75° specular gloss on the wire side from 4.5 to 7.1 % and on the filler-rich top side from 3.5 to 8.8 % whereas on the mill supercalendered paper it reduced it from 40.5 to 31.5 % on the wire side and from 39 % to 35 % on the top side. The PPS-roughness was also slightly changed, e.g. for the uncalendered paper from 5.9 to 5.3 µm on the wire side and from 6.9 to 6.1 µm on the top side, whereas on the mill supercalendered paper it was reduced by 0.1 µm on the wire side but not on the top side. Similar small increases in gloss were obtained by repeated brushing on standard and filler-containing MG-papers on the glossy Yankee side. e.g. from 23 % to 26 % (14).

Effect on friction coefficient

The effect of friction between the paper and calender roll has been discussed (15). Repeated extractions (by chloroform and subsequently by acetone) to remove the oleophilic material can easily more than double the paper-paper friction coefficient (16) and probably also that of paper to steel. Thus some hot calendering experiments were carried out to compare such papers in single nip pilot hot calendering at 20 m/min and with 100 kN/m linear load between a hot steel cylinder and a Nomex roll (cleaning the rolls before each sample). Results are shown in Table 2 and some data in Table 1. For the newsprint paper the static paper-to-paper friction coefficient was more than doubled from 0.25 to 0.6. It appears that a higher friction coefficient actually slightly lowered the achievable PPS-smoothness and gloss.

In a related experiment the rotogravure paper of Table 1 was subjected on both sides to a 15 kJ/m² Corona discharge. Thereby oleophilic wood extractives in the surface layers are removed by oxidation and the paper to paper friction coefficient increased considerably while also lignin can become chemically activated (17). After four hours of conditioning at 23 °C and 50 % RH the paper was given W_2T, 250 °C/23 °C steel-steel nips in the hammer-anvil calender simulator using 30 kPa•s impulse nips. The Corona pretreated samples showed 20 % (wire side) to 40 % (top side) higher PPS-roughness and somewhat lower gloss compared to untreated. This seems to indicate that a low friction coefficient promotes slip of the paper against the hot polished steel surface which in turn promotes gloss and smothness development in hot calandering.

Effect of yankee drying

Specular gloss can be increased on wet webs by a smoothing press and some of this effect remains after calendering (18). It can especially be improved by drying against a high polish Yankee cylinder. These processes combine a flattening and densifying action with an increase in fibre-fibre bonding area, and therefore increase strength and reduce opacity. The specular gloss of the MG-side increases with a wetter, i.e. a softer sheet, and with higher pressure applied with the press rolls against the Yankee (19) (20). Refining above a certain freeness leads to gloss reduction despite the greater conformability of the refined fibres to the polished Yankee surface (19) (20). Gloss increased with increasing lignin-to-hemicellulose ratio in sulphite papers (21) perhaps because fibre collapse and bonding area may have been reduced.

To summarize this section of the paper: Specular gloss in paper and board depends both on the micro- and mini-smoothness of the paper surface in a scale up to a very few microns and on the coherent size of reflecting areas in the surface layers of the paper or board. Hot calendering promotes a higher gloss at a given "air-leak" smoothness than colder calendering conditions, because densification is concentrated to the surface layers and because of shearing displacement in the surface layer is facilitated by thermal softening at the nip exit, i.e. when the paper surface has become hot and soft. Softer calendering nips give a higher gloss than harder nips at a given "air-leak" smoothness because of more intimate contact with both the hillsides and the valleys of paper macro-structure. Brushing in uncoated paper surfaces can only develop an insignificant gloss or even destroy gloss. The polish of the high steel roll against the paper is quite important since the paper surface layers soften against this steel surface and are then quenched in the deformed state due to a rapid temperature drop to below 100 °C by evaporation. The size distribution and orientation of local reflecting areas is important for high specular gloss as is shown by the gloss anisotropy of fibre oriented sheets. Fibre collapse increases the effective reflecting width of fibres in the surface layers.

Coated Papers

The coating of paper increases the paper flatness and smoothness up to a certain coating weight. It also produces a rather low 75° gloss level, which mainly depends on the coating composition. It might be slightly higher with a higher coating weight and also with a higher binder content for some high gloss binders. Considerable gloss thereafter is developed by mechanical action, much more so the lower the binder content of the coating. Additives which promote gloss development during this action such as calcium stearate, beeswax and polyethylene glycol PEG-4000 (22) (23) lower the bond strength of the dried coating film and probably thereby facilitate the changes therein during the mechanical action thereupon.

A very good correlation to 75° gloss was established on coated board with the squared deviations of the tops and valleys along each 25 micron profile length units determined by a Tallisurf profiler (24) (25). A good correlation also resulted if the coating layer was applied instead on a smooth polyester film, with the gloss going up to 85 %. These correlations over a large gloss range produce some understanding of gloss development in accordance with theory (2) (3) (4), e.g. when using coating pigments of different shape and size distributions protruding into the main reflecting plane.

Important experiments by Lepoutre and Means (26) show that supercalendering of a coated paper reduces the thickness of not only base sheet, e.g. by 15 - 20 % in 4 high linear load nips, but also that of the coating layer in this case by about 5 - 7 %, reducing the void volume of the coating layer by 18 to 24 %.

In comparison with such cold supercalendering it seems reasonable that hot calendering, especially soft hot calendering, produces a greater densification of the coating layer, with less densification of the paper. Unfortunately such measurements are lacking.

In calendered, hot calendered and brushed papers the reduction in K & N ink absorption rate is pronounced (27). This is exemplified in Figure 9 for a single hot calendering nip as a function of temperature using the calender simulator (6). With brushing the ink absorption rate falls off as more brushes are used, with higher brush pressure as well as with higher total energy applied against the sheet. The paper gloss in these cases increases (28) (29) (30). The K & N value also falls off with higher coating weight and with increasing coating binder content.

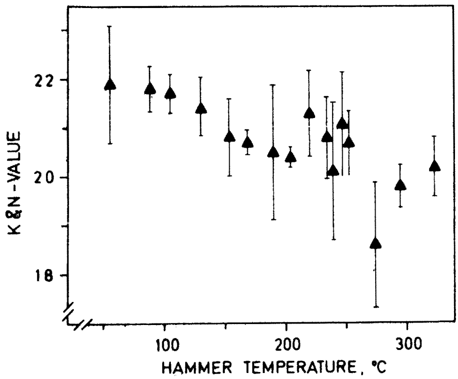


Figure 9 The effect of hammer temperature on the K & N value and its standard deviation for commercial coated board. Single hot nip calendering simulation using the calender pulse shown in Figure 10 with steel anvil supporting the sample.

In hot calendering the gloss increases up to about 250 °C roll temperature and then it levels off. A commercial operation is simpler with hard press rolls against the hot calender, but some gloss mottling can then appear. This mottling is reduced with a softer press roll and the total gloss is slightly increased hereby. The effect is illustrated by a hot calender simulation which utilizes the same impulse and the same pulse as measured below an anvil with the same overall built-up but with varying the order of its rubber and steel platens. In one case a 90 P & J rubber platen was placed just below the paper, i.e. uppermost in the anvil, in the other a steel platen placed just below the paper. Figure 10 shows the 75° gloss as a function of the PPS-smoothness with this set of experiments over a range of hammer temperature. Especially above 250° hammer temperature the harder steel backing of the board produced a higher PPS-smoothness but a lower gloss. The softer rubber backing produced a higher gloss but a lower smoothness - all at equal hammer temperature. In this hammer and anvil nip simulator the rubber platen is elastically compressed but also undergoes elastical radial deformation, which produces microslip between paper and hot steel hammer.

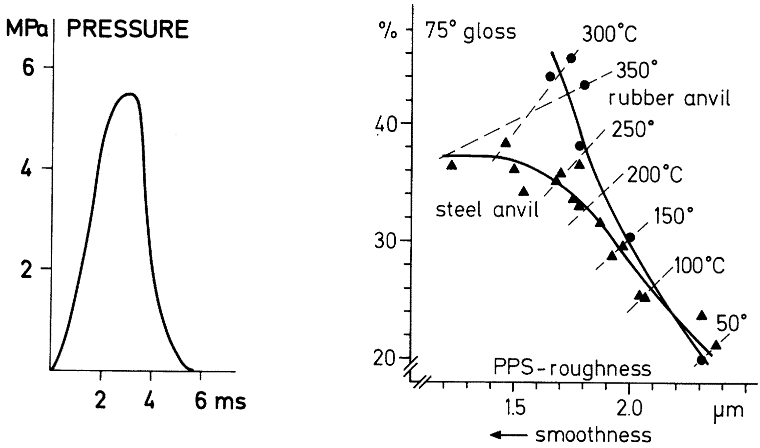


Figure 10 The effect of anvil platen material and hammer temperature on the relation between gloss and smoothness. The same pulse (right, as measured below the anvil was used and an impulse corresponding to a linear load of 71 KN/m at a machine speed of 300 m/min. Either a rubber platen or a steel platen supported the board in the single hot nip at 7 % moisture content. Dotted lines connect data for the same hammer temperature. The rubber platen anvil produced higher gloss for a given PPS-smoothness.

The additional effect of temperature on gloss as compared to smoothness appeared less pronounced on coated papers than on uncoated according to some data in the literature (31).

The total gloss developed by combining a hot calender nip with brushing leads to the same final gloss level independent of which of these two actions is applied first. This appeared in earlier laboratory experiments reproduced in Figure 11 simulating a nip of 300 °C. The difference in PPS-smoothness was also small, 1.56 when brushing first, and 1.04 when hot calendering first (6).

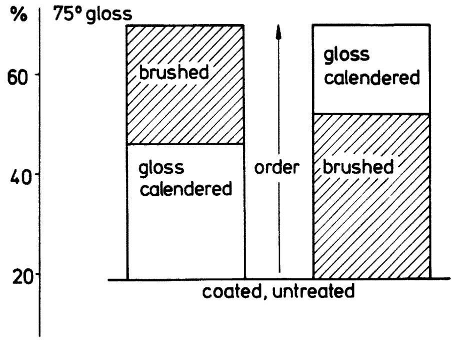


Figure 11 Combined effect of brushing and hot nip, referring to laboratory brushing and one 300 °C nip of Figure 10. The order of these treatments is varied.

There does not seem to be a large difference in gloss development by brushing and by soft hot calendering on coated papers. It is stated that brushing does not reduce the bulk and stiffness of the paper. On the other hand, the reduction in ink absorption rate and the increased gloss indicates a partial densification, i.e. void reduction of the coating layer, perhaps concentrated to its uppermost layers. Experiments to measure this densification with methods mentioned (26) would be useful. The brush horse tail hairs apply a pressure with intimate contact down to all the valleys of the macro-rough surface of papers, limited only by the hair diameter of about 0.2 mm. However, the light pressure of the brush gives a very small chance of smoothness development, if any, especially when the board is rough. When brushes were used against a cast-coated paper with an initial gloss near 90 %, this gloss was reduced to 79 % but the K & N value was reduced anyhow just as with other papers (32). Brushes thus appear to act by pressing down protruding parts of clay platens or of the long needles of satin white into a single lateral layer, which takes place as part of the surface densification, i.e. void reduction within the coating layer or its uppermost layer. Spherical calcium carbonate pigments do not produce this flat surface on densification and thus produce little gloss only if coarse. Finer carbonate particles produce more gloss in this surface densification (33). Size and shape distribution as well as optical properties of pigments thus affect the gloss development (34). As proposed earlier (35) brushing can thus be considered as a soft, low impulse calendering action which can densify - reduce the void volyme - in the coating surface, provided its bond strength or binder content is low. Thereby it produces the mini- and micro-smoothness necessary for gloss. No large lateral movement of pigments is thought to occur, nor a large polishing, i.e. reorienting effect on binder molecules. For example 8 times brushing a linters paper heavily treated with PVA-starch in a size press increased its gloss from 7 to 10 % only, while a single 200° hot soft nip improved it to 30 %.

There is insufficient information regarding the heat generated by the mechanical action of the brushes, but measurements indicate that this is not important (14). Also it has been reported that a roughened steel cylinder surface developed more gloss in a nip than a more polished one with two clay coated papers, while this was not true with a satin white based coating (36).

To summarize this part: Hot calendering nips on coated paper and board, also called gloss calendering, produce a significant densification which partly is located to the coating layer and thereby increase the gloss and reduce the ink penetration rate. The hot nip is thought more easily to overcome the bonds in the coating layer than a cold nip. Its action in respect to macro-smoothness, on the other hand, appears to take place within the upper layers of the backing paper. A softer roll backing against the hot, polished steel roll increases gloss but reduces develpment of macro-smoothness.

Brushing can be considered as a very soft calendering nip acting on all local surfaces within the macro-structure of the tops and valleys of the coated paper surface. It thus produces uniform gloss with few local variations, i.e. little gloss mottling. Its densification action in the coating layer is not very evident on total paper thickness nor on the macro-roughness as evaluated by Bendtsen or PPS_{10} but is seen in oil absorption rate. Its glazing mechanism is thought to be a flattening of the surface by laying down protruding particle ends into a more lateral position, probably without large lateral displacement. Because of its light mechanical action, a low binder content in the coating is especially important.

Print gloss versus paper gloss

Paper gloss in some cases is desired only as an aid to the development of print or lacquer gloss. Naturally, print gloss besides on paper micro-smoothness depends on ink flow properties, on ink to paper wettability and on ink penetration resistance of the paper surface layers. Although no general relationship exists between print gloss and paper gloss, good correlations might well be found when varying few paper parameters only such as when using a given ink and coating colour (37). For example there are special ink-hold-out additives which may have been added to the size press or the coating colour (22, 23). Also in statistical comparisons of ink to paper gloss over a large range of coated papers some good correlation can occasionally be and has been found (38).

For hot soft calendering of newsprint of the samples of the upper part of Figure 7, Figure 12 shows the ink gloss and paper gloss plotted against the Bendtsen smoothness. This ink gloss is based on a Prüfbau test printer using a thermosetting offset ink. The improvement of ink gloss by the 220 °C hot soft nip as compared to the 60 °C nip was impressive and relatively larger than the improvement of paper gloss.

The relative lack of correlation between paper gloss and print gloss is here illustrated for a boxboard, clay coated with two types of coating binders at various binder levels (40). Figure 13, courtesy Bristow and Ekman (40), shows both the print gloss, using 48 µm cell depth with a toluene-based gravure ink, and the lacquer gloss after gravure application of nitrocellulose, dissolved in an ethylacetate-ethanol mixture. Final gloss is plotted against the paper gloss and

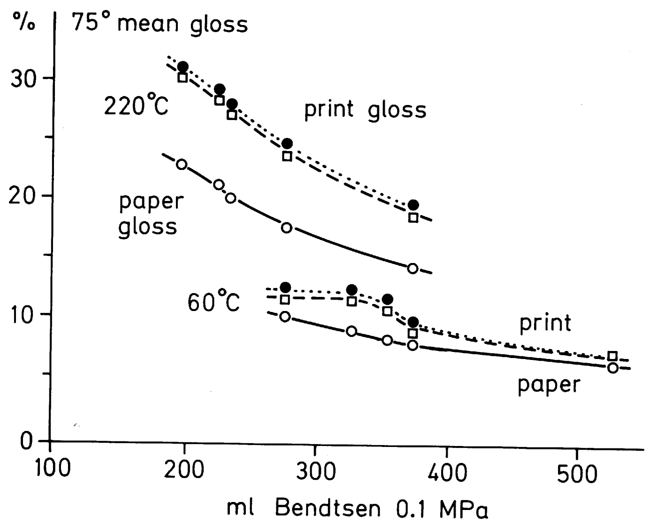


Figure 12 The effect of soft nip calendering temperature on paper and print gloss as CD/MD mean. Newsprint samples of the upper part of Figure 7 versus the Bendtsen roughness. Print gloss after Prüfbau laboratory printing (39) with a black heat-set offset ink at 0.5 m/s at various ink levels. Ink gloss for two levels of ink density ft = 0.95 (dotted line) and ft = 0.85 (dashed line). Ink consumption about 25 % higher for the higher ink density. Note the larger improvement both of paper and ink gloss for the same "air leak" roughness.

given both for the untreated but coated "raw" boxboards, for these boards after a single laboratory calender nip and after the laboratory brushing described. For each coating binder the paper gloss increases on calendering and especially in brushing, and thereby also brings about the positive effect of low binder content, not very significant in the raw board. On the hand, the corresponding increase in varnish or print gloss is much smaller. Especially when print gloss is high an increase in paper gloss by calendering or by brushing produces only a minor additional print gloss. At lower lacquer gloss levels brushing gives a greater advantage, but not like it gives for the development of paper gloss.

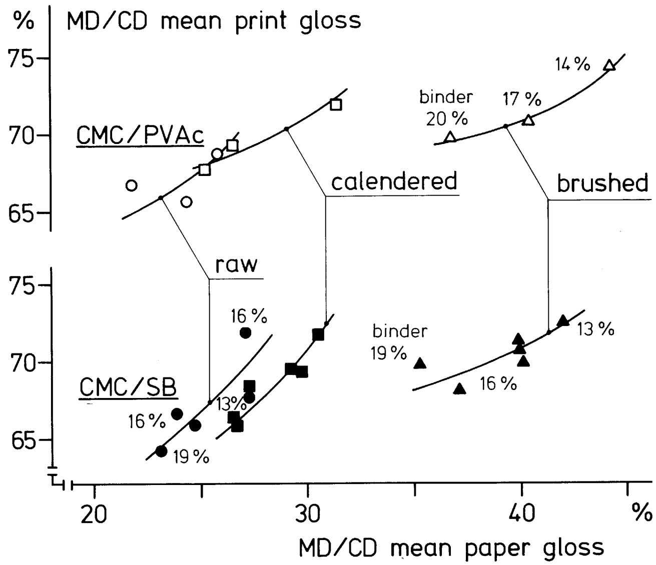
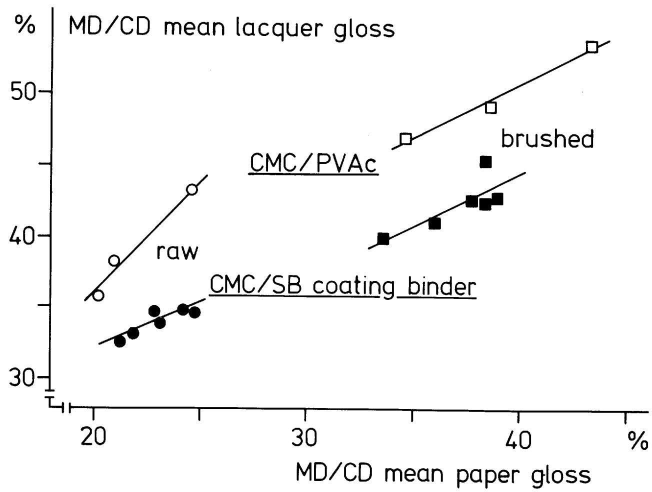


Figure 13 Above, the print glkoss after fulltone rotogravure, below, the nitrocellulose lacquer glóss both versus paper gloss (40). Brushing has a larger effect on paper gloss than on print or lacquer gloss. Binder to pigment ratio given in %.



To summarize: Ink gloss or lacquer gloss is often related to the surface gloss of the paper but not always directly proportional hereto. Densification and the subsequent void reduction in coating surface layers reduces the ink penetration rate. Surface smoothness facilitates the wetting of all local surface areas by the ink. Part of the gloss reducing mini-surface roughness of the surface can be levelled out by the ink itself to produce a more homogenous reflecting area and ink gloss (41) less independent on paper gloss.

Acknowledgement

The author is indebted to PFI, especially P.E. Lindem there, for their help with the calendering experiments of Tables 1 and 2. Also, the author is indebted to J.A. Bristow, H. Ekman and M. MacGregor, STFI, for discussions.

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Transcription of Discussion

DEVELOPMENT OF PAPER GLOSS IN HOT CALENDERING AND BRUSHING

Dr. E. L. Back

Dr. J. Marton SUNY

Dr. Back, you promised to make some comments about the S.D. Warren - Scott Paper patent can you do this?

Dr. E.L. Back

A comment has already been made by Dr. J. Peel. I have explained why it is worthwhile to bring the surface layer of the paper above the thermal softening point of its polymers and mould them into a smooth surface and then cool quickly. This must be done at the correct moisture content. Gloss calendering of a high basis weight sheet or board, by this method, has been in commercial use for about 25 years some work has been published by H. Baumgarten and W. Brecht about 15 years ago. There are other publications on hot calendering of uncoated paper by, for example, B. Krenkel (1) a long time before S.D. Warren applied for their first patent. Thus I cannot understand how the patent (2) was granted.

1. Krenkel, B., Wochenbl. Papiers. 104 (1976) 129, 621 and (1977) 105, 431.

2. Ref. 102 in Dr. J.D. Peel's review paper.