Calendering of Talc-Based Coated Paper in The Mill

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ABSTRACT

Effect of calendering coated paper in machine and on super calender, on the optical and other properties, has been studied. 36 coated sheets were produced from 12 different compositions using the Air-knife coater-6 with casein + SB latex and 6 with SB latex and PVA binder. Properties of uncalendered, calendered and super calendered were studied.

The marked difference in gloss, brightness and opacity in the coated sheets, between the two mill calenders, has been presented. Smoothness, oil absorbence, strength and printing properties of the calendered and uncalendered papers are also measured. The coating colour consists of the non-conventional but cheap talc pigment and binders such as casein, styrene-butadiene latex and polyvinyl alcohol. Effect on variation of PVA concentration has also been studied. Achievement of coating properties with the modified talc, comparable to china clay and specially titania, has been acclaimed.

INTRODUCTION

Calendering paper is essentially a mechanical operation by which the web is compacted and the surface properties are enhanced (1). A calender consists of sets of all metal rolls ranging from 2 to 14 in number arranged one above the other vertically. The metal rolls are made of chilled cast iron or alloy steel (2). Calender features are (2):

- soft cover characteristics
- temperature of iron roll
- nip pressure
- number of nips
- nip dwell time and
- roll sizes.

Supercalender is distinguished with its multi-nip off machine device from a single nip on machine calender, the alternate intermediate metal rolls with filled rolls of material possessing resilient or elastic properties (1). Such a filling is obtained by compressing fabrics, papers or nonwoven mats of cellulose fibre under high pressure. Soft calendering refers to finishing with soft nips in comparison to calendering with hard nips in a machine calender (3). These days highly supercalendered grades of papers can be produced using modern soft nip calenders as on machine or off machine units (4). Hot soft-nip and soft-nip calendering are reported recently to have high potential (5).

Coating and supercalendering enhance the printing characteristics (6) namely gloss, smoothness and density. The caliper and smoothness of a sheet after calendering are functions of the nip pressure applied, the number of nips the sheet passes through, the speed at which it travels through the nips, the temperature and the moisture of the sheet (7). Supercalendering helps in improvement of gloss in particular, smoothness also gets enhanced. Soft roll calendered paper, including supercalendered one, always looks more uniform and usually print better than machine calendered paper when compared to the

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paper finished to the same thickness (8). Soft nip calender operates in the electroplastic region of the stress-strain curve. Recently many publications on on line and off line soft calenders have come out (3-5). On line soft calender is considered the ideal option for new paper machines as well as rebuilds (9) in terms of both economy and quality.

This paper is intended to firstly point out the marked difference occurring due to the two types of calenders and secondly to establish a special talc product, imparting coating properties, comparable to titania.

EXPERIMENTAL

Materials

The base paper used was 144 gsm, procured from a nearby mill (sheet size = 30 x 40 cm). China clay, titania, casein, SB latex as well as the dispersing and defoaming agents were also obtained from this mill. The talc was supplied by M/s. Zoraster & Co., Rajasthan, India. It was specially prepared as a coating pigment.

Methods

The coating colour preparation requires separate cooking of casein with water and NH_4OH as well as PVA with water. Cooking of casein was carried out at 80 ^{0}C in a thermostatically controlled water bath for 20 minutes while PVA in water was cooked at water boiling temperature (98 ^{0}C).

The cooked products were added to the pigment suspension in a glass container and agitated at 700 rpm for 1 hour in a mechanical agitator. The slurry was then passed through a metallic screen of 60 mesh in order to arrest the uncooked hard particles, if any. The filtered slurry had been used for coating.

10 ml of this slurry was taken in a graduated cylinder and spread over the base paper, placed over the air-knife coater. Required air pressure (30 kg/cm^2) was applied before coating. The coated sheets were air dried.

The air dried sheets were taken to the mill and subjected to calendering. The machine calender (M/s J.M. Voith) served for calendering of printing paper including sized paper while the super-calender (M/s Kleinewefers) for coated paper only. The sheets were placed in between the metal rolls when no paper was there on the roll. Special care was taken for passing the coated sheets into the calenders.

The coated sheets were tested in the laboratory for various properties as per standard procedures (10). The viscosity measurements carried out by Brookfield viscometer.

RESULTS AND DISCUSSION

As no laboratory or pilot plant calenders (11) are available in India for carrying out developmental studies on the subject, the mill calender had to be used. In our earlier publication (12), the mill super-calender was used. In the present work, calendering had been conducted in the supercalender as well as machine calender. Comparison of results obtained on calendering the coated sheets in the two mill calenders helped better understanding of the coating mechanism leading to optimisation of coating performance. While supercalendering helped enhancement of gloss and smoothness values, the brightness and opacity were found to be reduced unlike in machine calendering. Machine calendering is known to alter the pore structure of the web in the non-coated paper (13).

Calendering of coated sheet causes filling up of the voids in the paper stock with the solid pigment particles and binding material. The filling-up of voids takes place according to the pigment particle size and shape (14).

The particle size analysis results of the three coating pigments used is china clay, titania and talc are given in **Fig.1.** The cumulative percentage of the three pigments is plotted against equivalent spherical diameter. The fine particle content in all the three pigments are much lower than normally accepted in USA for coating purpose (15). In case of china clay, the particles below 2 µm are 70% which is as high as 93-98% in USA. Even for titania below 2 µm, the percentage is 81. For talc, this percentage is as low as 20. However, the results will show that the performance of the pigments is fairly appreciable. It appears that the lower range of 2 µm should be elevated to 5 or 10 µm. Below 5 µm, the percentage of china clay is 85%, that of titania 93% and talc 67%.

Below 10 µm, these values are 96%, 99% and 95% for china clay, titania and talc, respectively. In this way, present talc has properties comparable to that of china clay apart from its structural similarities. Our experience shows that china clay of superior grade is very difficult to obtain in India. Probably, dispersion property of the pigments accompanied by the special property imparted by the synthetic binders

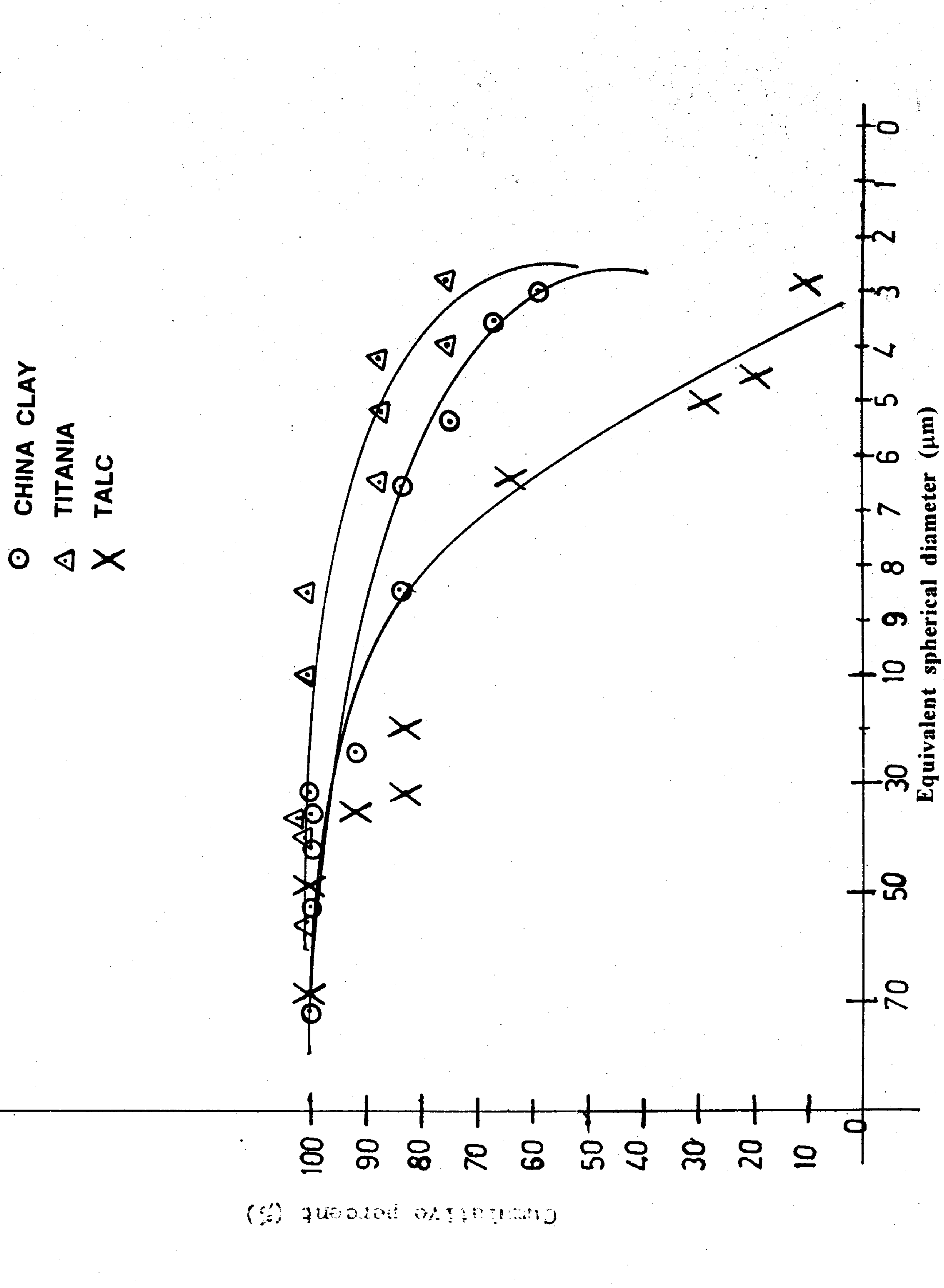

Fig.1: Size distribution of pigments.

Table-1		
Properties of pigments		
Pigments	**Brightness (% El)**	**Specific gravity**
China clay	78.2	2.6
Titania	92.0	4.0
Talc	93.5	2.7

brings an overall improvement of the coating colour, even though the pigment particles are coarser than available abroad.

Coating pigment, notably clay in India, is not of adequate quality and therefore search for alternate or better beneficiated mineral will continue. The binders and calendering are therefore every important as they can help to compensate for the poor textural properties of the pigments.

The brightness and specific gravity values for the three pigments studied are given in **Table-1.** The brightness of china clay was 78.2% El only while titania and talc had it as 92% El and 93.5% El, respectively. The talc has been specially produced for coating grade. The specific gravity of this talc is also marginally higher than that of clay i.e. 2.7 in stead of 2.6.

The properties of base paper are given in **Table-2,** with grammage being 144 g/m^2 and brightness and opacity values of 74.5% El and 94.9% respectively.

In all fifteen coating formulations were used with varying percentage of clay (100-60%), talc (0-40%) and titania (0-5%), first six having casein and SB latex binder (A-F), the rest nine with binders SB latex and PVA. The composition of coating formulations is same for machine calendering and supercalendering **(Table-3).** The titania content had been limited to 5% as one of our objectives in this work was to reduce cost of the coating formulation. With the same objective, on the contrary, percentage of talc has been taken up to 40%. Cost of talc is lower than clay and significantly lower than titania.

The coat weight applied is 12-14 g/m^2. For laboratory experiments, such coating weight is considered quite suitable (16). Coating experiments with titania have been accomplished with coat weight ranging from 9 g/m^2 to 15 g/m^2. However, in majority of cases, high solid content in coating colour are normally preferred, namely 50-60% with SBR latex (16), the other additives being sodium alginate (0.3 parts and calcium stearate (0.4 parts).

Table-2		
Properties of base paper		
Property	**Unit**	**Value**
Grammage	(g/m^2)	144
Bulk	(cc/g)	1.02
Brightness	(% El.)	74.5
Opacity	(%)	94.9
Gloss	(%)	13.0
Tear factor		53.3
Breaking length	(m)	3136
Double fold	(no)	9
Smoothness	(ml/min)	130
Oil absorbency	(sec.)	17

Table-3					
Composition of coating formulations					
Coating formulation	**Clay (%)**	**Talc (%)**	**Titania (%)**	**Binder**	**Cobinder**
A	100	Nil	Nil	Casein	SB latex
B	90	10	Nil	Casein	SB latex
C	80	20	Nil	Casein	SB latex
D	80	15	5	Casein	SB latex
E	60	40	Nil	Casein	SB latex
F	60	35	5	Casein	SB latex
G	100	Nil	Nil	SB latex	PVA
H	90	10	Nil	SB latex	PVA
I	80	20	Nil	SB latex	PVA
J	80	15	5	SB latex	PVA
K	60	40	Nil	SB latex	PVA
L	60	35	5	SB latex	PVA

The viscosity values of different formulations measured after agitation for 1, 2 and 4 minutes are shown in **Fig.2** at agitation speed of 12 rpm in fig.2 and 30 rpm in **Fig.3,** both using spindle 2. Though these values are not of much relevance, it can be seen that in general, viscosity values of coating colour with SB latex-PVA binder are lower than those of casein-SB latex. Secondly, the viscosity decreases on increasing the agitation speed because of breaking up of polymeric chains.

The coat weight and bulk properties of machine calendered papers are given in **Table-4** and for supercalendered in **Table-5.** There are some interesting observations both in coat weight and bulk values.

Table-4		
Coat weight and bulk properties of coated paper (Machine calendered)		
Formulation	**Coat weight (g/m^2)**	**Bulk (cc/g)**
A	13.4	0.92
B	12.8	0.91
C	13.0	0.90
D	12.4	0.90
E	12.8	0.90
F	13.0	0.91
G	12.4	0.90
H	11.8	0.89
I	12.1	0.88
J	12.0	0.89
K	11.7	0.89
L	12.2	0.88

Table-5		
Coat weight and bulk properties of coated paper (Super calendered)		
Formulation	**Coat weight (g/m^2)**	**Bulk (cc/g)**
A	14.2	0.86
B	14.0	0.85
C	14.1	0.85
D	13.5	0.86
E	13.3	0.86
F	13.5	0.85
G	13.4	0.85
H	13.0	0.84
I	13.2	0.84
J	13.0	0.84
K	12.8	0.84
L	13.3	0.84

The coat weight of casein-SB latex binder system (A-F) in higher than that of SB latex-PVA system (G-L). The coat weight and bulk values of the machine calendered paper are again higher than that those of the supercalendered papers in both the binder systems. In the coating formulations (A-F), in machine calendered, the bulk values are 0.90-0.92 cc/g, while it is 0.85-0.86 cc/g in supercalendered papers. Similarly in the papers coated with SB Latex-PVA system, the bulk values are 0.88-0.90 cc/g instead of 0.84-0.85 cc/g in super calendered coated paper. This is obviously because of the penetration effect which is more in case of supercalendered sheets than in machine calendered (17). Thus, the coating thickness in case of machine calendered sheets is higher than that in supercalendered.

The results of optical properties before calendering are presented in **Table-6.** The gloss values of the SB latex-PVA systems are higher than in the

Table-6			
Optical properties of coated paper (Uncalendered)			
Formulation	**Gloss (%)**	**Brightness (% El)**	**Opacity (%)**
A	10.8	77.5	97.10
B	9.9	79.0	97.02
C	9.3	78.0	97.07
D	10.2	79.8	97.20
E	8.2	78.5	97.13
F	8.4	79.9	97.54
G	13.2	79.3	97.18
H	11.4	79.4	97.56
I	11.6	79.6	97.39
J	11.2	81.2	97.74
K	11.7	80.3	97.57
L	10.6	79.0	97.34

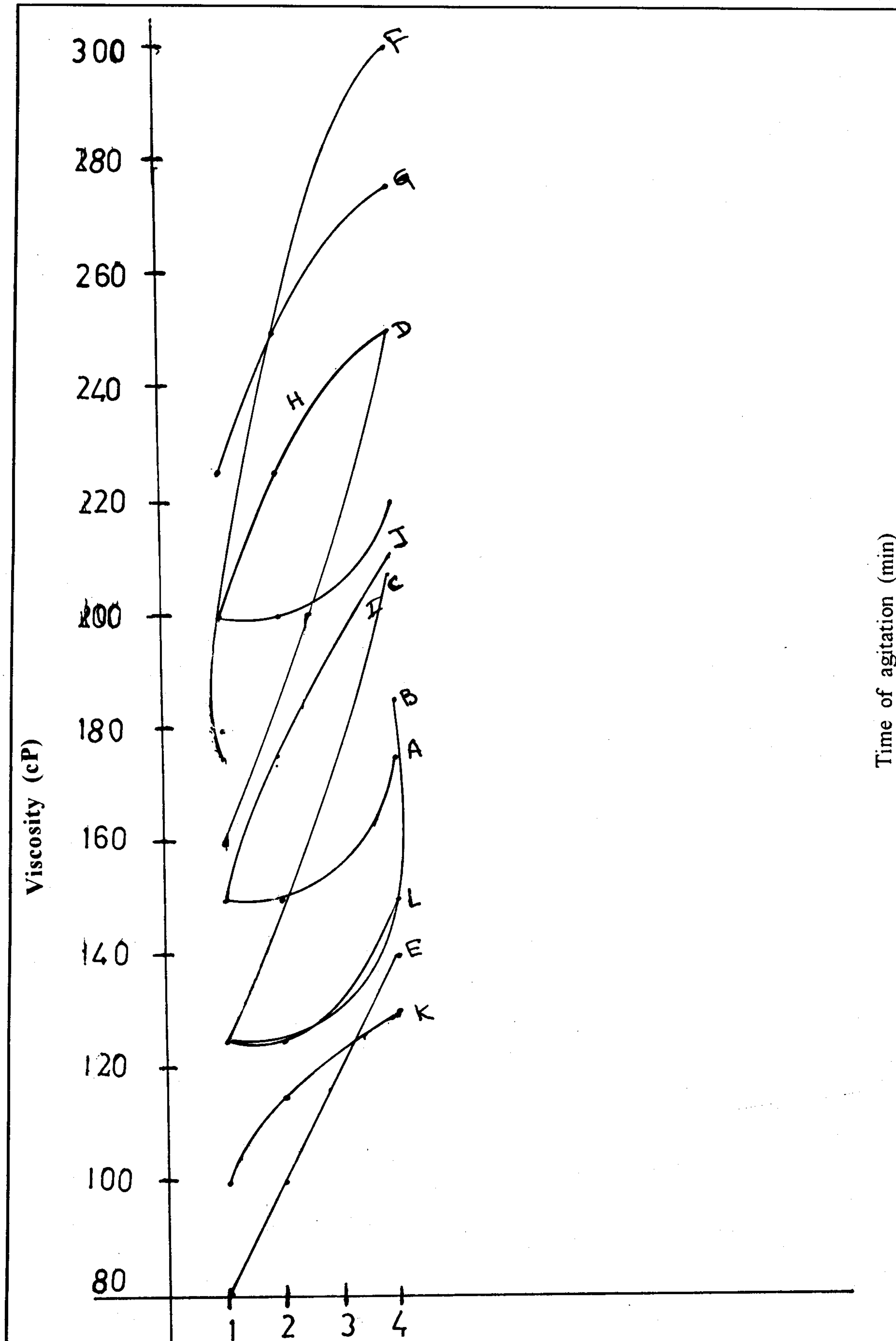

Fig-2 Agitation time Vs Viscosity (12 RPM).

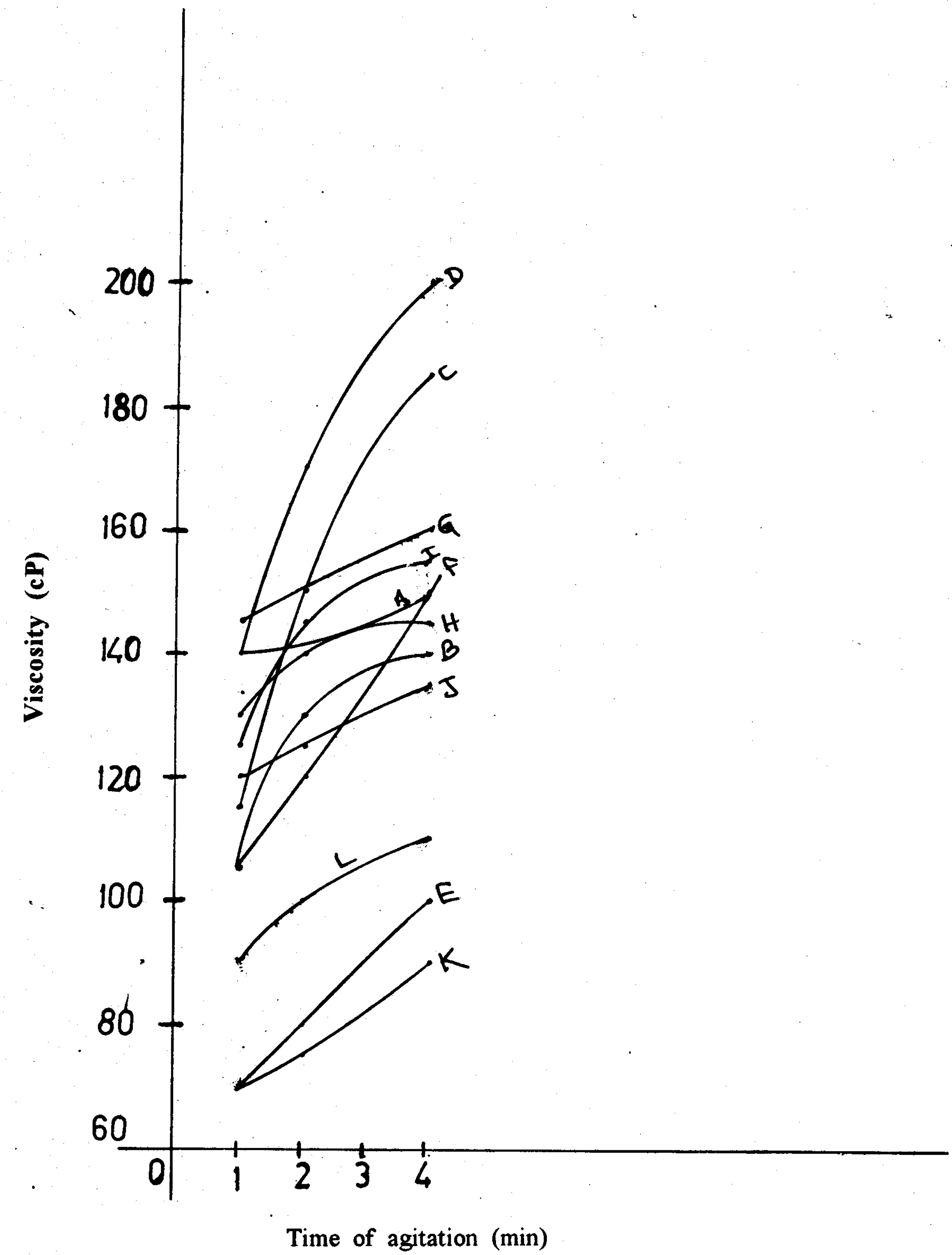

Fig-3 Agitation time Vs Viscosity (30 RPM).

Table-7

Optical properties of coated paper (Machine calendered)

Formulation	Gloss (%)	Brightness (% El)	Opacity (%)
A	36	76.04	96.62
B	35	78.0	96.40
C	33	77.8	96.48
D	38	78.3	96.52
E	31	77.5	96.20
F	33	78.7	96.53
G	43	78.5	96.53
H	42	78.3	96.00
I	39	79.4	96.19
J	44	80.0	97.00
K	36	78.2	96.50
L	35	78.9	96.07

casein-SB latex systems, same as the case with the brightness. However, the difference in brightness and opacity values are not significant. The higher gloss value in case of PVA containing system is due to the superior film forming capacity.

Opacity values in the range of 87-91% were obtained using titania (16), with on-line hot soft nip calendering, the opacity achieved is 85-87% with a coat weight of 8 g/m^2.

The optical properties of machine calendered coating paper are presented in **Table-7.** In the formulations G-L which contain PVA as cobinder, gloss values are higher than that of in the formulations A-F containing casein-SB latex. In case of G-L, the highest gloss values are observed in formulations J followed by that in G and H namely 44, 43 and 42%, respectively. However, even in formulations I, K and L, the gloss values are fairly good compared to the formulations A-F. In E, the gloss value of 31% has been observed. The brightness values of PVA containing systems are from 78.2 to 80% El. while for A-F, it falls between 76 and 78.7% El. Thus, there is an increase of 1-2% El with SB latex-PVA systems. In formulation J, the highest brightness of 80% El has been observed where the gloss value is also highest. The opacity value of formulation J is also highest of all (97%), However, the opacity values of other systems are more or less same.

The results of supercalendered coating papers in **Table-8** are worth comparision with those of machine calendered sheets (Table-7). The gloss values of supercalendered sheets are quite superior to that of simple machine calendered ones. Gloss values of 50-56% have been obtained in formulations A-F and 55-62% in formulations G-L. Here also the formulation J containing 80% clay, 15% talc and 5% titania with SB latex-PVA binder impart the best gloss property (62%). However, the other systems containing talc namely I, K and L have also quite appreciable gloss values and one may tempt to conclude that the talc proportion can be increased to as high as 35-40% provided there is supercalendering.

The brightness and opacity values of supercalendered papers are inferior to those of machine calendered ones. In case of brightness, the difference is 4-6% El while in opacity, it is 2-3% which is quite significant. The higher penetration of the pigment colour in supercalendering thus has adverse effect on the brightness and opacity values. As the voids are better pact in supercalendered coated paper, the particle-air surface gets reduced compared to machine calendered paper, as a result of which the scattering coefficient in the supercalendered paper is lower than that in machine calendered paper. Commercially, therefore, when coated paper with superior brightness and opacity values are required, machine calendering may be preferred but with compromise in gloss

Table-8			
Optical properties of coated paper (Super calendered)			
Formulation	**Gloss (%)**	**Brightness (% El)**	**Opacity (%)**
A	56	73.8	94.62
B	50	74.4	94.89
C	54	74.2	94.94
D	53	75.7	94.86
E	50	74.6	94.54
F	51	74.9	94.60
G	61	74.0	94.50
H	55	75.1	95.90
I	59	74.2	94.89
J	62	74.4	95.97
K	58	74.8	94.11
L	57	74.9	94.35

property. In the surface sized paper which is normally machine calendered, the brightness and opacity values are therefore superior to that of coated paper.

The smoothness and oil absorbency values are given in **Table-9** for machine calendered and in **Table-10** for supercalendered papers. It was observed in our earlier publication (12) that the PVA brings in enhancement in smoothness property in particular. The same observation has been confirmed here too. In case of machine calendering, the lowest value is observed in formulation K which is 18 ml./min. and in formulation J as 15 ml./min. in case of supercalendering. On the other hand, the smoothness values in formulations without PVA range from 23 to 32 ml./min. in machine calendering and 23 to 30

Table-9		
Surface properties of coated paper (Machine calendered)		
Formulation	**Smoothness (ml/min)**	**Oil absorbency (sec)**
A	26	420
B	28	480
C	30	550
D	23	420
E	32	720
F	30	660
G	23	300
H	24	240
I	22	288
J	22	150
K	18	180
L	29	220

Table-10

Surface properties of coated paper (Super calendered)

Formulation	Smoothness (ml/min)	Oil absorbency (sec)
A	23	430
B	26	495
C	22	557
D	25	380
E	30	1020
F	26	1090
G	20	285
H	22	300
I	20	310
J	15	355
K	20	470
L	29	325

ml./min. in supercalendering. It is obvious therefore that PVA improves the smoothness values compared to SB latex binder.

Comparison of the oil absorbency values in Table-9 for machine calendered and Table-10 for supercalendered sheets indicates that the former has marginally lower oil absorbance value than the later. The supercalendering effect closes the voids with more compacity than that in machine calendering as a result of which the oil penetrates at a slower rate and the time for absorption increases (17). In composition E and F, the oil absorbency values have gone upto 1020 and 1090 sec., respectively in supercalendered sheets (Table-10) while the corresponding values in machine calendering (Table-9) are 720 and 660 sec. The compositions E and F contain 40 and 35% of talc respectively and the high talc content can be the reason for higher oil absorbency values. The PVA containing sheets have comparatively lower oil absorbency values.

The printability properties (Ink density, absorbency index and IGT pick resistence) for machine calendered sheets are shown in **Table-11** and for supercalendered sheets in **Table-12.** The ink density values of supercalendered sheets are marginally higher than that of machine calendered ones. However, the difference is not significant. Similarly the absorbency index for the two sets of sheets is fairly close and there was no pick observed in any of the sheets. It appears therefore that the printing performance is affected little when machine calendering is improvised to supercalendering.

Three more coating formulations (M, N and O) with pigment compositions as in J but increasing PVA concentration (3% in J, 4% in M, 4.5% in N and 5% in O), have been taken for coating followed by machine calendering **(Table-13).** Like in J, it showed properties superior to others, pigment composition and PVA being fixed.

On increasing PVA concentration, the viscosity of formulation increases and results in sheets with higher coat weight here than in J, 15.6, 16.2 and 20 g/m^2 in M, N and O respectively in stead of 12 g/m^2 for machine calendering and 13 g/m^2 for supercalendering with 3% PVA in ƒ. The bulk values of the 3 sets are similar as in machine calendering (0.01 cc/g less) but lesser than that in supercalendering where it was 0.84 cc/g. In J on machine calendering, the brightness was 80% El (Table-7) whereas it is reduced to 75.6-76.1% El here. It may therefore be assumed that higher PVA content in the formulation has adverse effect on brightness property. However, opacity value is found to have improved from 97% in J to 97.35% in M, 97.64% in N and 97.82% in O. Thus opacity gets enhanced on increasing PVA concentration. The gloss value also marginally improves from 44% in J to 45.2% in O at 5% of PVA. The values in parenthesis in **Table-13** are on sheets before calendering.

The smoothness value remains practically same on increasing the PVA dosing from 3% to 5% in O. The oil absorbency value increases on increasing the PVA content i.e. 150 sec. in J to 300-390 sec. in these three formulations. PVA appears to be inducing

Table-11			
Printability properties of coated paper (Machine calendered)			
Formulation	**Ink density (X 10^2)**	**Absorbency Index**	**Pick resistance (cm)**
A	29.17	48.92	No
B	28.61	48.25	No
C	28.66	48.31	No
D	26.16	47.71	No
E	28.40	48.01	No
F	28.40	48.00	No
G	28.30	47.88	No
H	28.84	48.53	No
I	28.99	48.71	No
J	28.79	48.46	No
K	29.00	48.71	No
L	29.20	48.95	No

closing of pores and voids in the coated sheets causing difficulty in access of oil to the coated sheet. The oil absorbency value of 355 sec. for J on supercalendering is lower than that in N.

Adhesive penetration through hydrodynamic and capillary pressure in the pores and voids has extensively been dealt in the literature (17). It is evident that supercalendering causes more intensive penetration than machine calendering. In machine calendering, however, when PVA is used as a cobinder with SB latex, penetration of binder and pigment particles also takes place as it can be seen from oil absorbency values. The gloss, printability and smoothness properties imparted on supercalendering to the coated paper, can also be obtained fairly on machine calendering. Moreover, the brightness and opacity values are better on machine calendering than on supercalendering. Therefore, with application of synthetic binders, namely PVA and the specially produced talc as coating pigment, machine calendering can also serve the purpose. However, from versatility point of view, soft calendering with supercalenders will be preferred.

Titania at concentration of 5% or above is excellent as gloss improver (16). Titania has high light scattering efficiency; therefore high opacity is also possible on using titania but with the talc, similar opacity value is obtained. Thus, this special grade talc can replace titania.

Table-12			
Printability properties of coated paper (Super calendered)			
Formulation	**Ink density (X 10^2)**	**Absorbency Index**	**Pick resistance (cm)**
A	29.50	49.31	No
B	28.78	48.45	No
C	28.93	48.63	No
D	28.75	48.42	No
E	29.45	49.25	No
F	28.77	48.44	No
G	29.82	49.84	No
H	28.99	48.71	No
I	30.02	49.90	No
J	29.52	49.32	No
K	28.81	48.49	No
L	29.09	48.82	No

Table-13				
Properties of coated sheets (Machine calendered) with varying PVA dose				
Property	**Unit**	**M**	**N**	**O**
PVA content	(%)	4.0	4.5	5.0
Coat weight	(g/m^2)	15.6	16.2	20.0
Bulk	(cc/g)	0.88	0.88	0.89
Brightness	(% El)	75.6 (78.6)	75.9 (78.8)	76.1 (79.2)
Opacity	(%)	97.35 (97.6)	97.64 (97.75)	97.82 (98.0)
Gloss	(%)	44.3 (11.3)	45.0 (11.5)	45.2 (11.9)
Smoothness	(ml/min)	21	20	23
Oil absorbency	(sec.)	340	390	300
Values in parenthesis are for sheets before calendering.				

CONCLUSION

Supercalendering and machine calendering of coated sheets are found to produce different effects. The gloss of supercalendered sheets is superior to that of machine calendered sheets whereas the brightness and opacity values of machine calendered paper are higher than that of supercalendered ones. Printing properties and smoothness remain more or less same in the two calendering modes. Supercalendering brings in intensive penetration of the adhesive into the voids for which the bulk and oil absorbency properties are affected. Increasing PVA concentration in the coating formulation as cobinder with SB latex also favours adhesive penetration in coated sheets during machine calendering resulting in higher oil absorbency values. SB latex- PVA binder imparts better coating performance than casein-SB latex.

The special grade talc can replace titania and can be used upto 15-30% with china clay as coating pigment.

ACKNOWLEDGEMENT

The authors are thankful to the Management of Pulp and Paper Research Institute, Jaykaypur for giving permission to publish this paper and to M/s. J.K. Paper Mills, Jaykaypur, Orissa for their assistance and kind help.

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