A

DISSERTATION REPORT

ON

"IMPACT OF COATING ON PAPER PROPERTIES"

Submitted for partial fulfillment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY

IN

PULP AND PAPER

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Date: 10/06/2013

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CANDIDATE'S DECLARATION

I hereby declared that the work which is being presented in this Dissertation Report entitled "*IMPACT OF COATING ON THE PAPER PROPERTIES*" in partial fulfilment of the requirement for the award of the degree of Master of Technology in Pulp and Paper, IIT Roorkee, Saharanpur campus is a record of my own work carried out, under the supervision of ***Dr. Vivek Kumar***, Associate Professor, Department of Paper Technology, IIT Roorkee Saharanpur Campus, Saharanpur, U.P.

The matter embodied in this dissertation report has not been submitted by me for the award of any other degree.

Date: 10/06/2013

Place: Saharanpur

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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Introduction

1.What is Coating?

Coated paper is paper which has been coated by a compound to impart certain qualities to the paper, including weight, surface gloss, smoothness or reduced ink absorbency. A layer of coating mixture is placed over the base paper by using various pigments and then calendaring is done to obtain the desired properties.

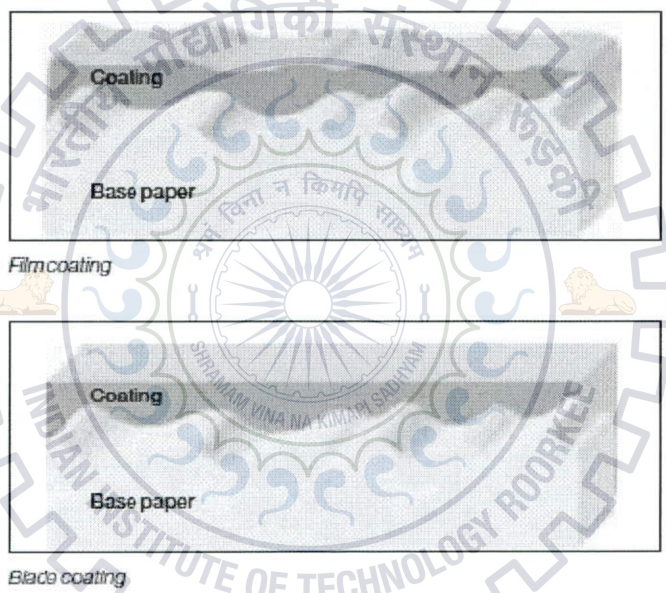


Fig 1: Coating on base paper

Pigments are the main constituent of the coating. The binders and various additives that may be included normally comprise less than 20 %(by weight) of the coating formulation. Pigment coating in which an aqueous mixture of pigment and adhesive is applied to the surface of the paper. This type of coating is used for publication papers used in magazines. The pigment coating provides a surface that is more uniform in appearance and more receptive to printing ink than the uncoated paper fibres.[9]-[10] Coating improves the printing properties of the paper. In the coating of paper, aqueous suspension called coating colour is applied to one or both sides of paper. After application of the required amount, the coating is dried and finished. In finishing, the coated paper achieves its smoothness and gloss potential.

1.1History of coating

There are many kinds of paper made in the world today, for many uses, but pigmented coated paper for printing is by far the most common. Speciality paper for specific function such as sandpaper, carbon tissue, gummed paper, photographic papers, wallpapers, conductive papers, are all coated one way or another but not in the volume of pigment-coated printing paper. Frequently, these special operations are classed as converting and carried out remotely from the paper mills. Pigment coating was invented to provide the printer with a sheet with superior surface for printing. It provided enhanced smoothness, better ink receptivity, more whiteness, and more gloss. A much improved printed sheet was obtained. The benefits justified the extra cost. By 1852, pigment coated paper was recognised product.

Coated paper was first developed commercially about 1852 because of the demand for better printing results. As it was first made, a thin layer of clay and glue was applied to the surface of web of paper, which was then dried and calendared. In the middle 1890's, casein began to replace the glue as an adhesive. Starch has not had any marked success as a full substitute for casein, but it has been used for many years and is being used satisfactorily in certain grades of paper. The original papers surfaced with clay, but modern practice has broadened the field to include other pigments, as blanc fix, satin white, precipitated chalk, titanium dioxide, alumina, talc, etc., each of which has certain desirable characteristics.

As first made, coated papers filled a place for which no other paper was satisfactorily. Since then, they have had to compete with greatly improved super calendared plain papers, while the present tendency is to replace the coated with so-called semi coated paper, which is made by applying a much thinner coating at high speed on the paper machine, or as a separate operation. This latter type of paper at first competed only with the lower grades of paper; but with increased experience, it is being improved very materially. Global coated paper production for printing amounts to between 45 and 50 million tonnes annually, with a growth rate of between 4 and 5%. Over the past 15 years there has been a downward trend in prices, and in order to remain competitive, mills have had to improve efficiency and reduce costs. [4]-[7]A series of technical innovations have made a major contribution to this by improving process efficiency. Examples in the coating line include moving from roll to jet applicators, then to metered size press. These developments allow faster production speeds. Spray and curtain coating have progressed through the development stage and are awaiting commercial adoption. Other innovations include the streamlining of papermaking, coating and calendaring into an continuous on-line process.

The quality of coated paper is mainly governed by the characteristics of base paper. The three main base paper properties which contribute to the variations on coat weight and print non-uniformity in coated paper are roughness, absorbency and sheet matrix formation. Increase in roughness of base paper gives coated paper of lower smoothness and gloss at a particular coat weight. Along with roughness the compressibility of base paper also plays important role.[2]

Porosity and sizing degree which affect absorbency of base paper also affect the coated paper quality. Porosity of base paper has minor effect on coated paper roughness. The gloss of coated paper is improved with sizing and sheet densification. Sheet matrix non-uniform formation has little effect on coated paper gloss, however, it adversely affects the smoothness and print uniformity.

Loading of base paper with PCC gives better effect on brightness, picking velocity and print saturation density than GCC and Talc.[2] In the paper coating process, a water based pigmented coating is applied to base paper to enhance the optical and topographical properties of the pigmenting surface. The quality of coated paper is mainly governed by the characteristics of base paper. The structural deficiencies of base paper get magnified after coating. Different mechanisms have been proposed to explain the effect of base paper on coated paper quality. Print non-uniformity has been often associated with local variation in coat weight originating in the base paper. The uniformity in ink transfer and setting is affected by chemical composition and pore structure which are responsible for coat weight variation. The three main properties which contribute to the variation in coat weight and thus print non-uniformity are smoothness, absorbency and sheet matrix formation.

1.2 Purpose and General process

The primary object in the coating operation is to produce a sheet with an even, semi absorbent surface for printing. This is affected by covering the fibre on the surface of the paper and filling the hollows between them with finely divided mineral matter, mixed with an adhesive or "size". When such paper is calendared, there results a smooth, even surface, which reproduces the halftone dots of the printing plate much more faithfully than any plain paper.

Originally, the coating mixture was spread on sheets with hand, being applied by a brush and then more uniform by rapid rotary strokes of a finer brush. Modern method applies the coating to the continuous web of paper on one or both sides of paper at one time, and a speed upto1200 f.p.m. The spreading is done by brushes, blade. It is worth noting that the final adhesive ratio in the dried coating not only can differ from the formula ratio but also can vary from region to region within the coating. Uniformity of this pigment to adhesive ratio is depends on the state of mixing and the rheology of the coating mixture.

Clay may be added to the coating mixer in dry condition as received, and many mills still use it that way. This practice is objectionable, because variation in the moisture content may cause variation in the solid content of the coating mixture, as well as in the proportion of clay to the adhesive. It also causes the loss of time in preparing the mixture and in adjusting the ratio of clay to the adhesive, if the proper strength of coating is not obtained at first trial.

A preferable method is to mix the clay with water in definite proportions and to measure this out by weight or volume when making the coating mixture. Such clay will vary in fluidity, according to the type of clay used and amount of water used. There is generally no difficulty in reaching 60 % solids or more and at the same time the slurry will be in proper condition to pump readily.

2.Coating Methods

2.1Spray coating has recently been introduced to the paper industry. The process is very simple, with the coat weight and speed limited only by the number of spray nozzles fitted. Again both sides are coated at once, and quality is improved by arranging the nozzles so that the spray fans overlap. It is important to allow the drops time to spread on contact with the paper so that all the surface is covered. Hence the coating solids is low and rapid immobilisation of the drop should be avoided. Only one commercial spray coater installation has been made to date. Spray coating has received considerable attention during the last few years. A commercial spray coating system for paper is available and there is currently one working installation in Europe. The spray coater is a simple system which can coat both sides of the paper at once. The speed and coat weight that can be applied is constrained only by the web handling system and the number of nozzles fitted. Coating quality is improved by arranging the nozzles in overlapping rows . Two banks of spray nozzles are fitted, so that one is in use while the other is being cleaned. The current life of each spray nozzle now extends to a period of weeks.[1],[11]

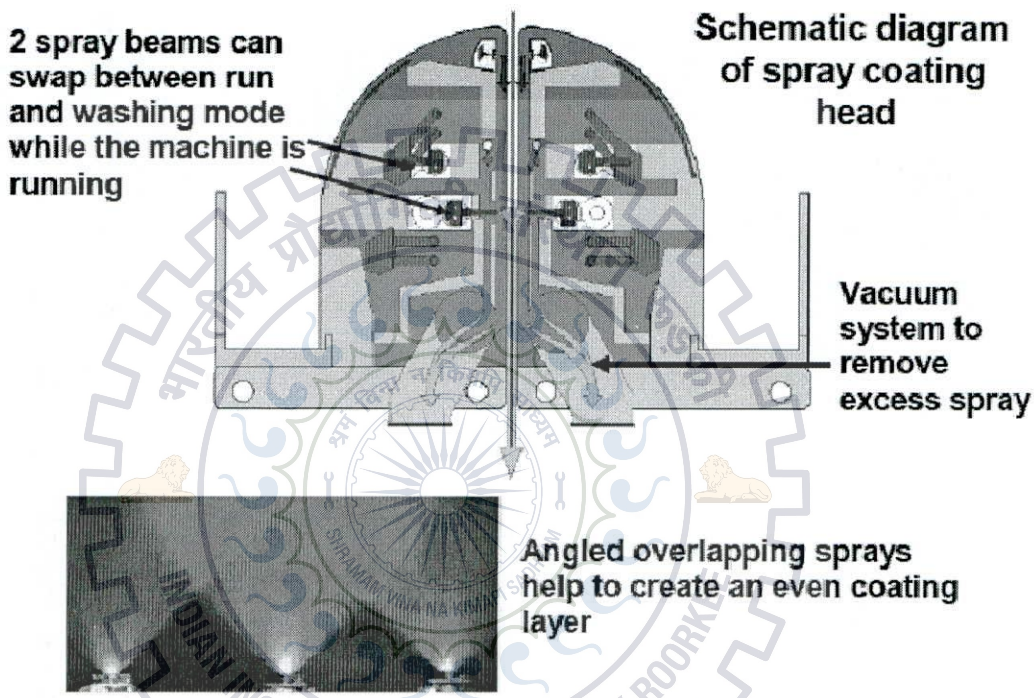


Figure 2. Spray coater layout (courtesy Metso)

2.2Curtain coating is currently being widely trialled by a number of suppliers. Already used in the coating of specialised papers such as carbonless copy grades, the higher quality required for graphic papers means that air bubbles must be reduced to a very low level. The advantages offered by curtain coating include very good fibre coverage resulting from the very low impact and the ability to apply multilayer simultaneously. This will enable the redesign of the coating to optimise both the optical and printing functions of the coating layer separately in a way not possible previously. Considerable research effort is currently being spent to apply the technique of curtain coating to graphic papers. Already used in less demanding speciality grades like thermal papers, its use in high quality graphic papers requires extremely low levels of air bubbles. Some publications have already been made which establish the operating parameters for high speed curtain coating of graphic papers at pilot scale. Triantafillopoulos *et al.* describe trials in which successful curtain coating of paper webs was achieved at speeds of 1400 m /min. Coating coverage was superior to MSP coated control papers. Other studies published recently describe the influence of parameters such as dynamic surface tension and elongational viscosity.

The most promising application currently is in the coating of paperboard, particularly when the substrate is dark in colour. Slow speed air knife coaters are often used to give a contour coat of opacifying mineral in order to cover the dark base. The curtain coater has been shown to provide a similar contour coating, but at higher speeds, which minimises brightness mottle in the final coated board. A joint study has recently been published which shows that while the contour nature of the coating gives an even appearance, it gives a coating with a high roughness and low gloss. The high roughness leads to very poor print quality when the board is printed by the rotogravure process. A combination of curtain and blade seems to best compromise to obtain even appearance and acceptable smoothness.

A second advantage of curtain coating lies in the potential to apply several layers simultaneously. Thus future coater designs could have a much smaller footprint, but more exciting is the potential to functionalise each layer. Hence the light scattering and ink accepting functions of the coating could be decoupled, allowing the sheet to be redesigned. Other functions, such as a barrier layer, could be introduced. Such concepts were illustrated recently in two papers presented at the TAPPI Coating Conference 2005.

Urscheler et al. Describe trials in which up to 3 layers were applied simultaneously. They also demonstrated the concept of an "carrier" or interface layer to assist the wetting of the substrate. Top layer coat weights as low as 2 gm-2 were shown to be effective in conferring gloss and printability. ***Hiorns and Kent*** showed that applying multiple thin (~2 gm-2) alternating layers of kaolin and precipitated calcium carbonate (PCC) gave synergistic increases in light scatter and gloss compared to using hick layers of each or simple blends of the two minerals. This is a result of the higher porosity and hence air content of the PCC layers compared to the kaolin, which generates alternating layers having different refractive indices - the minerals themselves have very similar RI values. Using thinner layers increases the number of refractive index steps and brings the size of each scattering layer closer to the wavelength of light. Similar effects could be achieved using minerals of higher RI such as TiO_2 but at much higher cost. Although Hiorns and Kent used wire wound rods and very dilute coating colours in the laboratory, using a multilayer die on a curtain coater is currently the only way of realising such a structure commercially.

2.3 Blade metering

Historically, production of coated paper was carried out using air knife metering, which has a severe speed limitation (200 m/ min). During the 1950s, metering using a steel blade was introduced and enabled paper to be coated at 600 m min^{-1}. The subsequent development of blade coaters during the following 2 decades tripled this speed to a maximum of 1800 m/min. The classical blade metering system consists of a roll applicator which initiates dewatering of the coating formulation into the base paper. The excess coating is then removed using a steel blade to give a controlled coat weight. Following drying, the process is then repeated on the other side of the paper. Such a system is referred as a long dwell, meaning that the wet coating is in contact with the paper for a relatively long time scale (of the order of tens of milliseconds) before metering. Later developments replaced the applicator roll with an applicator feed just before the blade, the so-called short dwell time system. Here the coating was only in contact with the paper for tens of microseconds. However, flow instabilities in the head gave problems with barring, and for the highest speeds with blade metering devices, current machines use a jet applicator, also a long dwell system.[1]

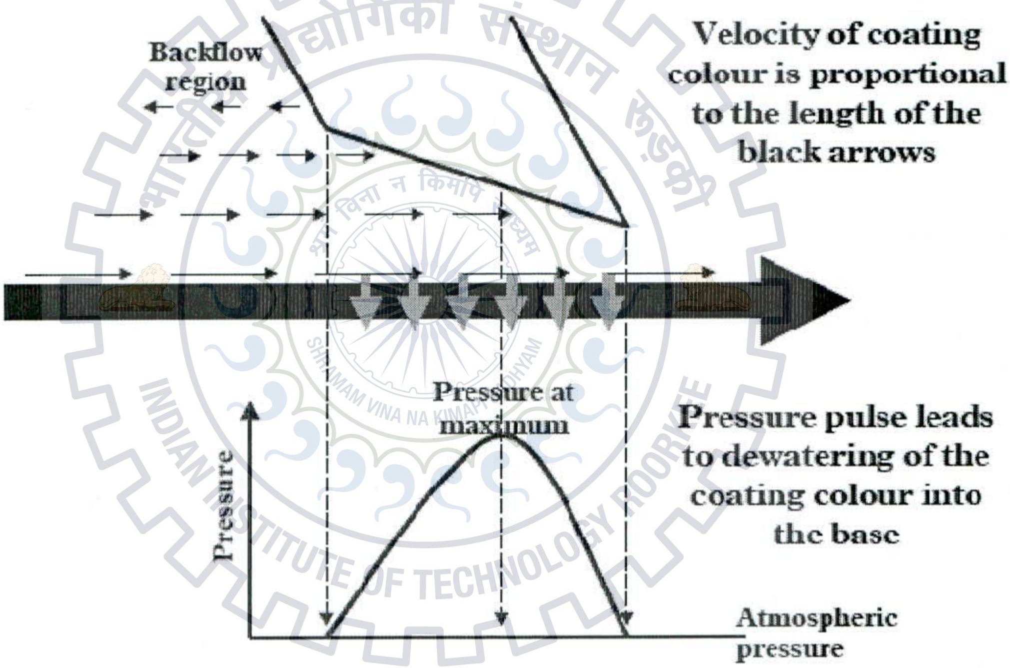


Fig 3: Diagrammatic representation of the pressure distribution under a metering blade.

All blade metering systems place a large stress on the paper, which increases with speed. The reason for this is shown in Figure 2, and arises from the loading applied to the back of the blade which balances the hydrodynamic force arising from the velocity of the coating. Kahila and Eklund have estimated that the pressure can be as high as 4 bar. The stress is concentrated over a relatively small area under the tip of the blade, and frequently results in breaks during production, especially when coating lightweight papers at high speeds. The downtime associated with production breaks represents a major increase in cost for the papermaker. This is particularly the case where the papermaking, coating and finishing processes are all carried out in-line in a single operation, which is the most cost effective arrangement.

2.4 Metered size press

In the search for more efficient paper production, methods which placed less stress on the paper were needed. The most successful of these is undoubtedly the metered size press (MSP), or film, coater, introduced in the 1980s. This is essentially a development of the pond size press, which is a rather crude system normally used to apply a layer of starch solution to the paper.[6]

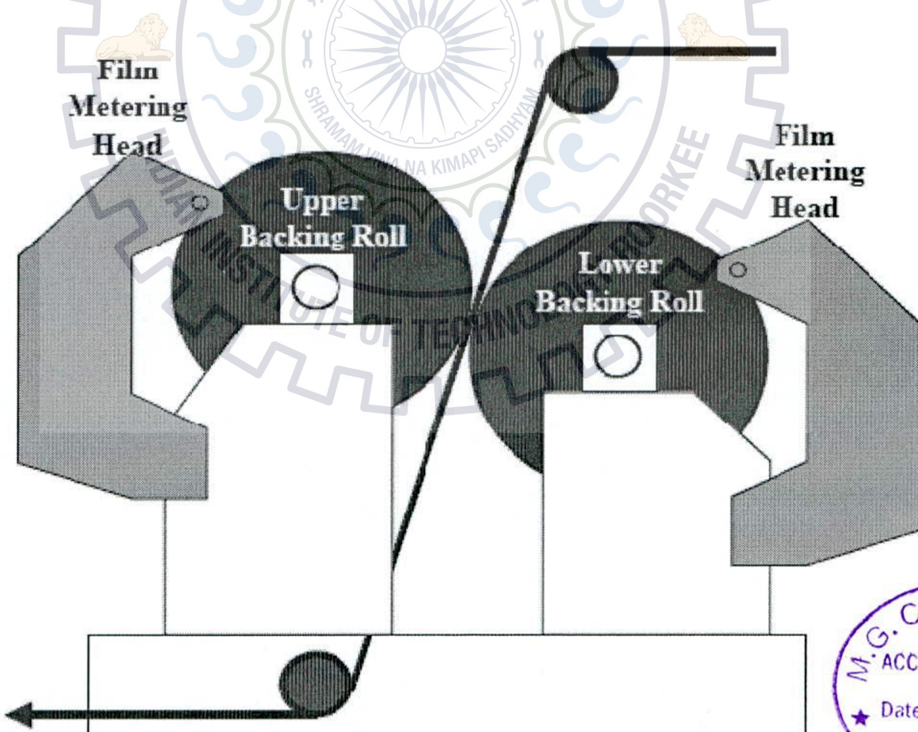


Fig 4: Layout of Metered Size Press

In the metering size press, the coating is premetered (using blades or rods) onto a pair of polymer covered rolls, which then transfer the coating to the paper.

Both sides of the paper are thus coated simultaneously (Figure 3). For information on the development and use of the MSP the reader is referred to the proceedings of the four MSP Forums run by TAPPI between 1996 and 2002. The device puts less stress onto the paper than blade metering, which as well as reducing the number of breaks, has the benefit of giving improved coating coverage. Preston and Hiorns showed that MSP coatings have a narrower distribution of coating thickness compared to blade coatings. A similar conclusion was reached by ***Endres and Tietz.*** The upper speed limit of the MSP is currently around 2000 m/min and is constrained by the phenomenon of misting at the exit of the nip. This arises from filamentation during the film splitting process. A number of studies have been made to understand the phenomenon and propose a solution. The key to obtaining acceptable coating quality using a spray is to allow the droplets to spread and coalesce after they hit the paper. This is done by adjusting the base paper properties and coating formulation so that the coating does not immobilise too quickly. Hence the base paper water absorption should be low and the coating formulation water retention high, with a low surface tension.

2.5 Dry coating

Dry coating is still in the early stages of development, the concept of applying the coating in powder form electro statically, and then thermally plasticising the coating layer has been developed in the laboratory. Based on the principles of xerography, this work has shown that, using conventional coating formulations and ingredients which have been freeze-dried, coating properties which are comparable to those of conventional papers can be obtained, although the binder level required is at least double. The average pore size is also larger than in conventional coated papers. However, there is much development still to be done, and it is unlikely that conventional film forming latexes and coating pigments will be optimised for this technology. Such a process removes the drawbacks associated with wetting and swelling of the fibres, but replacement of conventional coating processes would require huge volumes of very low density powder to be manufactured and transported. In our view, the process is most likely to be used as an "add-on" to a printing line to upgrade relatively small volumes of bespoke product.

3.1Function of different components in coating mixture

Binders:

- Also referred as adhesives
- Function: Bond the pigment particles to one another and to the surface of the base stock.
- Determine viscosity, water release and set time for the coating.
- Optimize use will have better optical and printing properties.
- Water soluble colloids: Starch, Protein, Polyvinyl alcohol
- Aqueous emulsions of synthetic fibres: Styrene-butadiene
Latex, Polyacrylate, Polyvinyl acetate

Dispersant :-

- A dispersant or a dispersing agent or a plasticizer is either a non-surface active polymer or a surface-active substance added to a suspension, usually a colloid, to improve the separation of particles and to prevent settling or clumping. Dispersants consist normally of one or more surfactants, but may also be gases.
- In order to provide optimal performance, pigment particles must act independently of each other in the coating film and thus must remain well dispersed throughout manufacture, storage, application, and film formation. The main purpose of the dispersant is to achieve minimum viscosity of the prepared coating formulation. Colloidal dispersions such as the pigment dispersions in liquid coatings are inherently unstable, and they must be stabilized against the flocculation that might occur.

Component	Examples	Function
Pigments	Kaolin, Calcium carbonate, Titanium Dioxide, Plastic pigments	Support a structure of fine porosity and form a surface which scatters the light.
Adhesives	Soluble in water (glues, starches, gums casein, soya protein and others); Polymer emulsions (latex, polyvinyl acetate, acrylates	Bind the pigment particles between itself and the coating layer onto the paper. Fill pores between the pigments.
Dispersants	Polyphosphates, Ligno sulphonates Silicates	Optimize the pigment dispersion
Cross Linker	Ammonium Zirconium Carbonate (AZC)	Provide wet pick resistant.
OBA	Natrium salts	To increase brightness
Lubricant	Calcium stearate	Improves flow properties, prevent coating adhesion on to calendar.
Thickener	CMC, Acrylic polymers	Modifies the rheology and/or the water retention of the color

Table-1

3.2ADHESIVE DISTRIBUTION

The adhesive ratio (parts adhesive/100 parts pigment) is a major variable in producing pigment coatings of a given strength. It is worth noting that the final adhesive ratio in the dried coating not only can differ from the formula ratio but also can vary from region to region within the coating. Such variations in adhesive content are more the rule than the exception in commercial pigment coatings.[4]-[5] Higher contents of adhesive may increase strength by forming more adhesive-pigment bonds, reducing the void volume, relaxing stresses, decreasing stress concentrations, and increasing the cohesive strength of the adhesive. It is worth noting that the final adhesive ratio in the dried coating not only can differ from the formula ratio but also can vary from region to region within the coating. Such variations in adhesive content are more the rule than the exception in commercial pigment coatings. It is worth noting that the final adhesive ratio in the dried coating not only can differ from the formula ratio but also can vary from region to region within the coating. Such variations in adhesive content are more the rule than the exception in commercial pigment coatings. It is worth noting that the final adhesive ratio in the dried coating not only can differ from the formula ratio but also can vary from region to region within the coating. Such variations in adhesive content are more the rule than the exception in commercial pigment coat.

4.Defects during the coating

4.1Defects in ON- Machine coated papers:

ON-machine papers generally have defects due to following reasons:

1. Coating formulations and its application.
2. Variation in concentration with time.
3. Variation in binder to pigment ratio with time.
4. Variation in concentration due to heat of draying system
5. Variation in temperature of paper

4.2 Defects in OFF-machine coated papers:

Defects developed in a coated paper due to one or more of the following reasons:

The defects might be due to defect in base paper itself. Some of the defects from base paper are following as:

1. Variation in moisture, calliper basis weight or retention in MD/CD.
2. Fluff in paper due to machine press picking or fluff from dryer due to high temperature difference between web and first machine dryer.
3. Calendar dust due to uneven retention, high filler content or surface strength.
4. Very low cob values resulting in poor coat weight pick and poor binder effect between paper and pigment.
5. Pin holes in base paper, resulting in binder flow to other face.

4.3 Defects due to coaters:

Temperature of the formulation and web: In on-machine coaters, the hot web goes to coater while in off-machine paper is at ambient temperature. Thus temperature of web must be considered while choosing binder, dispersant and other additives.

On-machine coating require very special attention. It is not only the temperature of paper but also the evaporation/drying taking place before coat is applied. The paper must have stabilised its temperature and moisture profile before coat is applied. The formulation should have binder which can tolerate the thermal shock. Generally the formulation is applied at higher temperature in such coaters.

Off-machine coating is relatively simpler. The temperature and moisture profile of paper stabilizes before the application of coat. Cooling of reel and moisture absorption from atmosphere can result in paper defects.

4.5 Control of flow and mixing of formulation

In coater, formulation is stripped in excess. The metering system (blade, air knife, roll nip) permit only required quantity of coat to go with paper and rest comes back to coat supply tank through as sieving or cleaning system. This coating formulation from coater can carry materials which can cause defects.

- Dirt from coater
- Fluff dust from paper
- Material from coater parts
- Dirt from machine

4.6 Objective of calendaring:

The objective of calendaring is to alter the surface characteristics of paper with regard to its further use, such as writing and printing, depending on the individual grades, the focus is put on different technological properties. These are mainly

- Gloss
- Smoothness/roughness
- Density
- Brightness and opacity

Smoothing the surface and increasing gloss are accompanied by reduction in calliper, strength properties, brightness and opacity to a certain degree.

The main factors in calendaring – apart from furnish and paper properties such as moisture, temperature and coating- that influence the above mentioned technological result are:

- Nip pressure/load
- Nip dwell time
- Roll elasticity
- Roll surface temperature and smoothness

4.6 Soft-nip calendaring:

Soft-nip calendaring is a method of finishing coated paper or paperboard in line with the coating and drying processes. In sequence, the web is coated, dried to optimum moisture, and finished by hot thermal calendaring in its simplest form consists of a smooth highly polished, hot roll or moulding drum and pressure roll which form a nip loaded by or just ground to a very smooth surface finish and is heated by steam, oil or other controllable means to temperature ranging from 200 to 600 ^{0}F.

5. Aim

To Study the Impact of Coating on Paper Properties.

6.Material and Methods

6.1 Material used

6.1.1 Base paper properties

Properties	Base paper -1	Base paper-2
Gsm (g/m^2)	65.8	122
Tensile Strength(N/15mm)	2.8	3.1
Tear Strength(g.force)	10	16
Burst Strength(kgf/cm^2)	1.3	1.2
Thickness(µm)	69	75
Brightness(%)	77.6	79.4
Opacity(%)	91.1	94
Porosity(ml/min)	360	380
Smoothness(ml/min)	208	120

Table-2

6.1.2 Clay characteristic

- Pigment - Clay
- Processed China Clay Powder
- Grade - AK-55
- Make - Alpha Minerals and Chemicals

6.1.2.1Particle size distribution of Clay

	D10	D50	D60	D85	D90	D95	D97	D99	D100
Size (µm)	0.33	0.86	1.00	1.48	1.96	3.10	3.82	5.70	25.00

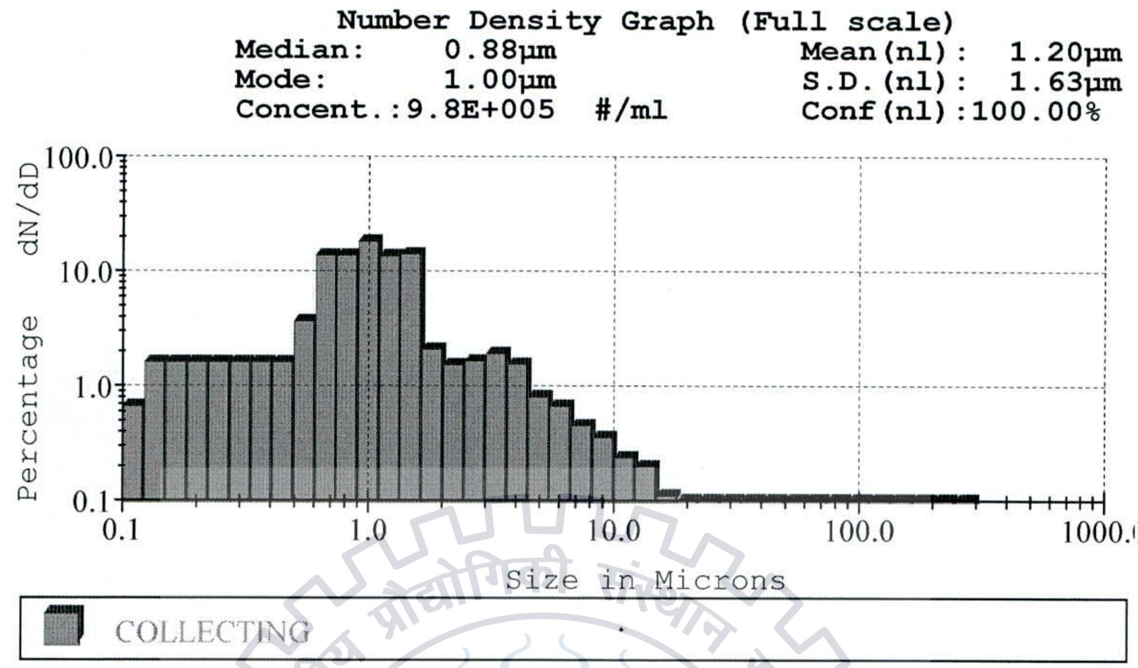


Fig:5

6.1.2.2 Oxide concentration (in %):

Oxides	Clay sample
Na2O	0.317
MgO	0.212
SiO2	35.002
P2O5	0.029
SO2	0.015
K2O	0.233
CaO	0.269
TiO2	0.513
Cr2O3	0.009
MnO	-0.011
Fe2O3	0.466
SrO	-0.197
Al2O3	24.790
Total	61.647

Table-6

The clay used in coating is a hydrated aluminum silicate of slightly varying composition and with small amount of impurities. The best grades formally obtained from England, but changes in treatment and manufacturing of American clays have so greatly improved them that they are now equal or superior in many respect to the English clays. These changes have been towards better color and brightness and smaller particle size, which means higher gloss and better printing qualities in the coated papers. Clay also the cheapest pigment used in the paper industry, hence it is cost effective and easily available. It provides stiffness to the paper. Disadvantage is that clay is not suitable to get the paper of high brightness. Its refractive index is 1.56.

6.1.3 TiO_2 specifications

Molecular weight-79.9

Loss on ignition- 0.5%

Iron (Fe) – 0.05%

6.1.4 Grounded calcium carbonate

Grounded $CaCO_3$ used in powdered form, available in the laboratory.

Molecular weight – 100

Level of purity – 99.5%

Latex in liquid form used as adhesive.

Starch is used as adhesive.

Dispersant was obtained from the industry.

6.1.5 PVA Characteristics

- Adhesive - PVA
- Polyvinyl Alcohol, cold water soluble
- Molecular Wt.- 140,000
- Maximum limits of impurities:
- Chloride(Cl)- .001%
- Viscosity- 4-6 cps(4% aq. Sol.,20 □C)

6.1.6 Latex and Starch were also used as binder.

6.2 Methodology

Using combinations of pigment, adhesive and dispersant, different coating formulations were prepared. These coating formulations applied to A4 size base sheet using an automatic bar coater for surface coating. The coating amount was adjusted using bar of different numbers. The coated sheet was placed immediately in an oven maintained at 104 ^{0}C for 1-2 minutes to dry. The sheets were coated on one side. The coated paper is calendared in the laboratory coater using hard nip. Each paper was calendared at the load of 30 bar and at room temperature.

The coating colour preparation was proceeded in the order of pigments (china clay, GCC, TiO_2) and dispersed in distilled water (with high speed mixing). The distilled water was used for even mixing of the pigment in proper concentrated slurry and dispersant (at high speed mixing) was added. Finally NaOH is added (at low speed mixing) to maintain the desired pH values and then water is added to maintain the desired slurry.

In this study Clay, GCC and TiO2 were used as pigment and adhesive used were PVA, latex and starch.

6.2.1 Coating – The Actual Process

Meter bars provide the simplest method of applying accurate, repeatable layers of surface coatings on top most substrates. A meter bar is produced by winding precision drawn stainless steel wire on to a stainless steel rod resulting in a pattern of identically shaped grooves. These grooves then precisely control the wet film thickness. Close wound bars will produce coating thickness from 4 to 120μm. Higher coating weights up to 500μm can be obtained using spirally wound bars.

- Different coating formulations of clay, GCC and binder have been prepared using different combinations of concentration.
- Paper sheets were coated using K Control Laboratory Coater (Model no-202) at different speed.
- Standard coating bar with different numbers with different speed combinations were used.
- Drying: Coated papers were oven dried.

Dried paper sheet tested for physical and optical properties in the laboratory to study the change in the paper properties.

- Comparative study of measured properties was done.

6.3 TAPPI Standards

6.3.1 Brightness and opacity

- Brightness and opacity of the prepared paper sheets without coating and with coating was measured with the "Brightness, opacity & colour transducer. Before the measurement, the instrument was calibrated using a standard procedure of using a tile having a brightness of 84.7% and monochromatic light of wavelength 457 nm according to the TAPPI standard (T 452 om-02). For opacity measurement, the monochromatic light of wavelength 557 nm was used and the instrument was standardized for 100% opacity with the help of plies of sheets.

6.3.2 Tensile strength

- The tensile strength of the prepared paper sheets was measured using **"Electro-hydraulic tensile strength tester".** Tensile strength is the maximum tensile force developed in a test specimen before rupture under prescribed conditions and it is the force per unit width of test specimen. [TAPPI standard 494 om–01]

6.3.3 Tear strength

Tear strength is the force required to initiate or continue a tear in a material under specified conditions.[TAPPI 414 om-98] **Elmendorf tearing resistance tester** was used.

6.3.4 Burst strength

Bursting strength of a material is defined as the maximum hydrostatic pressure required to rupture the material when a controlled and constantly increasing pressure is applied through a rubber diaphragm to a circular area of 30.5 mm diameter [TAPPI 403 om-02] using **"Mullen Burst Tester".**

6.4 Properties measured on the following standards:

Properties	Standards
Tensile strength (kN/m)	TAPPI T494
Tear strength(N/m^2)	TAPPI T414
Burst Strength(kPa)	TAPPI T403
Folding Endurance(No.)	TAPPI T571
GSM(g/m^2)	TAPPI T410
Brightness(%)	TAPPI T452
Opacity(%)	TAPPI T425
Porosity(ml/min)	TAPPI T460
Smoothness(ml/min)	TAPPI T479

Table-4

6.5 Variation in Coating thickness with wire diameter of coating bars

BAR NO	COLOR CODE	WIRE DIAMETER		Wet film deposit	
		Mm	Inches	micron	inches
0	White	0.05	0.002	4	0.00015
1	Yellow	0.08	0.003	6	0.00025
2	Red	0.16	0.006	12	0.0005
3	Green	0.31	0.012	24	0.0010
4	Black	0.51	0.020	40	0.0015
5	Horn	0.64	0.025	50	0.0020
6	Orange	0.76	0.030	60	0.0025
7	Brown	1.00	0.040	80	0.0030
8	Blue	1.27	0.050	100	0.0040
9	Tan	1.50	0.060	120	0.0050

Table-5

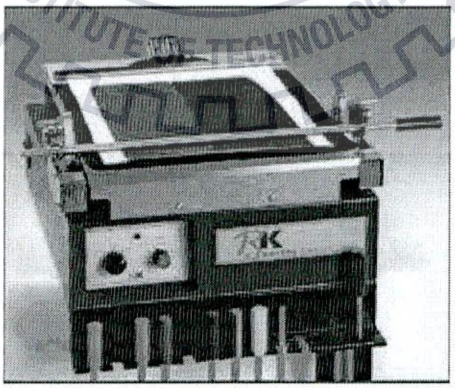


Fig 6: K CONTROL COATER 202

7. Results and Discussion

7.1Base paper 1

Clay coating results for base paper-1 with different adhesives at varying solid concentration.

Properties	Uncoated paper	CLAY + LATEX			CLAY+ PVA			CLAY + STARCH		
		A	B	C	A	B	C	A	B	C
gsm(g/m^2)	65.8	68	70.6	71.4	76	78	78	68.6	72.1	74
Tensile Strength(N/15mm)	2.8	3.0	3.3	3.4	3.6	3.6	3.8	3.0	3.2	3.5
Tear Strength(g.force)	10	10.0	10.0	10.2	10.2	10.3	10.5	10.0	10.1	10.2
Burst Strength(kgf/cm^2)	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.3	1.4	1.4
Thickness(μm)	69	70	70	72	69	70	71	70	71	72
Brightness(%)	77.6	78.0	78.3	79.0	79.7	80.0	81.2	78.5	78.9	79.2
Opacity(%)	91.1	91.8	92	92.1	93.0	94.2	94.7	91.7	91.7	91.9
Porosity(ml/min)	360	320	300	280	280	260	250	280	270	265
Roughness(ml/min)	208	200	170	160	190	170	150	190	170	160

Table - 6

A, B and C are doses.

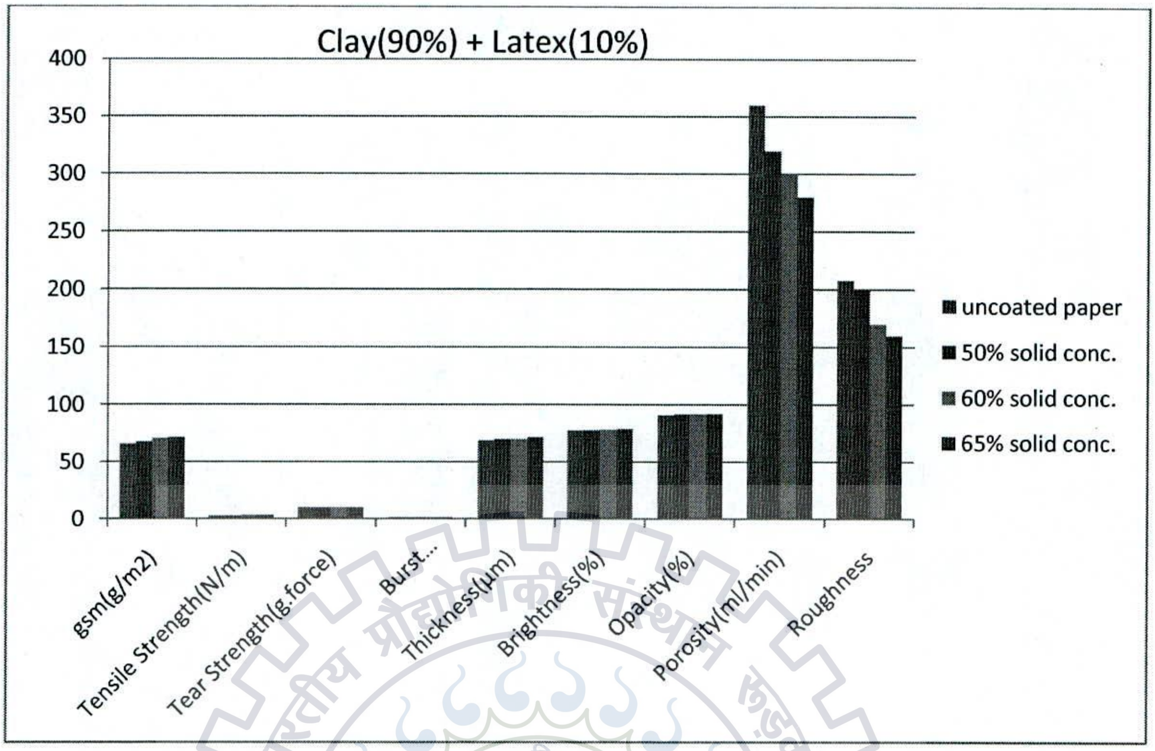
A= 50% solid concentration

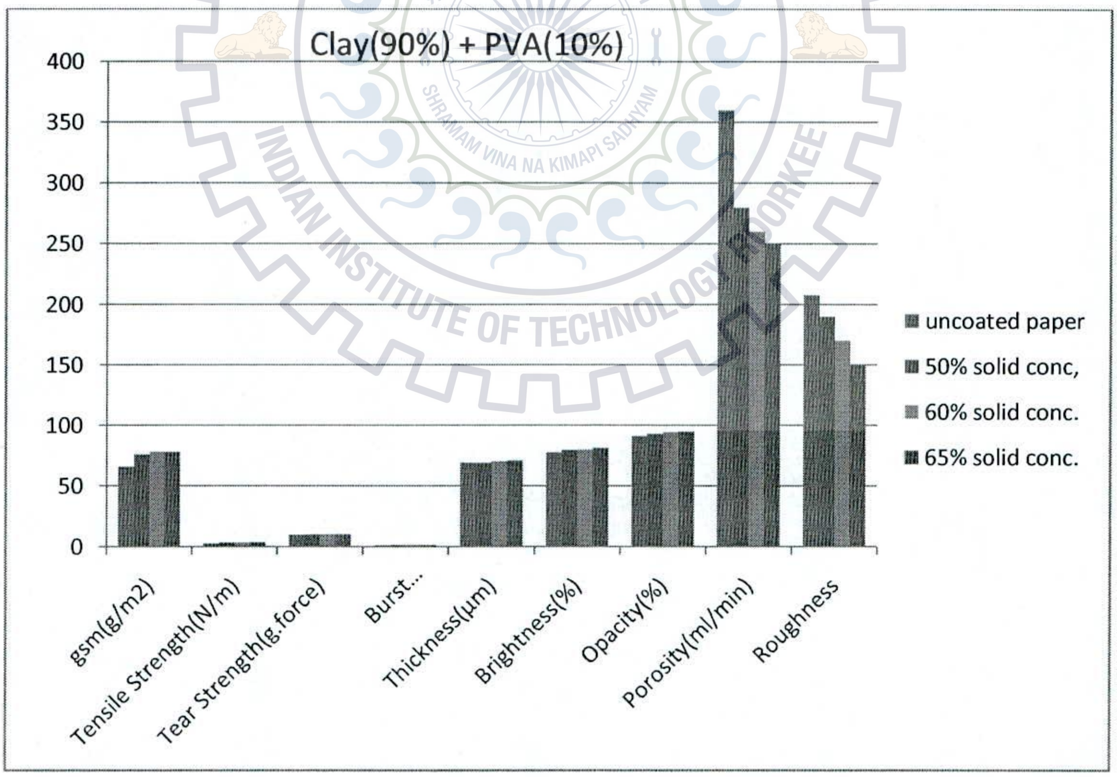
B= 60% solid concentration

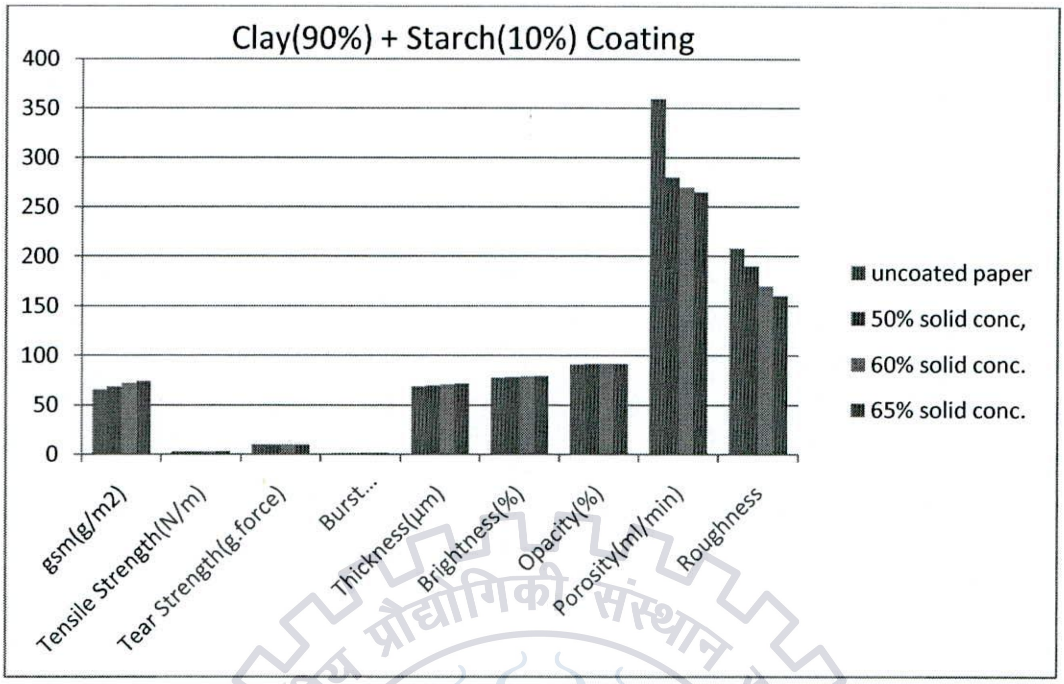
C=65% solid concentration

Few drops of dispersant were used for making 100 ml slurry of coating mix.

[(90% pigment + 10% binder) of total solids by weight]


Clay(90%) + Latex(10%)
400
350
300
250
200
150
100
50
0
gsm(g/m2)
Tensile Strength(N/m)
Tear Strength(g.force)
Burst...
Thickness(µm)
Brightness(%)
Opacity(%)
Porosity(ml/min)
Roughness
uncoated paper
50% solid conc.
60% solid conc.
65% solid conc.

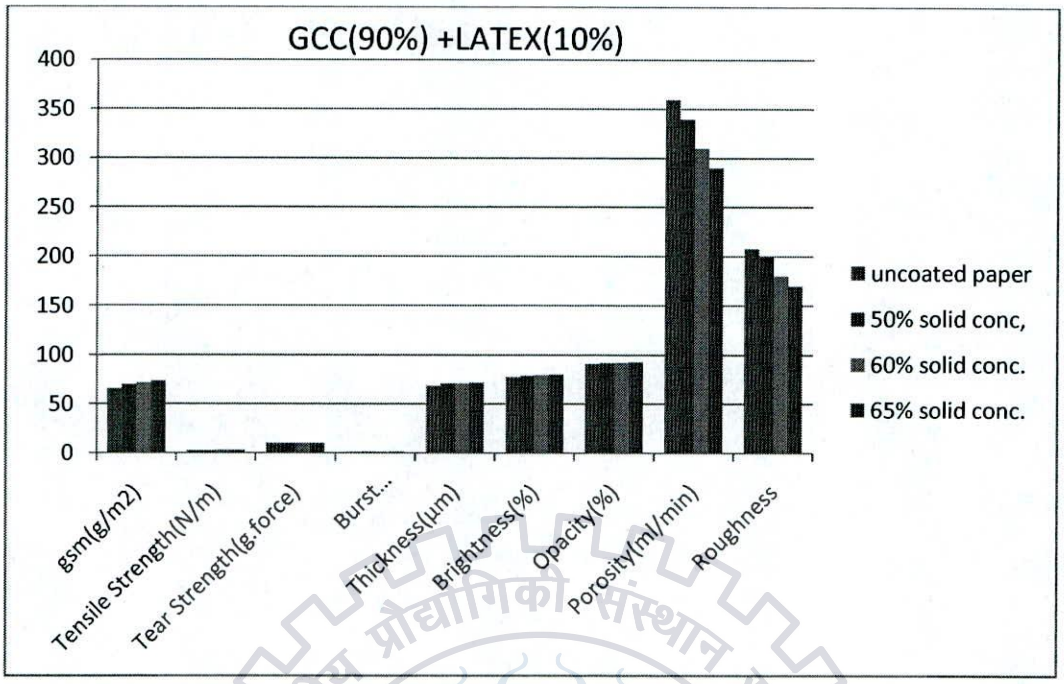

Clay(90%) + PVA(10%)
400
350
300
250
200
150
100
50
0
gsm(g/m2)
Tensile Strength(N/m)
Tear Strength(g.force)
Burst...
Thickness(µm)
Brightness(%)
Opacity(%)
Porosity(ml/min)
Roughness
uncoated paper
50% solid conc,
60% solid conc.
65% solid conc.

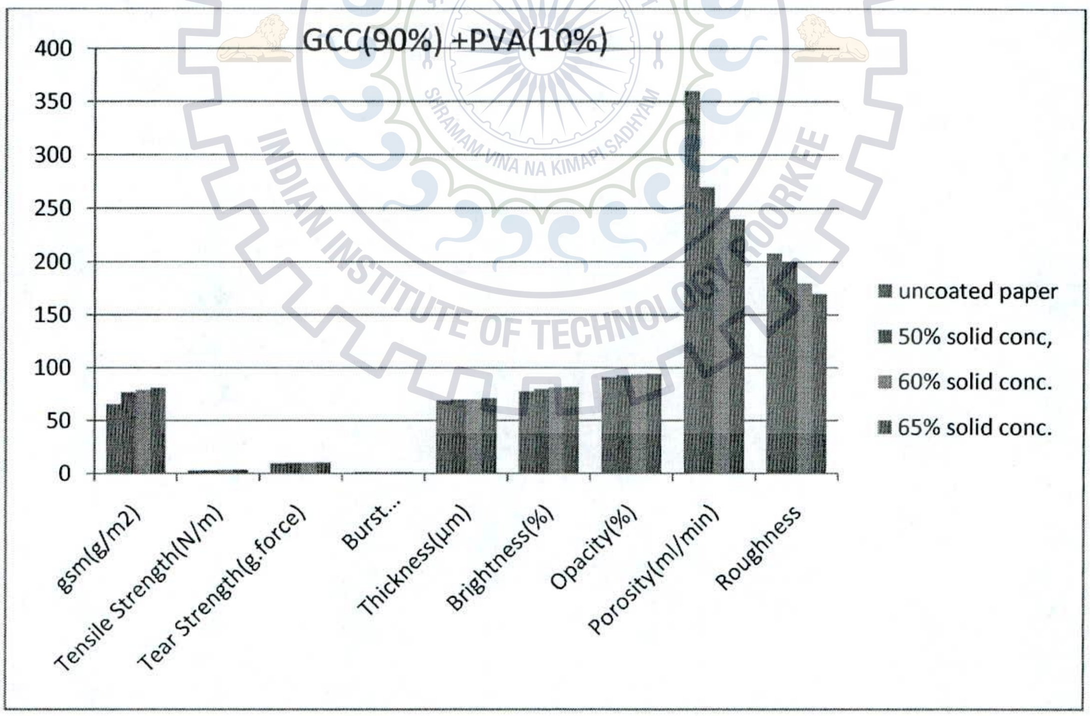


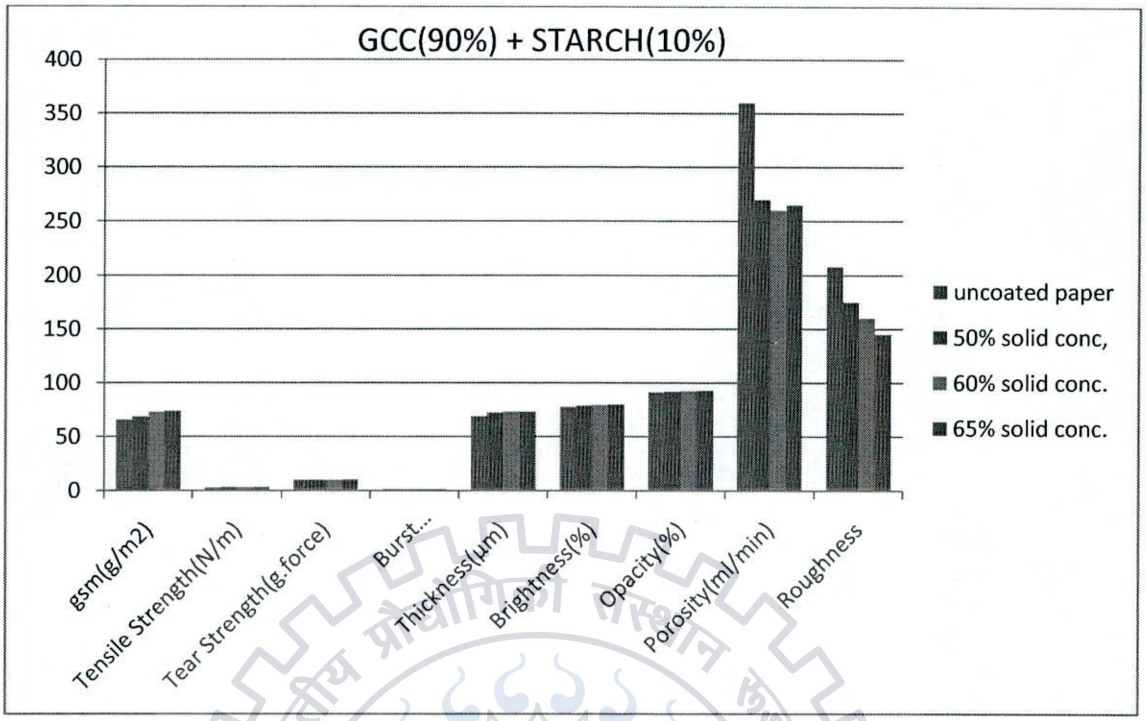
GCC coating results for base paper-1 with different adhesives at varying solid concentration.

Properties	Uncoated paper	$CaCO_3$ + LATEX			$CaCO_3$ + PVA			$CaCO_3$ + STARCH		
		A	B	C	A	B	C	A	B	C
gsm(g/m^2)	65.8	70.2	71.8	74.0	77	79	81	68.9	72.7	73.9
Tensile Strength(N/15mm)	2.8	2.9	3.2	3.2	3.0	3.4	3.7	3.1	3.1	3.4
Tear Strength(g.force)	10	10.1	10.1	10.2	10.3	10.4	10.5	10.1	10.2	10.4
Burst Strength(kgf/cm^2)	1.3	1.4	1.3	1.4	1.4	1.4	1.5	1.3	1.3	1.4
Thickness(µm)	69	71	71	72	70	70	71	72	73	73
Brightness(%)	77.6	79.1	79.7	80.2	80.0	81.4	81.9	79.0	79.3	80.0
Opacity(%)	91.1	92.0	92.4	93.1	92.9	93.7	94.3	92.0	92.5	92.9
Porosity(ml/min)	360	340	310	290	270	250	240	270	260	265
Roughness(ml/min)	208	200	180	170	200	180	170	175	160	145

Table - 7


GCC(90%) +LATEX(10%)
400
350
300
250
200
150
100
50
0
gsm(g/m2)
Tensile Strength(N/m)
Tear Strength(g.force)
Burst...
Thickness(μm)
Brightness(%)
Opacity(%)
Porosity(ml/min)
Roughness
uncoated paper
50% solid conc,
60% solid conc.
65% solid conc.


GCC(90%) +PVA(10%)
400
350
300
250
200
150
100
50
0
gsm(g/m2)
Tensile Strength(N/m)
Tear Strength(g.force)
Burst...
Thickness(μm)
Brightness(%)
Opacity(%)
Porosity(ml/min)
Roughness
uncoated paper
50% solid conc,
60% solid conc.
65% solid conc.



TiO_2 coating results for base paper-1 with different adhesives at varying solid concentration.

Properties	Uncoated paper	TiO_2 + LATEX			TiO_2 + PVA			TiO_2 + STARCH		
		A	B	C	A	B	C	A	B	C
gsm(g/m^2)	65.8	71.0	71.4	72.6	72	75	80	71.4	71.8	72.5
Tensile Strength(N/15mm)	2.8	2.9	3.1	3.2	2.9	3.2	3.4	3.0	3.1	3.3
Tear Strength(g.force)	10	10.2	10.2	10.3	10.2	10.4	10.6	10.2	10.3	10.4
Burst Strength(kgf/cm^2)	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.4	1.4	1.5
Thickness(µm)	69	70	71	71	71	73	72	72	74	75
Brightness(%)	77.6	79.2	80.0	80.3	80.2	81.1	81.5	79.6	80.4	80.8
Opacity(%)	91.1	93.0	93.5	93.9	93.3	94.2	94.6	93.2	94.0	94.1
Porosity(ml/min)	360	300	290	285	285	235	220	295	275	260
Roughness(ml/min)	208	185	170	165	190	175	155	180	170	160

Table – 8

Clay and GCC coating results for base paper-1at different doses of pigment.

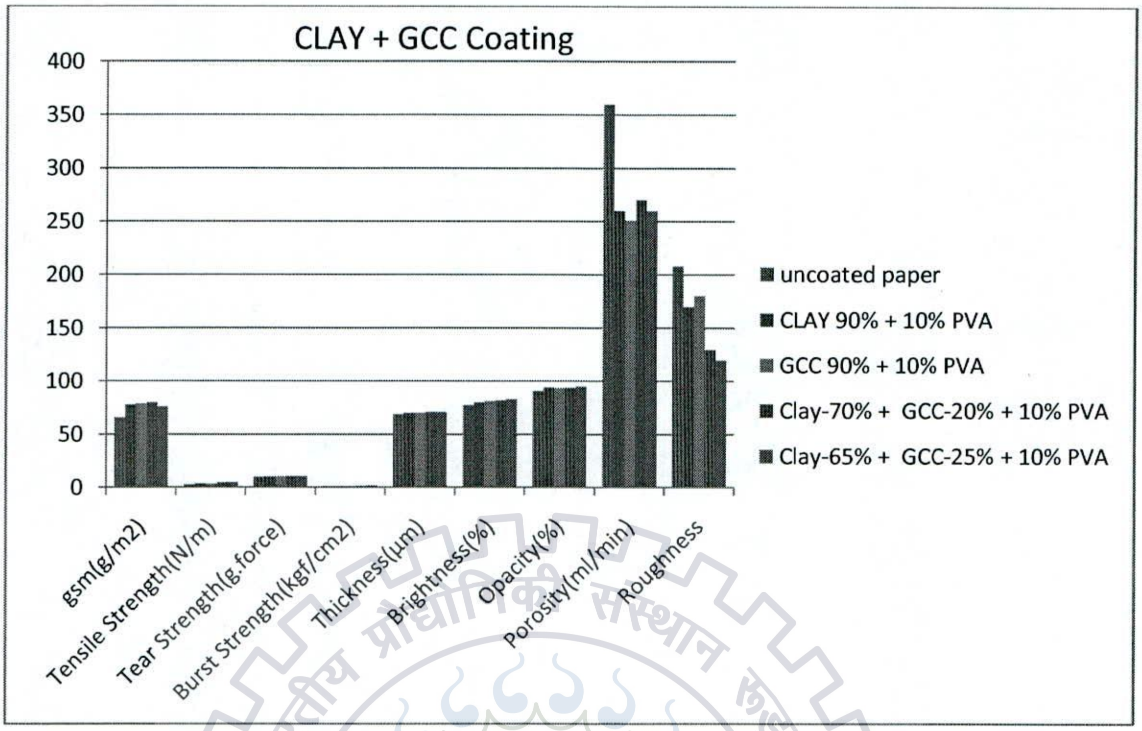
Properties	Uncoated paper	CLAY 90% + 10% PVA	GCC 90% + 10% PVA	Clay-70% + GCC-20% + 10% PVA	Clay-65% + GCC-25% + 10% PVA
gsm(g/m^2)	65.8	78	79	80	76
Tensile Strength(N/15mm)	2.8	3.6	3.4	4.5	4.7
Tear Strength(g.force)	10	10.3	10.4	10.8	10.9
Burst Strength(kgf/cm^2)	1.3	1.5	1.4	1.7	1.9
Thickness(μm)	69	70	70	71	71
Brightness(%)	77.6	80.0	81.4	82	83
Opacity(%)	91.1	94.2	93.7	94	95
Porosity(ml/min)	360	260	250	270	260
Roughness(ml/min)	208	170	180	130	120

Table – 9

The total solid concentration kept at 60%.

Binder conc. kept at 10%. (PVA is used as binder).

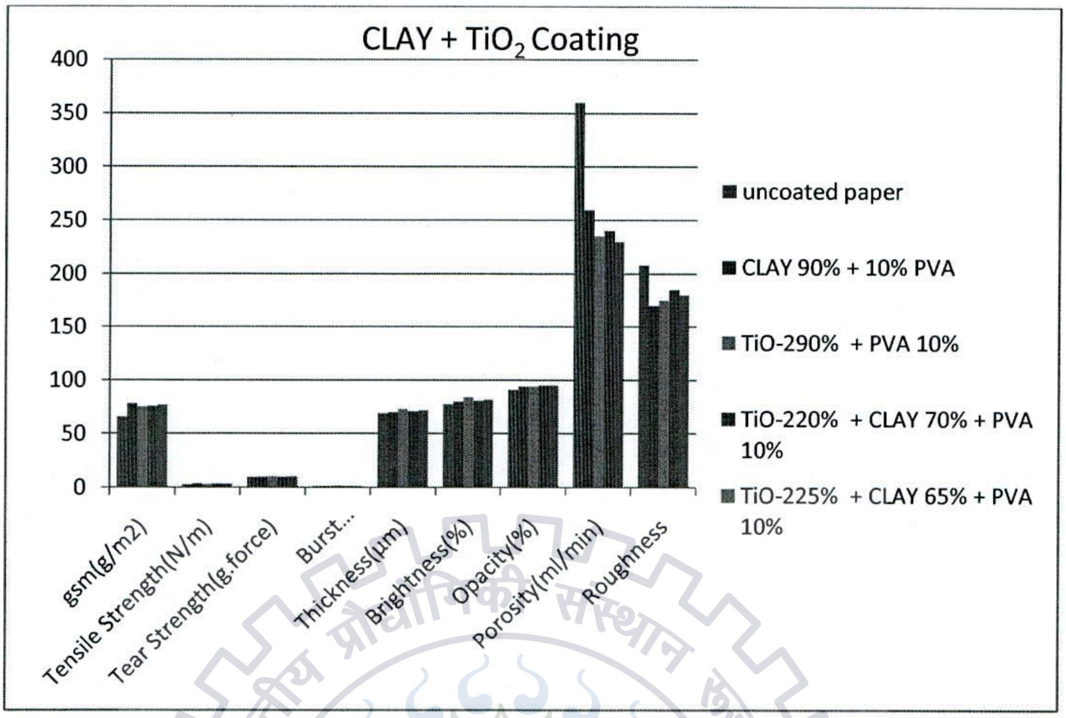
Few drops of dispersant were used for making 100ml slurry of coating mix.

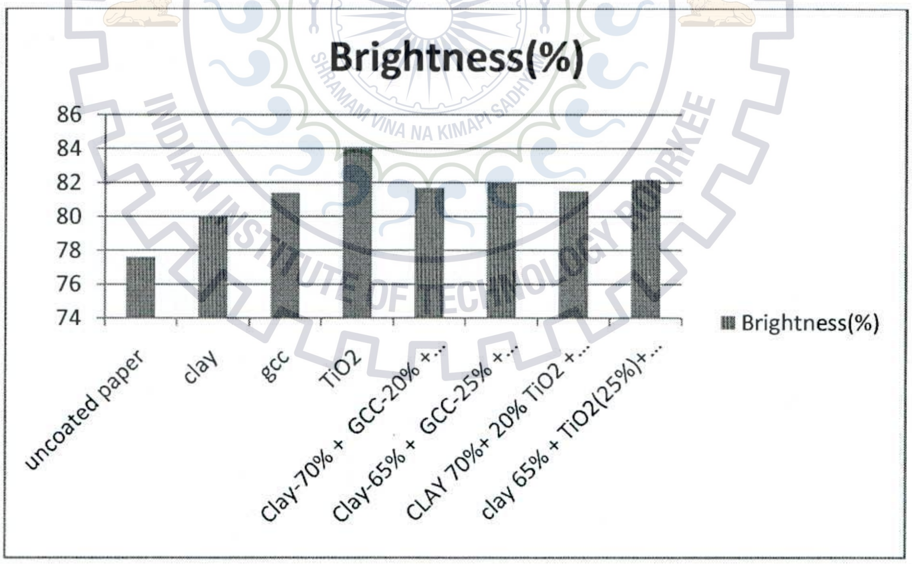


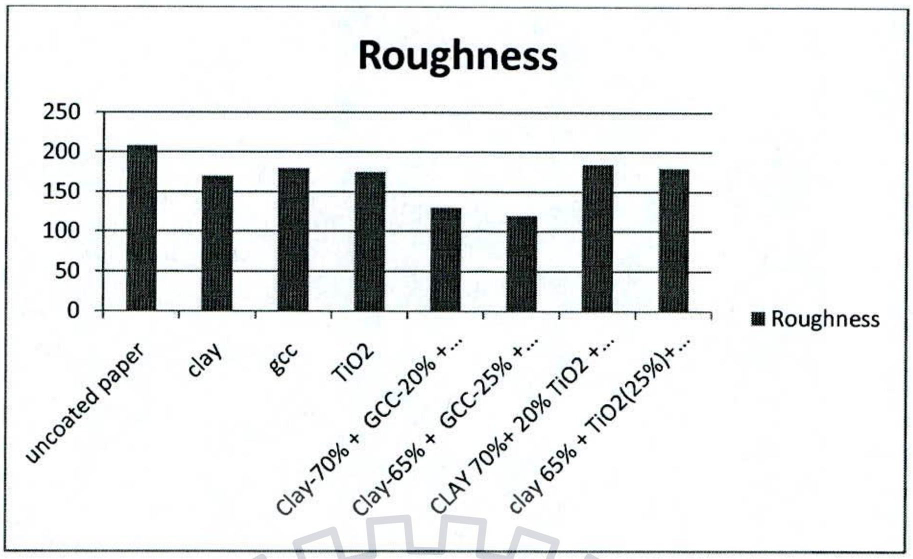
Clay and TiO_2 coating results for base paper-1 at different doses of pigment

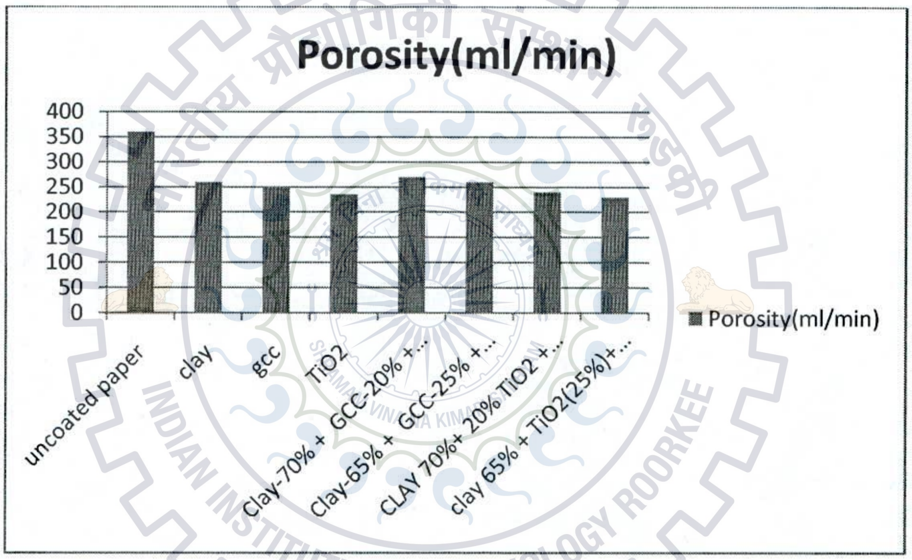
Properties	Uncoated paper	CLAY 90% + 10% PVA	$TiO_2$90% + PVA 10%	$TiO_2$20% + CLAY 70% + PVA 10%	$TiO_2$25% + CLAY 65% + PVA 10%
Gsm (g/m²)	65.8	78	75	76	77
Tensile Strength (N/15mm)	2.8	3.6	3.2	3.5	3.5
Tear Strength (g.force)	10	10.3	10.4	10.3	10.4
Burst Strength (kgf/cm²)	1.3	1.5	1.6	1.4	1.5
Thickness (µm)	69	70	73	71	72
Brightness (%)	77.6	80.0	84.1	81.1	81.9
Opacity (%)	91.1	94.2	94.2	95.0	95.2
Porosity (ml/min)	360	260	235	240	230
Roughness (ml/min)	208	170	175	185	180

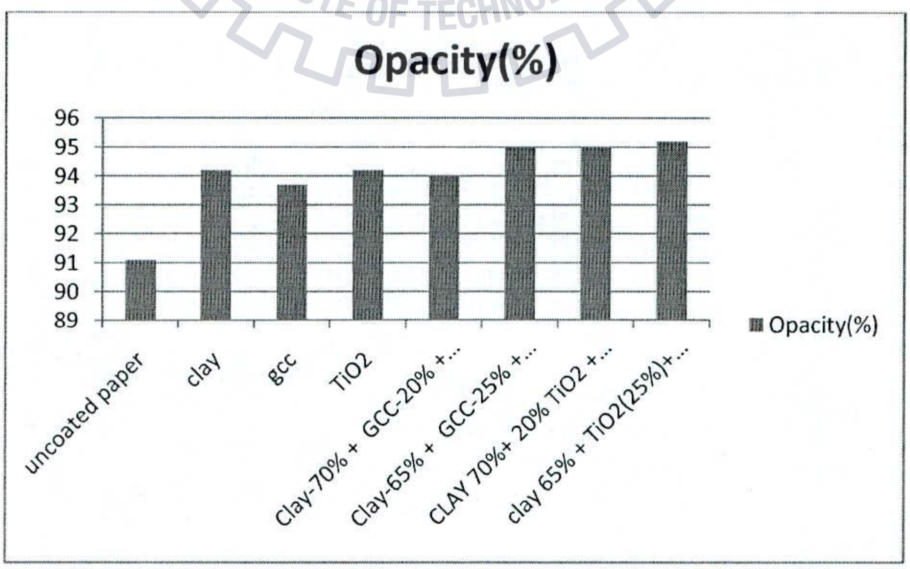
Table-10


CLAY + TiO_2 Coating
400
350
300
250
200
150
100
50
0
gsm(g/m2)
Tensile Strength(N/m)
Tear Strength(g.force)
Burst...
Thickness(µm)
Brightness(%)
Opacity(%)
Porosity(ml/min)
Roughness
uncoated paper
CLAY 90% + 10% PVA
TiO-290% + PVA 10%
TiO-220% + CLAY 70% + PVA 10%
TiO-225% + CLAY 65% + PVA 10%


Brightness(%)
86
84
82
80
78
76
74
uncoated paper
clay
gcc
TiO2
Clay-70% + GCC-20% +...
Clay-65% + GCC-25% +...
CLAY 70%+ 20% TiO2 +...
clay 65% + TiO2(25%)+...
Brightness(%)


Roughness
250
200
150
100
50
0
Roughness
uncoated paper
clay
gcc
TiO2
Clay-70% + GCC-20% +...
Clay-65% + GCC-25% +...
CLAY 70%+ 20% TiO2 +...
clay 65% + TiO2(25%)+...

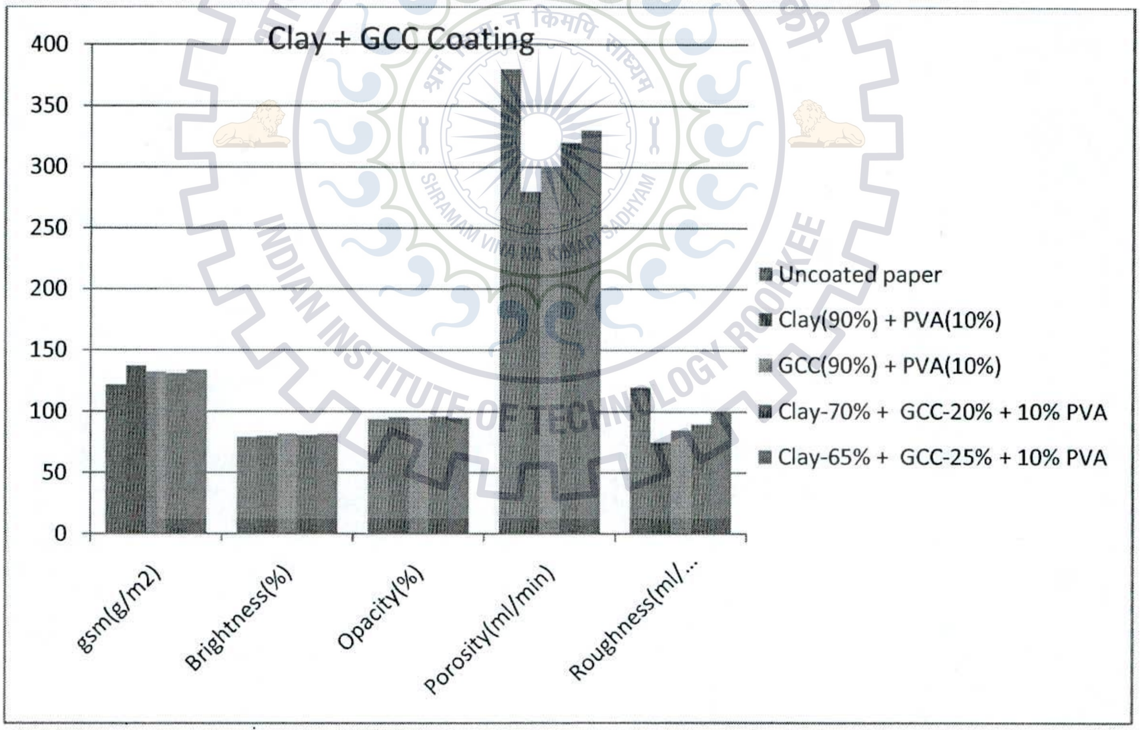

Porosity(ml/min)
400
350
300
250
200
150
100
50
0
Porosity(ml/min)
uncoated paper
clay
gcc
TiO2
Clay-70% + GCC-20% +...
Clay-65% + GCC-25% +...
CLAY 70%+ 20% TiO2 +...
clay 65% + TiO2(25%)+...


Opacity(%)
96
95
94
93
92
91
90
89
Opacity(%)
uncoated paper
clay
gcc
TiO2
Clay-70% + GCC-20% +...
Clay-65% + GCC-25% +...
CLAY 70%+ 20% TiO2 +...
clay 65% + TiO2(25%)+...

Clay and GCC coating results for base paper-2 at different doses of pigment

Properties	Uncoated paper	Clay(90%) + PVA(10%)	GCC(90%) + PVA(10%)	Clay-70% + GCC-20% + 10% PVA	Clay-65% + GCC-25% + 10% PVA
gsm(g/m^2)	122	137	132	131	134
Brightness(%)	79.4	80.1	82.1	81.1	81.8
Opacity(%)	94	95.4	95	95.8	94.9
Porosity(ml/min)	380	280	300	320	330
Roughness	120	75	85	90	100

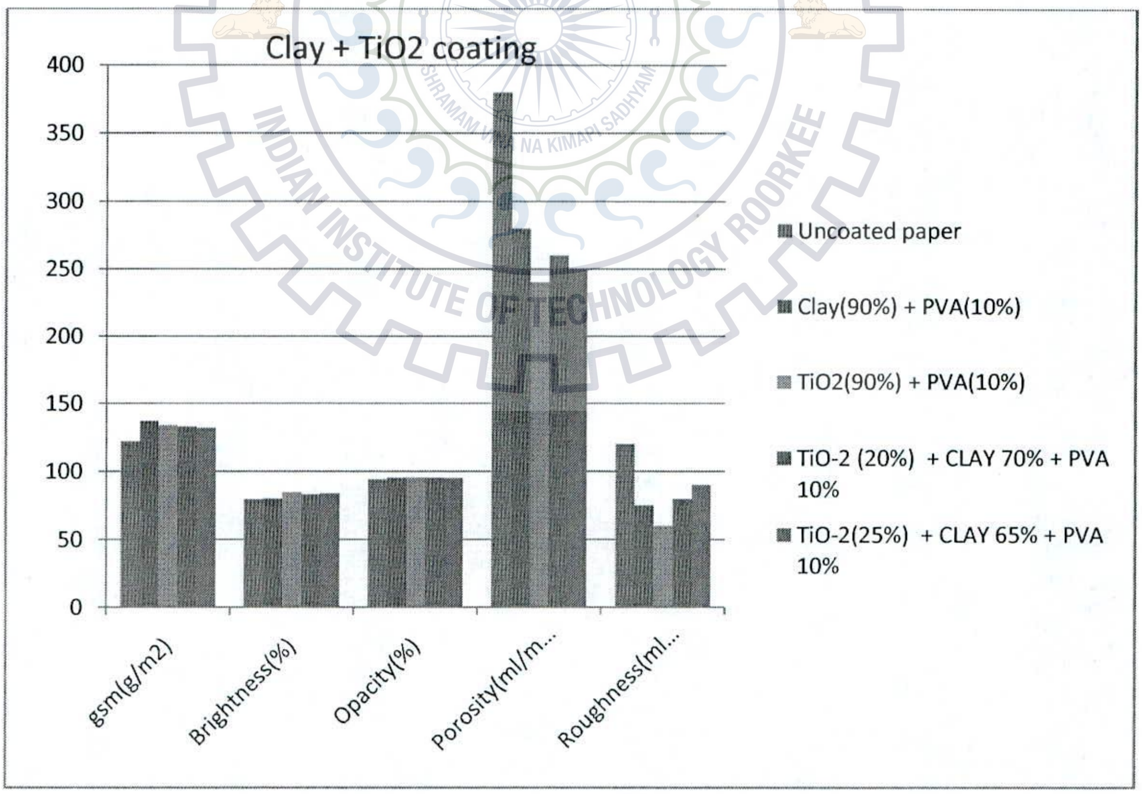
Table-11



Clay and TiO_2 coating results for base paper-2 at different doses of pigment

Properties	Uncoated paper	Clay(90%) + PVA(10%)	TiO2(90%) + PVA(10%)	$TiO_2$20% + CLAY 70% + PVA 10%	$TiO_2$25% + CLAY 65% + PVA 10%
gsm(g/m²)	122	137	134	133	132
Brightness(%)	79.4	80.1	84.6	83.1	83.9
Opacity(%)	94	95.4	95.5	95.3	95.2
Porosity(ml/min)	380	280	240	260	250
Roughness	120	75	60	80	90

Table-12



5.3 Variation in paper properties with the wire diameter of bar and coating speed

Coating of clay at 60 % solid concentration

Bar no.	Speed	Porosity (ml/min)	Smoothness (ml/min)	Opacity (%)	Brightness (%)
1	1	330	130	98	81.8
	2	320	90	96.9	81.6
	3	340	100	97	81.2
	4	340	100	97.8	81.1
2	1	330	155	98.1	81.3
	2	340	160	98	81
	3	330	140	97.9	81.5
	4	350	180	97.7	81.1
3	1	335	950	97.6	80.1
	2	340	1000	97	80
	3	330	1200	97.8	79
	4	370	1100	97.6	79.8
4	1	340	1200	97.2	79.5
	2	350	1300	97.4	79.4
	3	340	1350	98.4	79.8
	>4	Coating not done			
5	1	335	1500	97.9	79.6
	2	350	1500	97.4	79.8
	>3	Coating not done			
6		Coating not done			
7		Coating not done			
8		Coating not done			
9		Coating not done			

Table-13

8.Conclusion

This dissertation aimed at comparative performances of pigments and adhesives on the base paper. A pigment coating formulation was developed for the base paper. The pigment coating provides a surface that is more uniform in appearance and more receptive to printing ink than the uncoated paper fibres. Coating improves the printing properties of paper. A comparison was made between various grades of paper. Optical and mechanical properties were also evaluated.

- The optical and physical properties were affected significantly by coating and the coat weight. The correlation between improvements in optical properties and smoothness indicate that the property improvements were due to an increase in surface coverage with coat weight.
- The pigment coating provides the surface more uniform in appearance and more receptive to printing ink than the uncoated paper fibres.
- Application of the pigments (white) enhances the brightness of the paper.
- The opacity increases due to high light scattering of the pigments, this improves the optical appearance, because the shine-through of the back side printing is reduced.
- The coat layer reduces the porosity of the base paper so the penetration of ink into paper also reduces, therefore the ink does not spread as much and the print image is clear and sharp.
- PVA is a better binder than starch and latex as it gives more improved properties.
- After using Dispersant the fluidity of formulation increases even if at higher solid content.
- TiO_2 gives better result than the $CaCO_3$ and Clay.
- Air permeability (Porosity) decreased with coat weight. This is because the coating mixture molecules fill the gap between the fibres so decreasing the air voids within the paper.

9. Future demands of coated papers:

The demand for coated paper will increase globally. An increasing market will result in continuous development process of coated paper products. For coated papers, this development will be driven customer needs and price competition between producers. The future trends of coated papers will practically be accomplished by the following main facts in the development process are following:

- More specific paper products.
- Development of coating technology.
- Globalization of the paper companies.
- Progress in printing technology.
- Development of coating colour raw material.

10 .References

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