A

DISSERTATION REPORT

ON

"THE EFFECT OF PIGMENT COATING ON VARIOUS GRADES OF BASE PAPER"

Submitted in partial fulfillment of the requirements
for the award of the degree of

MASTER OF TECHNOLOGY
IN
PULP AND PAPER TECHNOLOGY

Submitted by
ANKUR KUMAR
Enrollment No. 075602
UNDER THE GUIDANCE OF

Dr. C.H. TYAGI
Associate Professor,
DPT, IIT Roorkee

Dr.N.K.BHARDWAJ
Assistant Professor
DPT, IIT Roorkee

M.G. CENTRAL LIBRARY
ACC No. G 20019
Date 13/7/10
I.I.T. ROORKEE

DEPARTMENT OF PAPER TECHNOLOGY,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE,
SAHARANPUR CAMPUS, SAHARANPUR

2008-2009

CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this dissertation report, entitled **"The Effect of Pigment Coating On Various Grades of Base Paper** " in partial fulfillment of the requirements for the award of the degree of Master of Technology in Pulp and Paper Technology, IIT Roorkee, is an authentic record of my own work carried out, under the supervision of Prof. ***Dr. C.H.Tyagi*** & ***Dr. N. K. Bhardwaj***, DPT, IIT Roorkee, Saharanpur Campus, Saharanpur.

The matter presented in this project report has not been submitted by me for the award of any other degree of this or any other Institute.

Date:
Place:

Candidate's Signature
(ANKUR KUMAR)

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

30/6/09

Dr. C.H.TYAGI
Associate Professor
DPT, IIT Roorkee

30/06/09

Dr. N. K. BHARDWAJ
Assistant Professor
DPT, IIT Roorkee

ABSTRACT

The advancing technologies of printing and packaging have placed greater demands on the surface of the paper sheet. To meet the more stringent requirements, many paper surfaces are coated with suitable formulations to provide improved gloss, slickness, colour, printing properties. The coating can be applied either on- machine or off-machine, usually, light coating treatments are carried out on-machine, while heavier coating are applied as off-machine operations. Technically any paper surface application can be considered a coating. For example, The size press is really a simple form of on-machine coater, however in modern usage, a paper coating usually refers to a layer made up primarily of fine mineral pigment. The mineral pigment used is similar to a filler, but is usually somewhat finer, it is mixed with adhesives and other components to hold it onto the paper surface and provide suitable finish and rub-resistance. A coating will tend to fill in the void areas on the surface of the paper sheet. After drying and calendaring, the coating provides a smooth, even surface for printing. However, a satisfactory coated sheet can be produced only if the base sheet is well-formed and free from defects.

ACKNOWLEDGEMENT

I would like to take this as an opportunity to express my profound sense of gratitude to my guide **Dr. C.H.Tyagi**, Associate Professor, **Dr. N. K. Bhardwaj**, Assistant Professor, Department of Paper Technology, IIT Roorkee, Saharanpur campus for their valuable inspiration and guidance throughout this dissertation work.

I am thankful to **Mr. Sanjay Tyagi** (Scientist B) at CPPRI for providing me the required facilities, material used during work.

Date:

ANKUR KUMAR
M.Tech. (pulp&paper)
Final Year

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

GCC	Ground Calcium Carbonate
PCC	Precipitated Calcium Carbonate
CC	China Clay
CW	Coat Weight
CMC	Carboxy Methyl Cellulose
PVA	Polyvinyl Alcohol
ATH	Aluminum Trihydrate
LWC	Low Weight Coated
MWC	Medium Weight Coated
HWC	High Weight Coated
MFC	Machined Finished Coated
FCO	Film Coated Offset Paper
ULWC	Ultra Weight Coated
GSM	gram per square meter
SW	Softwood
HW	Hardwood
MSP	Metered Size Press
WFC	Wood Free Coated
OBA	Optical Brightening agents

1. Introduction: The rate of growth in demand for pigment-coated paper exceeds the rate of growth for total paper and paperboard demand. This situation, which has persisted for several decades, has provided a strong stimulus for sustained technical effort and in turn is responsible for the continuing development of new and improved materials, machinery and methods for the production of pigment-coated paper. The coating consists of a pigment plus adhesives to bind the pigment particles both to one another and to the base paper. Pigments are the main constituents of the coating. The binders and various additives that may be included normally comprises less than 20 percent (by weight) of the coating formulation. Pigment coating in which an aqueous mixture of pigment and adhesives is applied to the surface of the paper. This type coating is used for publication papers used in magazines. Coated paper has made it possible to reproduce the finest halftone printing and to control such properties of the paper surface as ink absorbency, ink receptivity, smoothness, gloss and brightness. Most pigment coated papers are used in printing. The pigment coating provides a surface that is more uniform in appearance and more receptive to printing ink than the uncoated paper fibers. There are three basic raw materials used in pigment coating such as pigment, adhesives used for bonding the pigment and base paper, or raw stock, to which the pigment is bonded. There are many variables to be considered in pigment coating such as (1.) The type of coating process and operating variables, such as speed, roll pressure, etc. (2.) The type of pigment and adhesive used. (3.) The coating mixture variables such as percent solids, rheology, water retention, and pH. (4.) Raw stock characteristic, including formation, sizing, strength and porosity.

2. History: 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 a web paper, which was then dried and calendared. In the middle 1890, casein began to replace 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 satisfactory in certain grades of papers. The original coated papers were surfaced with clay, but it includes many other pigments , satin white, precipitated chalk, titanium dioxide, alumina, talc, etc.By 1920 pigment-coated paper was a commercial commodity with estimated consumption in the united state of about 100,000 tons, or approximately 15 percent of total printing and writing paper. The printing

fidelity and attractive appearance obtained with these pigment-coated papers gave them an aura of elegance that made them desirable for coporate annual reports and for brochures advertising high priced items such as automobiles. Weight range 90 to 150 g/m2 (60 to 100 lb per book ream) with most production falling in the middle of range. During the 1930 a number of developments combined to produce a marked increase in the demand for pigmented-coated paper. The application of coating on the paper machine, rather than as a separate operation, greatly reduced the cost of producing pigment-coated paper .In1935 pigment-coated paper consumption in the United States approximated 250,000 tons. During the 1950 and 1960 technical advances in coating materials and equipment fostered continuing growth so that by 1970 pigment-coated paper demand in united state reached 3,275,000 tons.

3. What is Coating: The coating consists of a pigment plus adhesives to bind the pigment particles both to one another and to the base paper. Pigments are the main constituents of the coating. The binders and various additives that may be included normally comprise less than 20 percent (by weight) of the coating formulation. Pigment coating in which an aqueous mixture of pigment and adhesives is applied to the surface of the paper. This type 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 fibers. Coating improves the printing properties of paper. In the coating of paper , aqueous suspension called coating color 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.

4. Objective of Coating: The main purpose of coating is to improve the surface quality of paper or board. The quality improvement can be aimed at optical properties such as brightness, gloss or opacity, at tactile properties such as smoothness, but, most importantly, at printability and print image quality. The application of (usually white) pigments to the base paper surface enhances the brightness of the paper. In addition, the opacity increases due to the high light scattering of the pigments. This improves the optical appearance, because the shine-through of the back side printing is reduced. Also, the coat layer evens out the surface topography of the sheet, resulting in an improved smoothness, which in turn gives a better gloss.

The coat layer reduces the penetration of ink into th paper sheet. Therefore, the ink does not spread as much and the print image is clear and shar The print density and the print gloss are enhanced, and the ink demand is reduc d compared to uncoated papers. The objective of Coating application may be done fo one or more reasons. The major reasons can be classified into three major categories:

1. Appearance
2. Printability
3. Functionality

Appearance: Gloss of paper, giving surface reflectio , is very important for high class printed papers. Coated papers can develop much higher gloss on supercalendering. Brightness of paper is important for all printing grades of paper. Coating application of high brightness pigments on moderately bright paper can increase brightness along with other printing specific properties like smoothness, opacity, ink absorption and gloss.

Printability: Coated paper is used for printing applications. The properties required for good printing are following as:

- Smoothness
- Opacity
- Uniform ink absorption
- Improved surface strength

Proper selection of pigment and binder can develop all the required for good printing.

Functionality: Sometime paper require specific surface properties for its function. Some of them are following as:

- Better printing properties of cheaper furnish paper
- Variety of products from same base paper
- One side colouring

To give special properties of barrier, plastic, water proof surface.

5. What is Base paper: The base paper is the most important component in determining the quality of a pigment coated paper. Base paper properties of prime importance are uniformity,

formation, porosity, resiliency, strength, moisture content, brightness, opacity, finish, and surface smoothness. The base paper in coating must ensure trouble-free running of the coater, provide an optimal basis for paper finishing, and form a base for fixing the coating layers demanded by the end users. The lower the basis weight the more important are the properties of the base paper. Generally, the best coated paper surface is achieved with the best and most uniform base paper. Variations in formation, absorption, thickness, moisture, and roughness of the base paper have a great influence on the properties and the uniformity of the coating layer. The furnish for the raw stock will vary and can contain from 20 to 50 % long fibre, 40 to 70 percent short or mechanical fiber and 10 to 15% pigment filler. The raw stock for low solids coating, for example, 40 to 50% solids, should be moderately sized to control penetration of coating into the raw stock and to maintain the integrity of paper. The strength of the raw stock is responsible for most of the strength of the final coated sheet.

5.1 Specific Base Paper Properties Affecting Coating: Base paper characteristics have a strong effect on the quality of coated paper and board and process economy. The main properties are as follows:

Strength Properties: To guarantee a good run ability of paper web in coating different strength properties are needed. Because base paper is wetted in coating units, it requires good temporary wet strength. Wet tensile strength, in principle, is measured using similar methods as for measuring tensile strength, but the sample is prepared differently. Other strength properties related to coating are tear strength and edge tearing resistance as well as bursting strength

Basis weight, caliper, and moisture profiles in the cross and machine directions: These have a strong influence on the uniformity of coating, e. g., calendaring very often controls caliper, which means that in the cross direction some parts of the web are pressed more than others to reach a uniform caliper profile. These more compressed parts will differ in porosity and smoothness of base paper, which affects the coating amount. Caliper before coating can be measured on-line for control. Basis weight variations usually cause caliper variations, they can be seen as streaks in the machine direction. Moisture variation will affect coating amounts with risks of wrinkles if moisture variations across the web are high. High moisture before coating can

affect coating color penetration and the gloss of coated paper and, subsequently, ink settling in printing.

Porosity: If porosity is very high, absorption of coating is also high and coating weight can increase dramatically and drying problems may also occur.

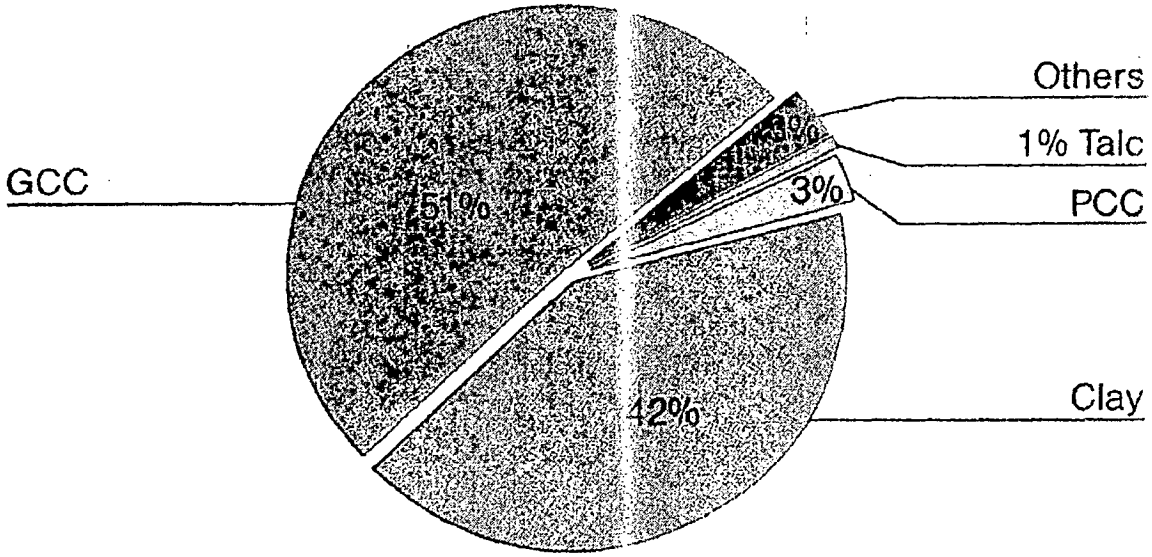
Formation: This property refers to small-scale basis weight variations in paper. There are some areas that are denser and less absorbent to the coating than other areas. To reach uniform coating penetration, base paper requires even formation, otherwise mottling may occur in printing.

Smoothness: Smooth base paper gives a uniform and closed coated surface. The various coating processes have slightly different smoothness requirements. Air knife coaters require a relatively smooth surface because, in that method, coating is applied in a layer of rather uniform thickness, regardless of the base paper contour. The blade coaters coating film fills the cavities and leaves the high spots uncovered.

Brightness: The brightness of the raw stock influences the coated paper brightness. Dirt specks will normally show through even the heaviest coating.If low coat weight are applied , the base paper brightness should approximate that of the pigment coating.

Opacity: Opacity of the base paper is important, especially for the lightweight coated grades. The base sheet porosity and opacity are directly related ,naturally, opacity is a direct function of the basis weight and can be a limiting factor in lightweight coated papers.

6. What is Pigment coating: Pigment coating is applied to paper and paperboard to improve printability and appearance. A pigment coating consists of a pigment and a binder and a small amount of other additives. The binder and additives normally comprises less than 20% of the coating. The pigment coating provides a surface that is more uniform and more receptive to printing inks than the uncoated papers.



The main pigments for pigment coating

Figure 1.

7. Classification of Coating pigments: An ideal pigment would have the following properties:

- Appropriate particle size and narrow particle size distribution.
- Free from impurities.
- Good dispensability for easy mixing with water and low water absorption.
- High chemical stability and low solubility in water.
- Good compatibility with other coating components.
- Good light reflectivity at all wavelengths for high brightness.
- High refractive index for good opacity.
- Good glossing properties for eye-pleasing coating gloss and high print gloss.
- Low binder demand.
- Cheapness.

There is of course no pigment that could meet all these requirements and however, the different pigments meet different combinations of them. The main coating pigments are clay (kaolin), ground calcium carbonate (GCC), precipitated calcium carbonate (PCC) and talc.

Pigment could naturally be classified in many ways are following as:

- **Main pigments**
- **Special pigments**
- **Additional pigments.**

The main pigment that form the major fraction of the pigment part of a coating color. Special pigments are similar to main pigments except that their application are limited. Additional pigments from the minor fraction of the pigments part of a coating colour.

Main pigments:

- Kaolin's
- Ground calcium carbonate(GCC)
- Talc

Special pigment:

- Gypsum and Plastic Pigment

Additional pigments:

- Precipitated calcium carbonate(PCC)
- Calcined kaolins
- Plastic pigments
- Alumina trihydrates
- Titanium dioxides

Kaolin clay:

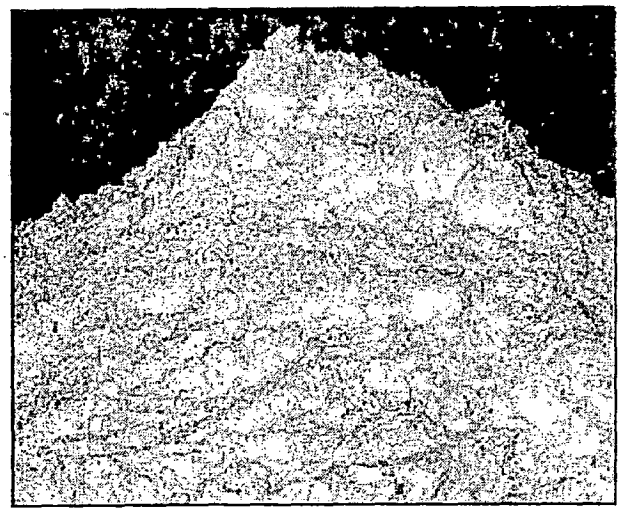


Figure2.

Kaolin china clay is generally obtainable in hydrated aluminum silicate (Al_2O_3 $2SiO_2$ $2H_2O$) and is formed by the alteration of Felspathic Rock.

Chemical Analysis:

Aluminum Oxide- Al_2O_3 (37 % - 39%)

Silica -SiO_2 (45% - 47%)

Ferric Oxide- Fe_2O_3 (0.4% - 0.5%)

Titanium -TiO_2 (1.9% - 2.1%)

Calcium Oxide –CaO (0.4% - 0.6%)

Magnesium Oxide- MgO (0.4% - 0.7%)

Sodium- Na_2O

The principal pigment for coating is Kaolin, commonly referred to as china clay. Kaolin clay is the most widely used in paper, both as a filler , where it is mixed with the fiber before the sheet is formed ,and as a coating, where it is mixed with a binder and other ingredients and applied to the surface of the sheet. Kaolin is a hydrated aluminium silicate. Kaolin clay is so widely used because it is low in cost, reasonably white, and readily available worldwide. About 65% of this was used in coating and most of the remainder in filling.

Some of the salient features of our china clay comprise: of the following:

•Good plasticity

• Absence of swelling in water

• High temperature resistance

• Bad-conductor of heat & electricity

Talc:

Figure3.

The use of talc in paper coating is most widely spread in Europe. Here the use of talc is based on the specific properties of the pigment rather than on local availability of talc. In some application s, however, talc can technically replace clay if it is economically viable and vice versa due to similar platy form of the particles. Coating talc are also used in special applications such as board, wallpaper, and label papers where their specific mineral properties bring various advantages. Due to its hydrophobicity and shape , talc can be effectively introduced to barrier coatings for board to replace PE lamination. As a coating pigment for wallpaper base , talc improves wallpaper washability. In label paper top coating , talc is used in grades targeted both for gravure and off-set printing process due to good printability in both end uses. Reverse sides of label papers coated with talc do not stick together when piled, thus improving the run ability of the labelling process.

Ground Calcium Carbonate(GCC):

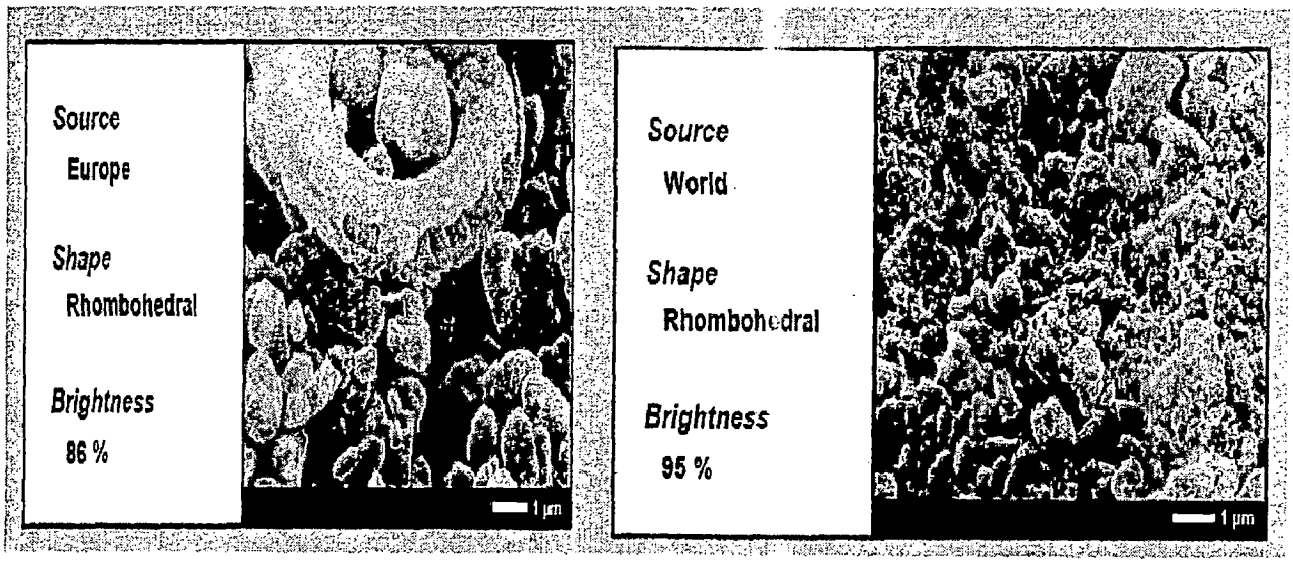


Figure4.

Calcium carbonate is the most widely used mineral in the paper, plastics, paints and coatings industries both as a filler – and due to its special white colour - as a coating pigment. In the paper industry it is valued worldwide for its high brightness and light scattering characteristics, and is used as an inexpensive filler to make bright opaque paper. Filler is used at the wet-end of paper making machines, and calcium carbonate filler allows for the paper to be bright and smooth. Calcium carbonate also is used widely as a filler in adhesives, and sealants. Calcium carbonate, as it is used for industrial purposes, is extracted by mining or quarrying. Pure calcium carbonate can be produced from marble, or it can be prepared by passing carbon dioxide into a solution of calcium hydroxide. In the latter case calcium carbonate is derived from the mixture, forming a grade of product called "precipitated calcium carbonate," or PCC. PCC has a very fine and controlled particle size, on the order of 2 micron. GCC, as the name implies, involves crushing and processing limestone to create a powdery-like form graded by size and other properties for many different industrial and pharmaceutical applications.

Precipitated Calcium Carbonate (PCC):

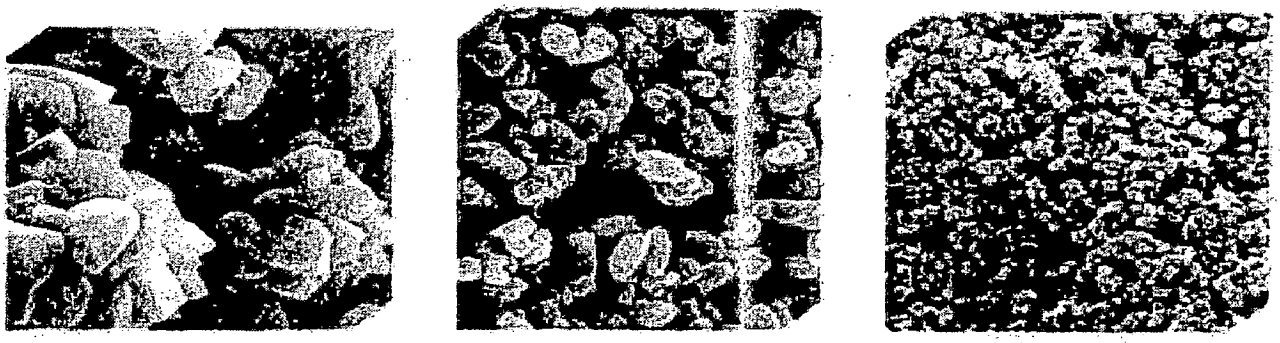


Figure5.

Calcium carbonate is apart from quartz the most common mineral on the earth surface. It occurs in three different mineralogical forms: calcite, aragonite, and vaterite.Calcite is the most common natural form , aragonite and vaterite are metastable and will convert irreversibly into calcite.It can be crystabilized in a wide variety of morphologies, calcium carbonate is versatile and can be used to change physical and chemical properties of filled or coated papers.

Chemically the simplified PCC process is as follows:

- **Calcination of limestone**

$CaCO3$ + energy = CaO (lime) + $CO2$ (gas).

- **Slaking of lime**

$CaO + H2O = Ca(OH)2$ + energy

- **Carbonation of slaked lime**

$Ca(OH)2 + CO2 = CaCO3 + H2O$ + energy

Separate additional impurities and grit from the PCC slurry.

PCC is to be used as a dry product, the slurry is dewatered, dried, milled, packaged and tested.

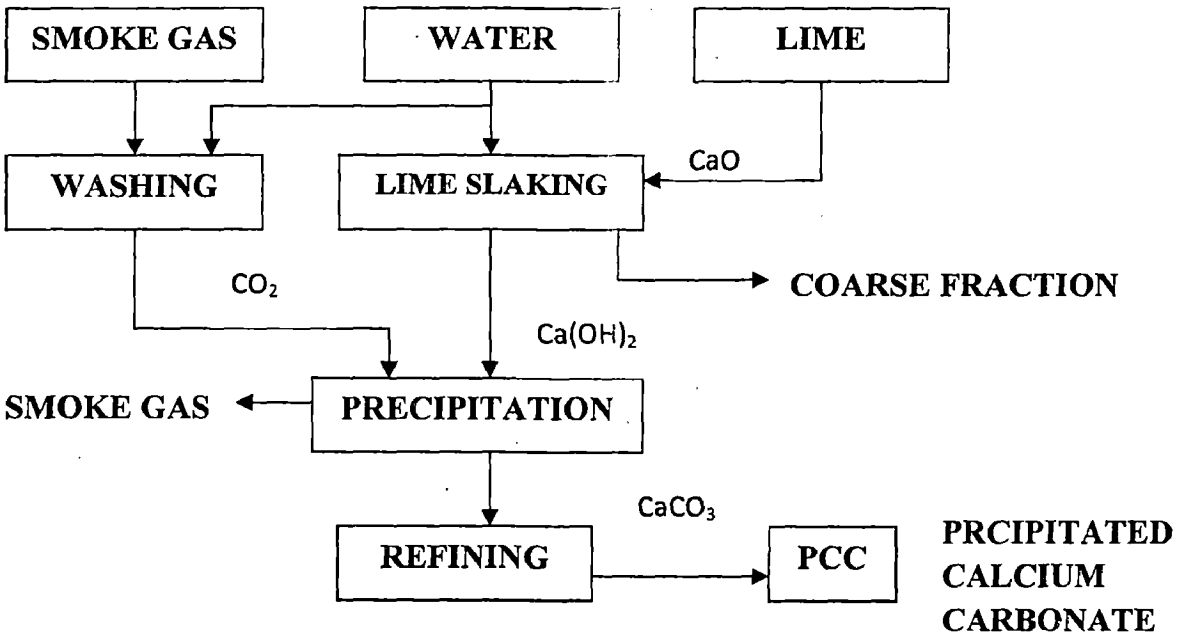


Figure6.

While the process is simple on a laboratory scale, making precipitated calcium carbonates commercially on a large scale requires a great deal of process control and process technology to assure the right size, uniformity, shape, surface area and surface chemistry.

Titanium dioxide: TiO_2 pigments are used in paints, plastics, paper, printing inks, rubber, fiber, and cosmetics, about 3% of total world TiO_2 consumption. The main function of titanium dioxide in paper applications is to increase the opacity of the final product. TiO_2 increases both brightness and opacity of coated paper. Titanium dioxide pigments are finely divided, chemically inert white powders which posses a higher refractive index about 1.98, than any other commercially available pigment. Commercially titanium dioxide pigment are available in two distinct crystal forms : anatase and rutile. Rutile TiO_2 makes a larger contribution to the opacity

of light weight coated paper than anatase TiO_2. The TiO_2 can be packed for delivery as a dry pigment or dispersed in water and delivered as slurry

8. Physical properties of coating pigments:

Table1.

Pigments	**Range of particles**	**Density**	**Refractive index**	**ISO Brightness%**
Kaolin clay	0.3-5	2.58	1.56	80-90
Talc	0.3-5	2.7	1.57	85-90
GCC	0.7-2	2.7	1.56-1.65	87-97
PCC	0.1-1	2.7	1.59	96-99
Titanium dioxide(anatase)	0.2-0.5	3.9	2.55	98-99
Titanium dioxide(anatase,rutile)	0.2-0.5 0.2-0.5	3.9 4.2	2.5 2.7	98-99 97-98
Plastic pigment	0.1-0.5	1.05	1.59	93-94
Alumina hydrate	0.2-2	2.42	1.57	98-100

9. Coating Binders: Binder is the second most abundant component in the coating colour after the pigment. Binders serve as pigment-pigment bonders, and to anchor the pigments to the base paper surface. They are also expected to control the coating colour viscosity and water retention, and to prepare the coated papers for printing and converting stages. Today, synthetic binders are preferred in coating kitchens. They are polymerized petroleum products that are

available in the form of dispersions in very fine distributions, often with 50 % solids. Some typical starting materials are nonnumeric styrene, butadiene, acrylic acid, and their derivatives from which products such as styrene butadiene latexes, acrylic acid esters and polyvinyl acetate are obtained. Besides synthetic binders, natural binders are also used. They are often multifunctional in that they contribute to bond strength, water retention and improved run ability. Natural binders include starch and derivatives, and with some restriction carboxy methyl cellulose (CMC). These products are normally supplied dry and need to be dissolved during colour preparation. Among binders, styrene-butadiene latexes dominate beside modified starches. Styrene-acryl ate dispersions are specialties and of high importance for impressive prints.

The binder can be classified in the following way by their origin and solubility in water is following as:

1. Not soluble in water:

Latexes:

- Styrene butadiene latexes (SB latex)
- Styrene acrylate latexes (acrylate latex)
- Polyvinyl acetate latexes (PVAc latex)
-

2. Soluble in water:

Derivatives of natural polymers:

- Starches
- Proteins
- Cellulose derivatives
- Carboxy methyl cellulose (CMC)

3. Fully synthetic:

- Polyvinyl alcohol.

An ideal binder can be characterized as follows:

- Good binding power
- Good water retention properties
- Can be mixed or dissolved easily into water
- Mechanical and chemical durability
- Good optical properties
- Good mechanical properties
- Low tendency to foaming
- Low price and good availability.

10. Coating Additives: Coating formulation requires some additive to improve the properties of formulations or its application on paper. Generally most additives are used in small amounts and rarely exceed 5% of the coating solids. Coating additives are a heterogeneous group of coating colour component that fulfil various functions in coating colours or coating layers.

The various type of Coating additives can be classified as:

Lubricants: Lubricants improve the run ability of the coating color by reducing the friction between the machine part and the coating color. This can be seen for example as fewer scratches in the coating and longer lifetime of coater blades. Lubricants enhance the plastic deformation of the dry coating in the supercalender by preventing the cracking of the soluble binder film that would lead to dusting. It also improves gloss, During calendering, lubricants migrate from the coating onto the hot calendar rolls and form a monolayer on the rolls, thus preventing sticking of the coating to the rolls. Dusting at printing machines has been a problem in LWC, especially when delaminated kaolin's are used. Different kaolin's have different dusting tendencies, dusting can often be reduced or eliminated by using a lubricant.

The most commonly used lubricant is calcium stearate. Wax emulsions (mostly emulsions of paraffin waxes, microcrystalline waxes, or polyethylene waxes) are the oldest group of lubricants in paper and board coating. These emulsions give good run ability but have less effect as anti dusting agents than stearate.

Foam control agent: With respect to surface sizing and paper coating, foam control usually means anti-or defoaming or deaeration to maintain the foam volume at a desired level using foam control agents or by appropriate adjustment of the process. The presence of foam can influence the flow behaviour of coating colours directly and indirectly the level of air in the liquid can also affect amount and type of microbial growth. Foam control agent are usually applied during the coating preparation stage. The anti foam is added before the pigment and adhesives, normal dosage lie in the range of 0.05% to 0.2% on dry coating solids.

Flow modifiers: They are generally viscosity reducing agents like urea, dicyandiamide for the formulations of high viscosity. Some the viscosity of formulation is lower thus flow modifier is required to increase viscosity. If the formulation shows the tendency of leaving water and separation of solids/pigments, alginate can improve the flow properties.

Insolubilizers: There are many chemically different types of insolubilizers or cross linkers. They all have the same function – to increase water resistance. Water resistance is particularly important in offset printing, but also for wallpaper and in the storage of board packages. In double-coated boards, cross linkers are used in the precoating to impart water resistance against the topcoat. The water resistance can be measured.

The type of insolubilizer used according to binder are:

Casein and protein -(Formaldehyde, hexamethylene)

Starch -(Urea formaldehyde, melamine,formaldehyde,latex)

Latex -(Urea or melamine formaldehyde resins)

Polyvinyl alcohol -(Glyoxal, and latex).

Dispersants: The use of dispersants stabilizes deflocculated particles in the dispersion and hinder their interaction. Dispersant must be mixed with water at once, when the breakdown of pigment clusters start. Only then can interaction and therefore reagglomeration of particles be avoided, for this reason the dispersant is added into water in the beginning of the dispersing process, even before pigment is added. Dispersants, which works as steric stabilizer, is also

called protective colloids example of these are starches and polyvinyl alcohols. A good example of dispersant, which work as an electosteric stabilizer , is carboxyl methyl cellulose(CMC).

Thickner: The main function of thickeners is to adjust the viscosity of the coating colour to the desired level and to impart the necessary degree of water retention. Thickners need to be able to interact strongly with water molecules if they are to increase the water retention of the coating colour, and they also need to interact with other ingredients of coating formulations, especially pigments in order to display a thickening effect.The nature and strength of these interactions depend on the chemical composition of the polymer.

pH Control: pH control can use a number of additives, but the most common today are ammonium hydroxide and sodium hydroxide are used for pH control.

11. Coating Component and their Functions:

Table2.

Component	Example	Functions
Pigment	Clay,$CaCO_3$(precipitated) TiO_2, Plastic pigment(polystyrene)	Builds a fine porous structure provides a light scattering surface
Adhesives **(Binders)**	Water soluble adhesives (glue, starch, gums, casein ,soya protein), Polymer emulsions (latex, polyvinyl acetate)	Binder pigment particles together Binds coating to paper, fills the pores of the pigment structure
Additives		
Insolubilizers **(waterproofing agent)**	Formaldehyde donors,glyoxal,lattices	Makes the coating less sensitive to water.

Plasticizers	Stearates,wax emulsions	Improves the flexibility of coating films.
Rheology Control agent(thickner)	Natural polymer,cellulose derivatives,synthetic polymer	Control coating viscosity and water retention properties.
Dispersent	Polyphosphates, lignosulfonates,silicates	Optimize pigment dispersion.
Preservatives	Formaldehyde	Prevents a spoilage of formulation between runs.
Defoamers	Proprietary agent	Control foam problems, eliminates air bubbles.

12. Coating Colour Formulations: The objective of a coating colour formulation is to prepare the desired amount of coating colour in the required quality using a combination of mixing, pumping, storing, conveying, metering, and screening processes.

Coating colors consist of several components, white pigments (e. g. clay, calcium carbonate, talc, titanium dioxide) and binders (e. g. starch, latexes) being the most important as regards volume and cost. Further specific additives influence and control the applicable solid content, the rheology, water retention and immobilization of the coating color during the coating process (e. g. dispersant, co-binders, thickeners), and others influence the physical and optical surface structure and properties of the coating layer (e. g. associative thickeners, lubricants, fluorescent whitening agents, defoamers, degassing agents).

Water is an essential component of a coating color making it possible to mix the components of a coating color, e. g., so that all the pigment particles are separated from each other, which is impossible in the dry state. Water also makes it possible to transport the color elsewhere and apply it onto the base paper so that the coating color remains uniformly dispersed. As water evaporates from the coating layer, the coating layer consolidates when the binder forms bridges between pigment particles and base paper. Coating colors should contain only as much water as the flow properties need, in order to save energy and costs for drying. The solid contents of the

coating colors can be as high as about 70 wt. %.Th : most of the pigments are delivered as slurries or dispersions with 60–78 % solids.

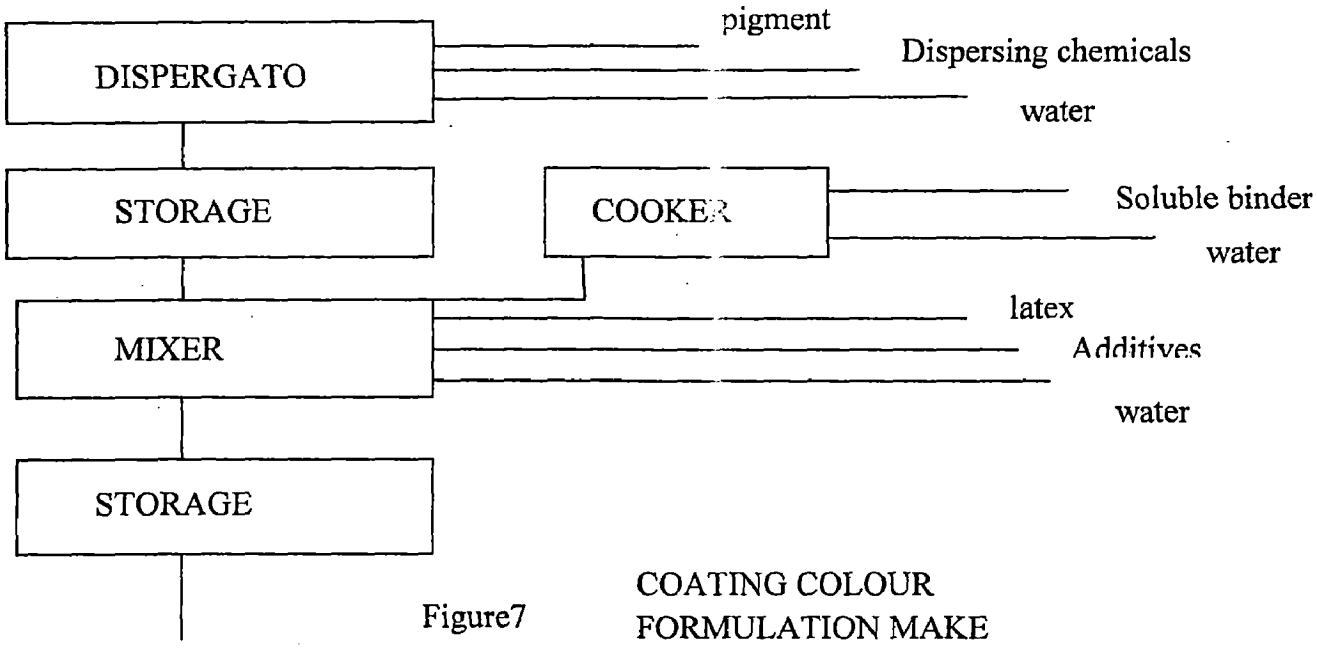


Figure7 COATING COLOUR FORMULATION MAKE DOWN

13. Principles of Coating Techniques for Base Paper:

The principle of coating technique can be divided into different phases:

1. Application of the coating color onto the base paper. Surplus of coating color is applied in several coating methods. .

2. Metering of the coating (metering may take place before, during or after the application).

3. Drying of the coating.

4. Smoothing of the surface e. g. by supercalendering or soft calendaring.

Pre-metering, or metering before application takes place, e. g., in the metered size press (MSP) and in the gate roll press. Simultaneous metering or metering and application take place at the same time in the short dwell time applicator (SDTA) and in the conventional size press. Post-metering, or metering after application takes place in the blade coater, in the rod coater, and in the air knife coater. The applicator roll runs at a slower rate than the paper sheet and applies a generous amount of color (20–30 times in excess) to the base paper. After wetting the base

paper, the waterline migrates into the coating base. Thi penetration is assisted by hydrodynamic pressure building up in the nip as a result of the web speed. Consequently, the kinds of application and metering characterize the various coating methods. In both the metered size press (MSP) and in the gate roll press, metering takes place on the surface of a roll, and the coating film is then transferred onto the paper in the nip between two rolls.

Coating can be done double-sided, i. e., both sides of the paper are coated simultaneously or on only one side at a time. Printing papers are usually coated similarly on both sides, and boards often on one side only. Single coating means that only one coating layer is applied per paper side, in multiple coating several coating layers are applied per paper side. The most common multiple coating is double coating. So-called art papers may be triple-coated, i. e., three coating layers per paper side. If coating is done on-machine, then the coating will immediately follow the manufacturing of the base paper without intermediate reeling. Off-machine coating means that the paper is reeled after the paper machine and coating is done in a separate machine. Web defects may be removed during re-reeling.

The basic function of the coater supply system is to supply coating colour to the coating heads to be evenly spread on the paper or board web. In most cases only about 10 % of the pumped coating colour will be applied onto the running fiber web. About 90 % of the coating colour flows back to the supply tank. This high internal coating colour recirculation is required to ensure homogenous and constant colour properties for trouble-free coater operation. The feed of the fresh colour into the supply tank is controlled by its level. From the supply tank, the coating colour will be pumped first to the screens, which eliminate all impurities larger than 50 mm, depending on the geometry of the screening elements. The second key process is degassing of the coating colour. Depending on the design of the coating heads, the coating colour flow is led to the ponds or chambers through one or two inlet pipes , controlled by a throttling valve for accurate flow. The overflow goes back freely to the supply tank. The contents of solids and gas as well as temperature and pH and their variations are monitored continuously.

13.1 Applicators: The actual coating process usually comprises two steps: (i) the application of the coating medium onto the paper or board and (ii) the metering of the coating medium to the desired quantity (or coat weight). If the metering is done directly on the paper after the

application, the process is called direct coating or blade coating. If, however, metering is done before the transfer of the coating medium to the paper or board, the process is called indirect coating or film coating.

13.2.Direct Coating: In direct coating, the web is supported by a backing roll and the coating medium is fed in excess onto the web. After a certain distance, defining the "dwell time", the coat layer is metered down to the final thickness, being the desired coat weight. In the "roll applicator" or "LDTA" (long dwell time applicator), feeding is done with a roll, which draws the coating medium from a pan onto the web. The applicator roll and the backing roll form a nip. The nip pressure and, consequently, the nip gap are adjustable, determining the amount of coating medium fed to the web. The nip load also yields an external penetration pressure which, together with the capillary pressure, causes penetration of some coating medium or components thereof into the paper or board web. This is to a certain extent desirable, because it anchors the coating to the base paper and gives surface strength. Excessive penetration, however, would reduce the gain in surface properties, such as smoothness or gloss.

13.3 Indirect Coating: As an alternative to direct coating, a film press can be used for the application of coating media. The film press was derived from the size press, which is used for the application of starch or size solutions. Today, a wide variety of coating media are applied, including pigment dispersions with high solids content. In a film press, a film of the coating medium is formed and metered on a large diameter roll. This roll forms a nip with another roll. The paper or board web passes this nip.

13.4 Application Concepts: The coat weight is typically 25–40 % of the final basis weight of the paper. Wood-containing papers are mainly single-coated (LWC). Coat weights are usually between 6 and 10 g/m^2 per side. Traditionally, the coat is applied with a blade coater. More modern installations use a film press for the single coat. At higher basis weights (MWC), two coat layers may be applied per paper side. Here, the top coat is usually a blade coat. The pre-coat may be either a film or a blade coat. Wood free papers cover a very wide basis weight range. Depending on the basis weight, the application can be single coat, double coat or triple coat. The coat weight per layer can vary in a wide range between approximately 8 and 20 g /m^2.

13.5 Web- Drying after Coating: The purpose of the dryer section is to increase the dry content of the paper web, usually to 90 to 98 %, by evaporation, During drying the fibers develop hydrogen bonds which provide the natural strength of the paper. Drying is mass transfer process in which heat has to be transferred from a heat source to the paper and the evaporated water has to be carried off. During drying, the paper web which has been picked up from the press section has to be guided safely throughout the dryer section to the reel where it is wound up.

13.5.1 Drying Principles:

Contact Drying by Steam Heated Cylinders: The most common principle in paper drying steam condenses at the inner surface of the cylinder wall, the heat is transferred through the wall to the paper web, the web is heated and water is evaporated. The heat transfer rate from the steam to the cylinder shell depends on the flow pattern of the condensate motion. This flow pattern is mainly dependent on the machine speed, and to a lower degree on the amount of condensate volume in the cylinder and on the cylinder diameter. At low speeds of up to about 300 to 500 m min–1 a pond of condensate is found in the cylinder. At higher speeds – above the "rimming speed" – the condensate builds up a ring. Acceleration during "ascending" of the condensate ring is against the rotating direction, and in the rotation direction when descending. The syphons either rotate with the cylinder (for higher machine speeds) or are stationary. Heat transfer through the wall depends on the thickness and conductivity of the cylinder material which is mainly cast iron (in some cases steel). Higher steam pressure increases the temperature difference and thus the drying rates. Accumulation of air in the cylinder has to be avoided as it would reduce the condensing temperature according to the partial pressure. Good heat transfer from the cylinder to the paper web is obtained by pressing the web tightly to the cylinder e. g. by means of dryer fabrics.

Air Impingement Drying: This drying principle is mainly used in tissue production or in coating machines but also for enhancing the drying capacity of drying cylinders in multi-cylinder dryer sections. Hot air is blown through a nozzle plate at high velocity onto the paper. The impinging air transfers heat to the web and takes up the evaporated water. The air is then sucked back into the hood. Heat transfer in impingement drying increases with increased air temperature and velocity and by reducing the spacing between the nozzle plate and the paper surface.

Through Air Drying: This method is used in the drying of tissue and nonwovens. Hot air is sucked or blown through the air permeable paper web supported by a heat resistant wire. Heat is transferred directly into the fiber network and the evaporated water is carried off. Through air drying results in the highest drying rates.

Infrared Drying: This heat transfer method is mainly used to enhance the drying capacity in coaters when the web is wet. Infrared heaters are usually gas fired. The gas heats to a temperature of about 900 to 1100 °C. Infrared drying units need sufficient air flow in order to carry off the evaporated water and to prevent coat quality problems.

Press Drying: This method is a combination of pressing and drying. First the web is dewatered mechanically in a press nip and brought into tight contact with the hot surface on one side. At the opposite side the web is covered by a permeable belt such as a felt or a wire which continues to press the web to the hot surface over a longer distance.

Impulse Drying: This method is also a combination of pressing and drying. The process takes place in a press nip (for instance with a shoe press) where one surface, which is in direct contact with the web, is heated. The other web side is in contact with a felt. The wet web is compressed and thus mechanically dewatered. The vapor generated at the hot surface pushes the water through the compressed capillaries towards the felt and finally the generated vapor can flow freely through these channels. This kind of process is still in development.

In the all above six methods of drying coated paper, there are three phases of evaporation takes places are following as.

1. Pre-heat phase: At this stage most of the heat energy gets absorbed in the system to establish heat equilibrium between paper, coating and water content. Very little evaporation occurs in this first phase.

2. Steady-state evaporation: In this stage the evaporation starts and continues uninterrupted at the equilibrium .Most of water is removed in this stage.

3. Falling rate phase: In this stage as the paper&coating dry,the evaporation rate falls, this is due to paper temperature to rise. Hence drying variables need to be controlled once the paper substance starts getting hot.

In all the phases of drying, it is extremely important to ensure that the binder i.e.(clay and other ingredients) gets distributed evenly on the web surface because it ultimately affects printing quality of paper.

14. Coating Processes: The coating mixture has been prepared, it must be applied to the paper in the coating process, which consists of applying the fluid coating mixture to the base paper, smoothing, drying and calendaring the coating. All these are important steps in the coating process and must be carefully carried out in order to obtain a satisfactory coated paper.

Coating can be divided into different phases:

- Application of coating colour onto the base paper.
- Metering of the coating (metering may take place before, during or after the application)
- Drying of the coating
- When the desired amount of coating on the both sides of paper has been obtained, it is time for the finishing phases. The most common method of finishing is supercalendering .Soft calendaring is a growing alternative, which can be applied also to boards because it does not decrease bulk too much.

There are mainly two types of coating processes are following as:

- On machine coating
- Off machine coating

14.1 On-Machine Coating Process: On Machine coating is carried out on the paper machine as an integral part of the papermaking operation. The paper is coated and dried at normal paper machine speeds. Machine coating was developed to fill the need for mail-order publications papers which would reproduce illustrations better than standard uncoated papers. Coating on the paper machine is preferred by mills making one grade and weight. Most

publication grades and paperboard are coated on the machine. Capital investment and labour costs are lower .

14.2 Application of On-Machine Coating: Generally, on machine coating is practical where the application is light to moderate and quality requirements are not too exacting. Many types of equipments are used for on machine coating, including size press coater, print roll coaters, air knife coaters, metering bar coaters, and blade coaters. The first equipment used for on machine application was the Massey print roll coater. The coating is applied between two large applicator rolls(1.2 m diameter), forming a nip similar to a vertical size press.The colour is supplied by a series of metering or transfer rolls that smooth out the coating mixture and spread it evenly by the time it reaches the applicator roll. The coating mixture is fed into the nip between the first two metering rolls, and pressure is varied between rolls to control the amount of coating transferred.

14.3 Advantage of on-machine coating:

1. Eliminates transport of rolls to the coating machine, thus reducing handling and potential damage to the rolls.
2. Reduces space requirements.
3. Reduces labour requirement(i.e. reduces the cost of coating).
4. Encourages early identification of coating raw stock quality problems.

15. Off-Machine Coating Process: Off machine coating is carried out as a separate operation in a coating plant. It has always been a low speed process designed to make high quality papers, but because of the competition of machine coated paper, off machine coating plants have become interested in replacing their old slow speed coaters with modern high speed machines. The highest quality coated papers are still produced by off machine coating. Off machine units are generally more expensive than on machine coating units.

15.1 Application of Off-Machine Coating: Off-Machine coating is usually carried out as a completely separate operation. A diversity of equipment is available, depending on the requirement of the product, the coating weight, and the speed of operation. One of the oldest methods of off-machine coating employs the brush coater. The coating can be applied by brush,

spray, or roller, the sheet is then passed over a roll and the coating is distributed by a series of brushes than move from side to side across the sheet, the first brushes being coarse and the last very fine. A specialized technique known as cast coating is used to produce paper of exceptional gloss and smoothness.

15.2 Advantage of off-machine coating:

1. Provides great flexibility (i.e. facilitates grade changes, conditions can be tailored for the coating independent of paper machine conditions, can handle tonnage from different paper machines).
2. Eliminates interdependence between operations (i.e. downtime on either coater or paper machine does not impact on the other operation).
3. Provides superior coating quality.
4.

16. Pigment Coating Process and Equipment: Paper coating operations are classified as on-machine or off-machine indicating whether the coating is applied on the paper making machine or apart from it in a separate operation. There are five major coating processes.

1. Size Press Coating.

2. Roll Coating.

3. Air Knife Coating.

4. Blade Coating.

5. Cast Coating.

16.1 Size Press Coating: Coating applied at the size press generally require a binder content significantly higher than that required for coating applied by other methods because of the high absorbency of the paper web at the size press location. Size press coating has been used for upgrading papers for printing in those mills not equipped with regular machine coaters. It can be used to raise the brightness, increase the ash content, and improve printability. The percent solids of the coating mixture used in size press coating ranges from about 12 to 50%. The ratio of pigment to adhesive ranges from 0.5 to 9:1.In vertical size press, there is a tendency to pick more

coating on the top side. The horizontal size press has the advantage of applying more even coating to both sides of the sheet. The base paper for size press coating should be moderately sized, have a moisture of about 5% and be tinted the same as the colour of the coating.

16.2 Roll Coating: In roll coaters, a metered amount of coating is applied to the paper surface with the help of a rubber covered applicator roll. Much higher coat weights can be applied and higher application solids can be used.There are two types of roll coater such as reverse roll coaters and transfer roll coaters. In order to classified as reverse roll coater, two fundamental principles must be met, first one there must be reverse running direction in the metering nip which is formed by the applicator (casting roll) and the metering roll.The second principle that must be met is that of reverse application of the coating from the applicator roll to the web ,which is supported by back-up roll.The transfer roll coater was developed to coat paper with mineral pigmented coating on the paper machines and to produce a publication –grade paper in line in continuous process.

16.3 Air Knife Coating: In air knife coating system an excess of coating mixture is applied to the paper surface and an air-jet doctoring unit is used to remove the excess coating. The main advantage of air knife coating is its applicability to wide range of raw stocks and coating conditions. It is essentially a low-solid, low viscosity operation. The air knife coater is require in that it doctors the coating from the web without any direct physical contact with the web so that it produces a coating that is uniform in thickness regardless of the topography of the paper surface. A uniform thickness of coating is desirable for highly coloured coating or when applying high-opacity coating to an unbleached raw stock.

16.4 Blade Coating: Blade coating is now the dominant form of coating. Blade coaters produce a high quality coated surface, which is due to the absence of the film split pattern that is characteristic of roll-coated papers. The basic feature of blade coating is the application of direct-contact physical doctoring principle. There are a number of variations of coaters using this principle Champion Rod Coater, Champ flex Coater, Puddle type Blade Coater, Bent Blade Coater etc.

16.5 Cast Coating: Cast coating is used to produce ultrahigh-finish pigment-coated papers. Cast coating involves bringing a wet, plastic coated surface into contact with a non –adhering surface

with a high finish then rendering the coating non plastic, and there after removing the coated paper from the non adhering surface. The final coated surface mirrors the finish of highly polished drying surface, thus eliminating the need for super-calendaring and maintaining high bulk and ink absorbency of sheet.

17. The classification of pigment coated papers:

LWC papers: LWC paper is a light weight coated paper, where the coat weight varies from 5 to 12 g/m^2 per side . The end uses of LWC are magazines, catalogs, and commercial printing. LWC grades are produced for both heat set web offset and gravure printing. The basis weight varies for LWC offset (LWCO) from 39% to 80% and for rotogravure (LWCR) from 35 up to 80%.The most frequently used coating technology for LWC papers is blade coating.LWC base paper is normally precalendered before coating to stabilize thickness and to reduce roughness and porosity.

MWC papers: Medium weight coated (MWC) papers are mechanical pulp dominating papers , where the coat weight amount to 12-25g/m^2 per side . MWC papers are also known as double coated papers, whose information carrying capacity is higher than that of LWC paper. MWC papers can also be coated only once. They are used for high quality special magazines with high power advertisement, but also for catalogs, direct mail, and for other advertising. The basis weight varies between 70 and 90 g/m^2.The most common properties are high brightness, good opacity and gloss, excellent smoothness, and no cracking when folding. MWC papers are produced with lower speeds than standards LWC. MWC papers are made from 40%-55% mechanical pulp and 45%-60% chemical pulp. The total pigment content varies from 28% to 45%.

HWC papers: High weight coated (HWC) papers differ from other coated, mechanical pulp dominating paper grades in their higher coat weight. Traditionally they are produced at the basis weight level of 100-135 g/m2 , and they compete with coated fine papers at such end use areas as high quality magazines, catalogs, and magazines covers as well as in the area of direct advertising. HWC papers can be double or triple coated.

MFC papers: Machine finished coated (MFC) papers have higher bulk, are stiffer than LWC and usually have a matte surface. The coat weight is low and varies from 2 to 10g/m^2 per side.

MFC papers are used for special magazines, catalogs, books. MFC is a good option in situation where high readability, high delta gloss (printed gloss vs. paper gloss), a good opacity and brightness combination, and stiffness are needed. They are printed in heat-set web offset. MFC papers are made up of 60%-85% ground wood or TMP and 15%-40% chemical pulp. The total pigment content is 20%-30%.

ULWC papers: Ultra weight coated papers (ULWC), also sometimes known as low lightweight papers are used in Europe for rotogravure printed catalogs and in the United States in offset printed magazines. Basis weight area ranges normally from 35 to 48 g/m^2, and ISO brightness is at the level of 69%.

FCO papers: Film coated offset (FCO) paper is a fairly new paper grade. Film coating technology was introduced as a coating method for mechanical pulp dominating papers in mid 1990s in Europe. FCO is used for example such as special magazines and catalogs. It is currently produced in the basis weight range of 45 to 65 g/m^2. This grade gives a high bulk, good surface strength with low fiber roughening, and sufficient gloss.

Coated one side (C1S)- Coated one side also called as chromo paper / board mainly used for printing labels, wrapping etc. Where only the coated surface is printed.

Coated two side (C2S)- Coated two side also called art paper/board. Bulk of this grade is used for magazine publishing , and the remainder being used for commercial printing. A major portion of the research and development work in pigment coating has been focused on publication grades.

18. Coating quality and process runnability: Coating quality and coating process run ability are two concepts of utmost importance in the economical and competitive manufacturing of coated paper .Paper quality must meet a specification, if the quality is below specification, reclamation and even demands of economical compensations can be expected from the customers. Run ability means the smoothness of the coating operation. It includes the easiness to reach and maintain the desired, faultiness coating quality. It also includes break-free operation of the coater. Bad run ability leads to inefficient and uneconomical production of coated paper.

Coating quality involves, e.g., smoothness, gloss, and ink absorption. These depends on the coating structure, by which is meant the spatial arrangement of the main components- pigment and binder in the coating layer as well as the air. Quality depends also on the coverage, Coverage indicates how well the coating is able to hide the base paper under it.

The run ability of coating colors is affected by a variety of factors , such as the porosity, roughness, degree of sizing, and stiffness of the base paper. However , the main factors influencing run ability are the solids content of the coating color and its rheology and water retention. Water retention of a coating color indicates to what degree a coating color retains its aqueous phase when it has been applied onto the base paper.

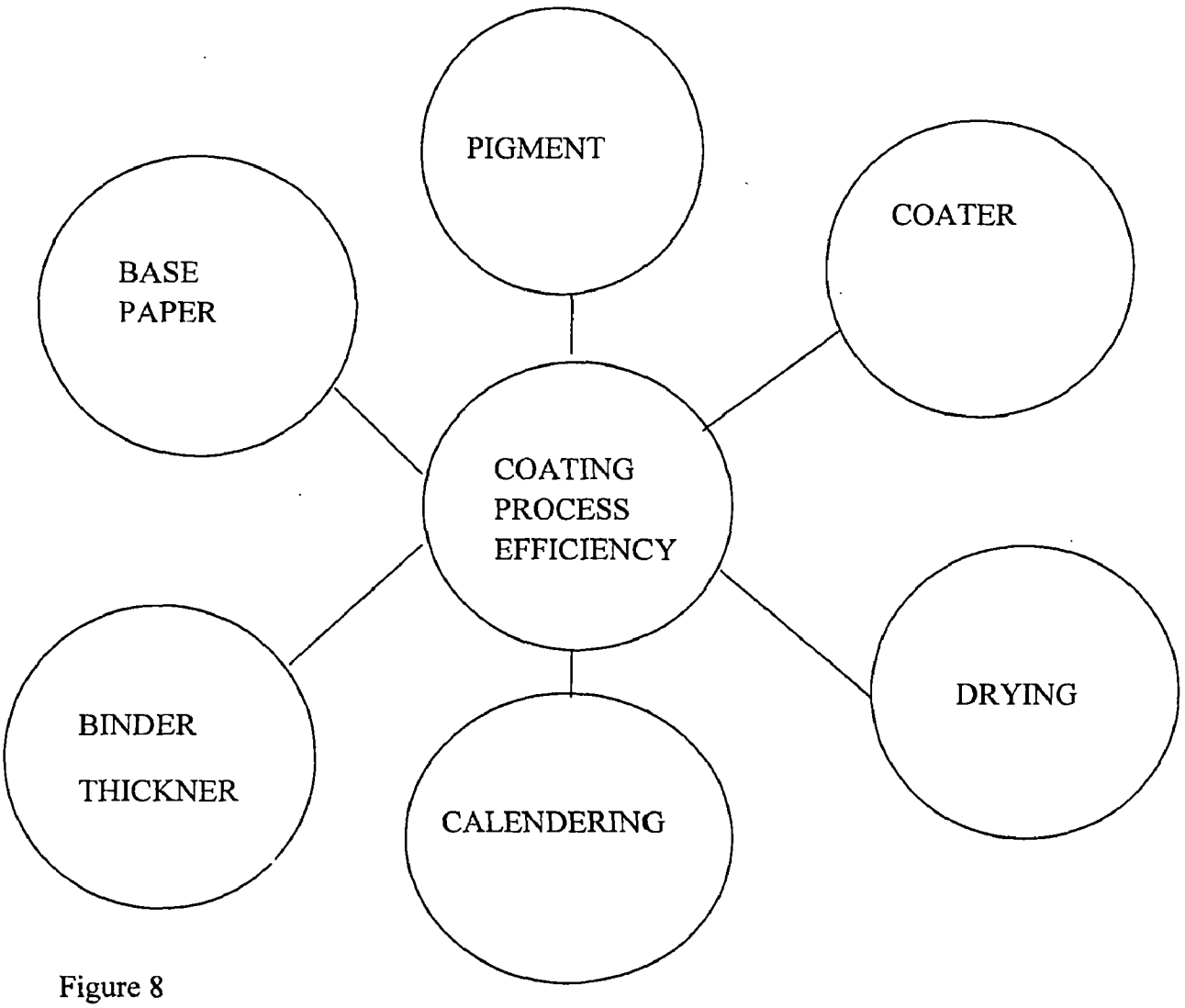


Figure 8

COATING QUALITY AND PROCESS RUNNABILITY

19. Defects during the Coating:

19.1 Defects in On –Machine Coated Papers:

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

Coating formulation and its application:

- Variation in concentration with time.
- Variation in binder to pigment ratio with time.
- Variation in concentration due to heat of drying system.
- Variation in temperature of paper.

19.2 Defects in Off-Machine Coated Papers:

Defects developed in a coated paper can be 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:

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

20. Defects due to Coaters:

20.1 Temperature of 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 stabilized 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.

20.2 Control of Flow and Mixing of Formulation: In coaters, 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

21. Objective of Calendering:

The objective of calendaring is to modify 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.

Calendaring is a process where the smooth surface of the hard rolls is replicated on the side of the web that contacts the hard roll, Still others argue that it is the shearing action in the nip which causes gloss and smoothness by "aligning" the surface particles of the web. Thermal energy transferred to the web softens the cellulose fibers (glass transition point) and thus enhances the development of gloss and smoothness.
Smoothing the surface and increasing gloss are accompanied by reduction in calliper, strength properties, brightness and opacity to a certain degree.

Calendaring is done by pressing the paper web in one or more "rolling" nips formed by rolls with special properties.
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.

21.1 Soft- nip calendering: 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 a one or two nip thermo finisher , called gloss calendar. A softnip 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 ^{O}F.

22. Evaluation of pigment coated papers: The coating amount has a big influence on the physical and optical surface properties. Different printing methods have their own requirements for coated paper and paperboard. Physical properties are smoothness, gloss, surface strength, ink absorption, dusting/linting, and visual defects. Optical properties are brightness,

whiteness, colour shade, opacity, mottling and print unevenness and Taste and odour are important properties, especially for paper and paperboard grades used for food packages.

Coat Weight: Coat weight measurement in the laboratory is based on the ash content (925 °C) of base paper and the ash content of coated paper. Several different technologies have been used to measure on-line coat weight. The Beta or dry weight technique measures dry weight before and after the coating operation and the coat weight is calculated by difference. Weight and moisture sensors are required at both locations. The ash or X-ray absorption method is similar except that ash sensors are used instead of basis weight measurement.

Smoothness: A principle reason for pigment coating paper is to produce a smooth surface that will ensure good contact between the coated paper and the printing plate. As rotogravure printing is the most demanding printing method for paper surface, a special test method is used only for that purpose.

Gloss: Gloss is a measure of the degree to which a coated surface approaches a perfect specular surface or mirror in its ability to reflect light. Gloss describes the mirror-like property of a coated surface and is defined as the percentage of the light that is reflected from the surface at an angle equal to the angle of incidence, in comparison with a standard surface.

Ink Absorption: This is the ability of a (coated) paper surface to absorb ink during printing. If ink absorption is too slow, there may be a risk of set-off. The K&N test method (TAPPI Method 553), depending on the test ink used. The ink used is applied to a paper surface in a thickness of 0.1 mm; after 2 min no absorbed ink is wiped off. The brightness of the colored area is measured and subtracted from the original brightness of the paper to give the ink absorption value as a percentage. The test area can also be used for visual evaluation of the evenness of absorption. If the area is mottled, there is a risk of mottle during printing.

Surface Strength: This is the internal and surface bond strengths of paper which are necessary to prevent fibres, fines, filler, or coating from being removed in printing or converting operations that involve ink and/or aqueous liquids such as in offset printing. Generally, for coated paper, the picking test and rub resistance are used. The picking test is done either by using a wax pick test (Dennison Wax/TAPPI Method UM 463) or a simulated printing by using a device from the

ite for Graphic Technique (IGT tester/TAPPI UM 591). Rub resistance describes the abili ıted paper to withstand marking, scuffing, or smudging during handling.

l Defects:

primary objective in pigment coating is to improve the printability and appearance of th al, no visual defects should appear. Typical defects are holes, spots, blade scratches and s and creases. Visual defects are controlled using on-line detectors and visual checking. checking is done in two places: The machine crew take a cross sample from the web at) of each machine reel and examine it under strong light sources with different light angle k the defects. In laboratories, sheets are checked visually under a light source, and defect ınted and recorded. The on-line devices measure faults like slime holes, wrinkles, creases icks, turnovers, blade stripes, etc. Detection and counting of dirt specks are done online

ness and Whiteness: In pigment coated paper, the coated paper grade structure is based ghtness, and to lesser degree on raw stock composition. Absolute brightness for paper is on the reflectance of the blue light at a wave length of 457 nm. Whiteness, on other hand ure of the reflectance values of visible light in the range 400-700nm. In practice, because ghtness of pigmented-coated paper depends heavily ,the raw stock should have a ıess that is very close to that of the dry coating.

y: Opacity is a measure of the amount of light transmitted through paper. When no lig smitted, the opacity is 100 %. The measuring principle is based on comparison ı ınce for a single paper sheet over a black background compared to an opaque stack ı samples. As opacity increases with increased absorption and scattering of light, th ng parameters are of prime importance for opacity, basis weight, filler content in bas degree of calendaring, type and treatment of pulp, as well as coat weight and coatin components.

ıg properties: The printing properties of paper results from complex interactions betwee g ink, printing process and paper. Test printers are also suitable for this purpos ıents for offset printing, gravure printing, and flexography printing can be used wit d printing inks under laboratory conditions to test the dry pick resistance or wet pic

resistance of paper. Printing is done by using a device from the Institute for Graphic Technique (IGT tester/TAPPI UM 591).

Print Gloss: Print gloss is evaluated on the prints in a manner similar to that used for measuring gloss of paper. The measurement of the print gloss is useful for print quality. The gloss is a compound property of a surface, dependent on its smoothness, its refractive index and its absorbing characteristics.

Print Density: Print density is defined as contrast between the printed and unprinted papers. This contrast can be determined from reflectometer measurements on the prints. Print density is the ratio of the reflectance on the unprinted paper measured with paper backing to the reflectance on the printed area of the paper measured with paper backing.

That is print density will be $D=\log R_{\alpha}/R_{\alpha p}$.

Picking Velocity: The pick velocity is defined as the velocity at which picking starts.The picking of paper is defined as the damage of the paper surface during the printing operation, at that time the printing form is lifted off the paper the ink is exerting a certain force on the paper. When this force exceeds a certain value, the surface of the paper will be damaged. The determination of the picking velocity is one of the most widely used tests performed on the IGT printability testers.

23. Property requirement for Coating Paper:

Table3.

Properties	Effects
Sizing	Regulates of receptivity of paper to coating (machine coating papers are unsized or slack sized , highly sized paper is used for papers to be coated on one side using air knife coater.

Wet strength	To prevent breaks during coating operation
Not too porous Less pore volume	Porosity (together with sizing)determines amount of penetration of adhesives in coat mixture.
Smoothness	To have uniform coating and smooth coated surface wire marks are more prominent on coated surface rather than uncoated.
High bulk	More uniform calendaring of coated paper without producing hard spots (bulky sheet more resilient better cushion while printing)
High Tear, Folding Endurance	Good indication of amount of handling, the coated paper can stand in modern high speed folders and automatic press feeders.
Burst strength	High degree of fiber bonding (resistance of coated sheet to split or rupture during printing operation)
Brightness & Opacity	Affects appearance and see through property in the case of thin coated papers.(generally coating is thin)

24. Laboratory Coater: The laboratory coater has the following characteristics:

- Suitable for blade coating and films press coating studies.
- Options for sheet and web blade coating.
- Options for sheet and web film press coating maximum speed 80m/min.

- Equipped with Rod and blade coating facilities.
- Equipped with infra-red drying with paper surface temperature from 65 ^{O}C to 85 ^{O}C .

Equipped with 2-6 KW Air dryer with the maximum temperature of 180°C.

Can handle web of any gsm in 25 to 30 cm width

25. Laboratory Calendar: The laboratory calendar is the capable of doing calendaring under soft nip and hard nip conditions with the following variables.

- Variables temperature option from ambient to 150^{O}C.
- Variables pressure option from 0 to 175 bar.

Suitable pressure for board< 10 bar

For paper-11bar

- Variable speed from 0 to 20m/min.

26. Coating Colour formulation: The coating colour preparation was proceed in the order of pigments (china clay, GCC, PCC) and dispersed in distilled water (with high speed mixing). The distilled water was used to proper mixing the pigment in proper concentrated slurry and add the dispersant (at high speed mixing), defoamer (high speed mixing), thickener(low speed mixing), and finally added NaOH (at low speed mixing) to maintain the desired pH values than add the distilled water to maintain the desired slurry. The total solids of coating slurry were maintain around 60% and pH was 8 to 9.

27. Coating Experiment: For coating experiment ,The base paper used from different mills of different wood characteristics . All coating chemicals that is pigment, binder, thickener, dispersant and defoamer were used to make the coating formulation which was applied on the

base paper for surface coating. This coating formulation prepared and applied to 21.0x29.8 cm base sheet using an automatic bar coater for surface coating .The coating amount was adjusted using bar of different numbers .The coated sheet were placed immediately in an oven maintained at 120 ^{0}C for 25-30 seconds to dry. The sheets were coated one side with the coat weight of 20 gsm. The coated paper was calendared in laboratory calendar (DT Paper Science Finland) using soft nip. Each paper was calenderer at the load of 100 KN/m and temperature of 60 ^{0}C. The speed of calendared was kept up to 20m/min.

28. Raw materials for coating experiments:

There are two grades of Base papers used from different paper mills are following as:

- **Base paper 1. (From Star paper mill)**

100% Hardwood based Base paper

- **Base paper 2. (From HPC)**

100% Bamboo based Base paper.

29. Properties measured on the following standards:

Table4.

Properties	Standards
Tensile strength(kN/m)	TAPPI T494
Tear strength (N/m2)	TAPPI T414
Burst strength(KPa)	TAPPI T403
Folding endurance (No.)	TAPPI T571

Gsm(g/m2)	TAPPI T410
$Cobb_{60(g/m2)}$	TAPPI T411
Ash(%)	TAPPI T413
Brightness(%)	TAPPI T452
Opacity(%)	TAPPI T425
Gloss(%)	TAPPI T480
Porosity(%)	TAPPI T460
Smoothness(ml/min)	TAPPI T479
Thickness(μm)	TAPPI T500

30. Pigment coating formulation apply at the desired condition on the Base paper:

Exp1: For Base paper 1.(100% hardwood based Base paper.)

Table 5.

Experiment	Doses	China clay	GCC	PCC	Binder	Dispersant	Defoamers	Thickener	Solids %	pH
Exp.1	parts	80	20		12	1	0.2	0.4	60	8-9
Exp.2	parts	70	30		12	1	0.2	0.4	60	8-9

										9
Exp4.	parts	**70**	**20**	**10**	**12**	**1**	**0.2**	**0.4**	**60**	**8 9**

Properties measured of the coated and uncoated papers for base paper-1

Table 6.

Properties BASE PAPER - ONE	UNCOATED BASE PAPER PROPERTIES	COATED BASE PAPER PROPERTIES DOSES-1	COATED BASE PAPER PROPERTIES DOSES-2	COATED BASE PAPER PROPERTIES DOSES-3	COATED BASE PAPER PROPERTIES DOSES-4
Grammage (g/m^2)	65.8	88.2	89.0	88.5	89.5
Tensile strength(kg/15mm)	2.8	4.5	4.7	4.3	4.4
Tensile index(N.m/g)	25.48	30.1	30.3	29.5	28.5
Tear strength(g.force)	10	10.5	10.6	10.4	10.5
Tear factor	30.6	23.4	23.0	21.0	22.3
Tear index	3.0	2.2	2.0	2.3	2.1
Burst strength (kgf/cm^2)	1.3	1.5	1.7	1.6	1.4
Burst factor	19.4	22.0	24.0	23.0	21.0
Burst	1.8	2.1	2.4	2.2	2.0

index(k.Pa.m^2/g)					
Double fold	9	3	2	3	4
Thickness	7.3	7.0	6.5	6.8	6.5
Smoothness(ml/min)	90	15	13	14	12
Porosity(ml/min)	195	48.8	50.2	54.0	53.0
Brightness (%)	**77.2**	**89.5**	**88.5**	**91**	**94.1**
Opacity (%)	89.9	84.4	87.9	88.2	90.4
Ash (%)	7.8	24	23	25	23
$Cobb_{60}$	18	22.5	21.5	22	22

32. Pigment coating formulation apply at the desired condition on the Base paper:

Exp.5 For Base paper 2. (100% bamboo based Base paper.)

Table 7.

Experiment	Doses	China clay	GCC	PCC	Binder	Dispersant	Defoamers	Thickener	Solids %
Exp.1	parts	80	20		12	1	0.2	0.4	60
Exp.2	parts	70	30		12	1	0.2	0.4	60
Exp3.	parts	75	20	05	12	1	0.2	0.4	60

Exp4.	parts	**70**	**20**	**10**	**12**	**1**	**0.2**	**0.4**	**60**

Properties measured of the coated and uncoated paper for base paper-2

Table 8.

Properties BASE PAPER - TWO	UNCOATED BASE PAPER PROPERTIES	COATED BASE PAPER PROPERTIES DOSES-1	COATED BASE PAPER PROPERTIES DOSES-2	COATED BASE PAPER PROPERTIES DOSES-3	COATED BASE PAPER PROPERTIES DOSES-4
Grammage (g/m^2)	71.8	89.5	88.2	89.4	90.1
Tensile strength(kg/15mm)	2.6	4.6	4.8	4.7	4.5
Tensile index(N.m/g)	23.6	29.3	30.0	29.5	30.4
Tear strength(g.force)	10.2	11.5	10.2	10.8	11.2
Tear factor	14.2	22.3	22	23.2	23.5
Tear index	1.3	2.2	2.1	2.4	2.1
Burst strength (kgf/cm^2)	1.2	1.5	1.8	1.6	1.7
Burst factor	14.7	22	21.5	22	21
Burst	1.4	2.3	2.25	2.1	2.2

index(k.Pa.m^2/g)					
Double fold	7	5	4	3	3
Thickness	7.2	7.1	6.3	6.5	6.8
Smoothness(ml/min)	94	15	18	15	10
Porosity(ml/min)	245	47.5	48.2	50	45
Brightness (%)	**79.1**	**87.5**	**89**	**90**	**96.4**
Opacity (%)	88.3	84.4	86.5	88.5	89.5
Ash (%)	8.5	20	22	21	23
$Cobb_{60}$	18	21.5	21	22	23

33. Experiment Conducted for the same above two base papers for the printing properties measurement:

Now the experiment conducted for different coating formulation for the two same base papers ,and determining the printing properties such as , print gloss , print density and picking velocity properties and optical properties are measured at the standard conditions at the variation of the pigment coating formulations.

Pigment coating formulation apply at the desired condition on the Base papers 1 &2.

Table 9.

Experiment	Doses	China clay	GCC	PCC	Binder	Dispersant	Defoamers	Thickener	Solids %
Exp1.	Parts	100			12	1	0.2	0.4	60

Exp2.	Parts	80	20		12	1	0.2	0.4	60
Exp3.	Parts	70	30		12	1	0.2	0.4	60
Exp4.	Parts	60	40		12	1	0.2	0.4	60
Exp5.	Parts	**70**	**20**	**10**	**12**	**1**	**0.2**	**0.4**	**60**
Exp6.	Parts	50	30	20	12	1	0.2	0.4	60

Table 10.

34. COATED PAPER CHARACTERISTICS MEASURED FOR BASE PAPER -ONE

(100% Hardwood based paper) :

Experiment	Brightness%	Smoothness (ml/min)	Gloss%	Print gloss%	Delta gloss%	Print density kg/m^3	Picking velocity m/sec^2
Exp1.	79	42	44	77	32	2.6	170
Exp2.	80	37	42	71	29	2.7	180
Exp3.	81.5	40	38	70	32	2.5	178
Exp4.	76	41	40	78	38	2.56	184

Exp5.	**88.5**	**40**	**46**	**85**	**39**	**2.4**	**189**
Exp6.	85.	35	35	75	40	2.2	185

35. COATED PAPER CHARACTERISTICS MEASURED FOR BASE PAPER- TWO

(100% Bamboo based paper) :

Table 11.

Experiment	Brightness%	Smoothness (ml/min)	Gloss%	Print gloss%	Delta gloss%	Print density Kg/m^3	Picking velocity m/sec^2
Exp1.	78	43	43	79	36	2.7	170
Exp2.	82	39	41	75	34	2.5	175
Exp3.	83.4	42	39	76	37	2.6	161
Exp4.	77	44	44	77	33	2.56	181
Exp5.	**89**	**42**	**45**	**83**	**38**	**2.35**	**195**
Exp6.	87	38	39	78	37	2.1	187

34. Result and Discussion:

- The base paper one (100% hardwood base paper) attain the brightness 94.1% at the desired coating formulation (China clay70,GCC-20,PCC-10), but second base paper(100% bamboo base paper) attain the maximum brightness at same coating formulation at the desired condition and these properties are mentioned in table no.6 and 8.

- The base paper one (100% hardwood base paper) attain the desired brightness, smoothness, print gloss, print density and picking velocity as compared to second base paper (100% bamboo base paper) at the same coating formulation that is (China clay70,GCC-20,PCC-10)., these properties are mentioned in table no. 10 and 11.

- Print gloss was improved with the presence of china clay as it has shown better effect in table no.10 and 11 indicating the better effective result and While GCC, PCC gives the some extent effect on print gloss.

- China clay gives the smoother surface (i.e. smoothness better), when china clay is used as pigment in coating.

- Presence of GCC improves the picking velocity, when china clay and PCC used as pigment gives the some extent effect on picking velocity and better effect of picking velocity has been shown in table no.11.

- GCC helps in improving the print density relatively higher than other pigment, while china clay, PCC provides the some extent effect on the print density that is the lower print density indicates the paper require high ink quantity. The better effect of print density has been shown in table no.10.

35. Conclusion: This Dissertation aimed at comparative performance of base paper based on various raw materials. 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 fibers. Coating improves the printing properties of paper. A comparison was made between various grades of paper. Properties of papers such as, Surface, Optical, Opacity, Gloss and printing related were evaluated. There are some efforts made to assign reason for variation in gloss and opacity of paper depending upon raw material on which the paper was based. The mechanical properties were also evaluated.

- The pigment coating provides the surface more uniform in appearance and more receptive to printing ink than the uncoated paper fibres.
- The application of (white) pigments to the base paper surface enhances the brightness of the paper.
- The opacity increases due to the 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 penetration of ink into the paper sheet, therefore the ink does not spread as much and the print image is clear and sharp.
- The print density and the print gloss are enhanced, and the ink demand is reduced compared to uncoated papers.

36. Future demands of coated papers: The demand for coated papers will increase globally. An increasing market will result in a 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 as:

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

37. References:

1. .Jan C. Walter, Chairman Emeritus., "The Coating Process." Prepared by the Coating Process Committee of the Coating and Graphics Arts Division,TAPPI PRESS Atlanta.,/1953

2. Hannu Paulapuro,Johan Gullichsen., "Pigment Coating and Surface Sizing of Paper." Papermaking Science and Technology., Helsinki University of Technology ,Pub. In cooperation with Finish Paper Engineers Association and TAPPI.

3. Linnonmaa J., Rajala, P., Ringbom, K., Solin, R., " Future Developments of the Coating Machine ," TAPPI, Coating Conference Proceeding, TAPPI PRESS, Atlanta, page.963/1998

4.Preston J., Nutbeen,C., parson,J.,and Jones, A., " The printability of coated papers with controlled microstructure",Paper Technology, 42(2),33,/2001.

5.Ynichi Yamazaki, Toshiyasu Nishioka, Yashihiko hattori and Kazuyo fujita. "Print mottle effect of binder migration and latex film formation during coating consolidation.," Tappi j., vol76,no5,/may/1993. G 20019

6.Sood Y.V., Tyagi Sanjay, Tyagi Renu, Pande P.C., Tandon R. & Roy T.K., Quality of indigenous Coated Papers and Ways to Improve it"., IPPTA J. Vol.20,no4,oct-dec/2008.

7.Letzelter,and,Eklund, D., " Coating color Dewatering in Blade Coaters". TAPPI , Coating Conference Proceeding, TAPPI PRESS, Atlanta, page.47/1993.

8. Goran Strom, Anna Englund and Michael Karathanasis, " Effect of Coating structure on print gloss after sheet fed offset printing ",Nordic Pulp and Paper research Journal vol.18,no1/2003.

9.Kiiha, T., "Evaluation Methods for Blade Coating Heads." M.Sc. Thesis, Helsinki University of Technology, Department of Forest Products, Espoo, page93/1996.

10.Prankh F.R. and Scriven , L.E., " The Physics of Blade Coating of Deformable Substrate.," TAPPI , Coating Conference Proceeding, TAPPI PRESS, Atlanta, page.217/1978.

11.J.Newell Stephson, "Manufacturing & Testing of paper and board."Pub.Mc Graw-Hill book company New York, INC, first edition, Vol.3 /1953.

12. James P. Casey, " Paper Testing and Converting" , Pub.Interscience publisher, New York, Second edition , Vol.3.

13. Robert W. Hagemeyer, John E. O' Shea, "A Project of the Coating Pigments", Committee of TAPPI Coating &Graphic Arts Division., TAPPI PRESS Atlanta.

14. G.A. Smook., " Hand book for Pulp and Paper Technologist ."Joint Text book Committee of the Paper Industry.

15. Ting hung, Piere Lepoutre, "Coating paper interactions-the effect of basestock roughness, absorbancy and formation on coated paper properties" paperi ja Puu-paper and Timber vol.77/no.8/1995.

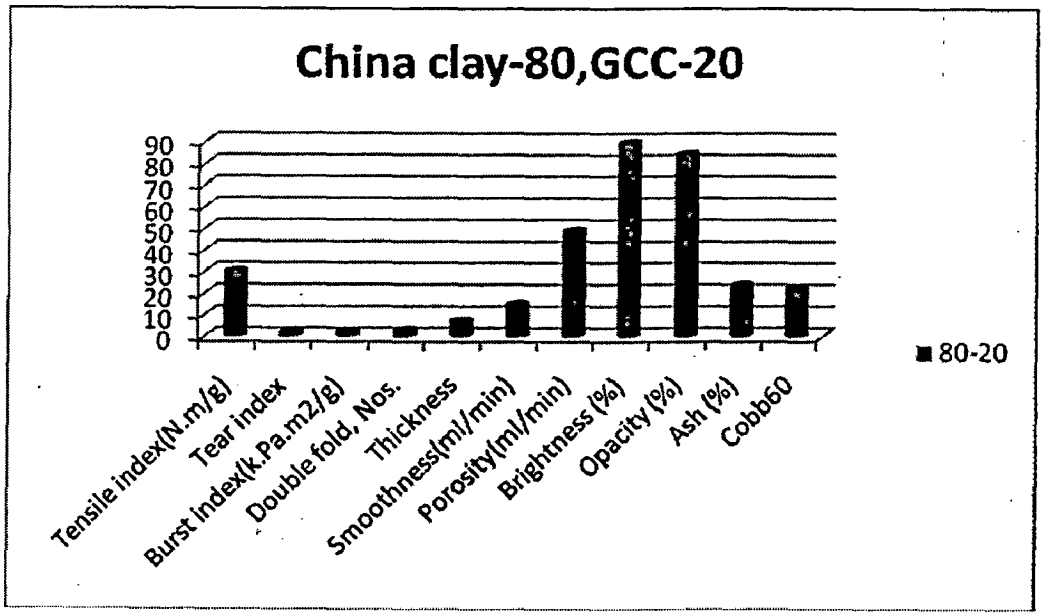
16.HRD notes on "Paper&The Use of Clay "., Human Resource Development Program., Institue of Paper Technology(University of Roorkee), April 14-16,/1994.

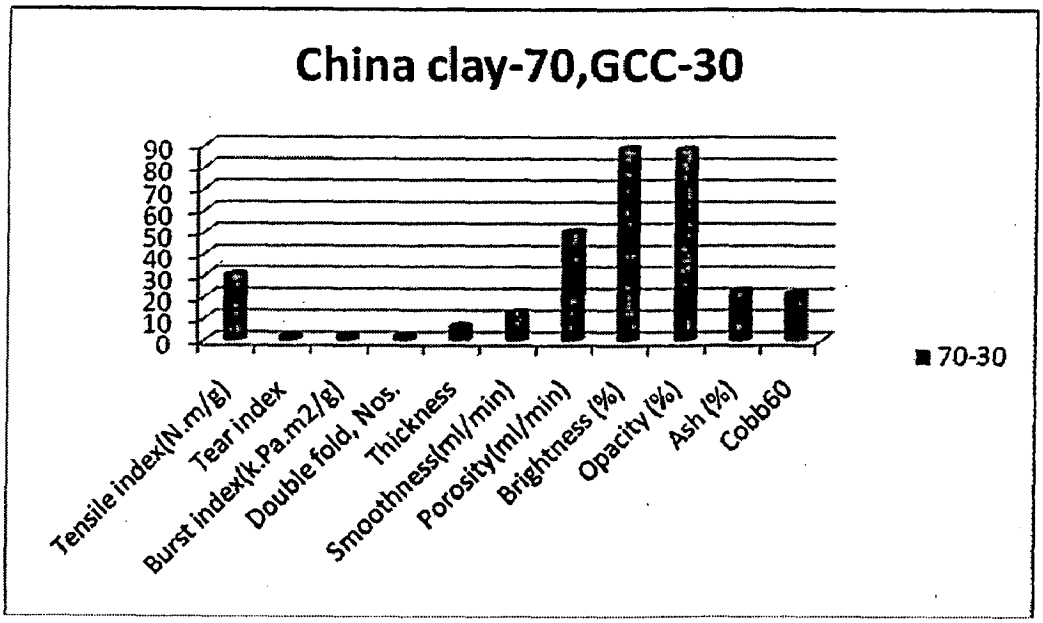
17. Hannu Paulapuro,Johan Gullichsen. "Paper and Board Grades"., Papermaking Science and Technology., Helsinki University of Technology ,Pub. In cooperation with Finish Paper Engineers Association and TAPPI.

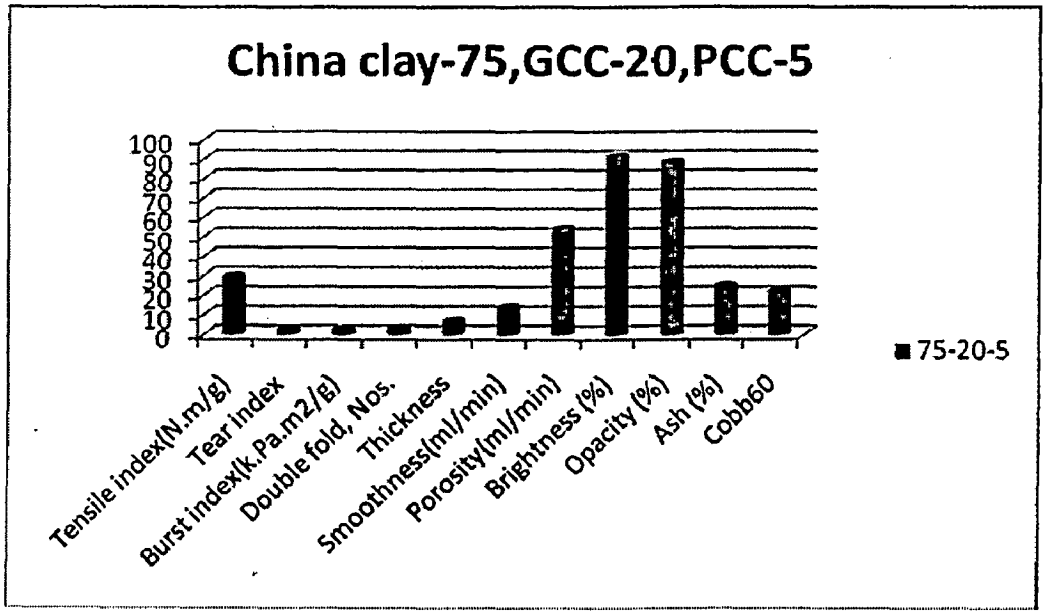
18. Xuelun Zou, Rafik Allem, Testu Uesaka, "Relationship between coating uniformity and basestock structure", paper technology,june/2001.

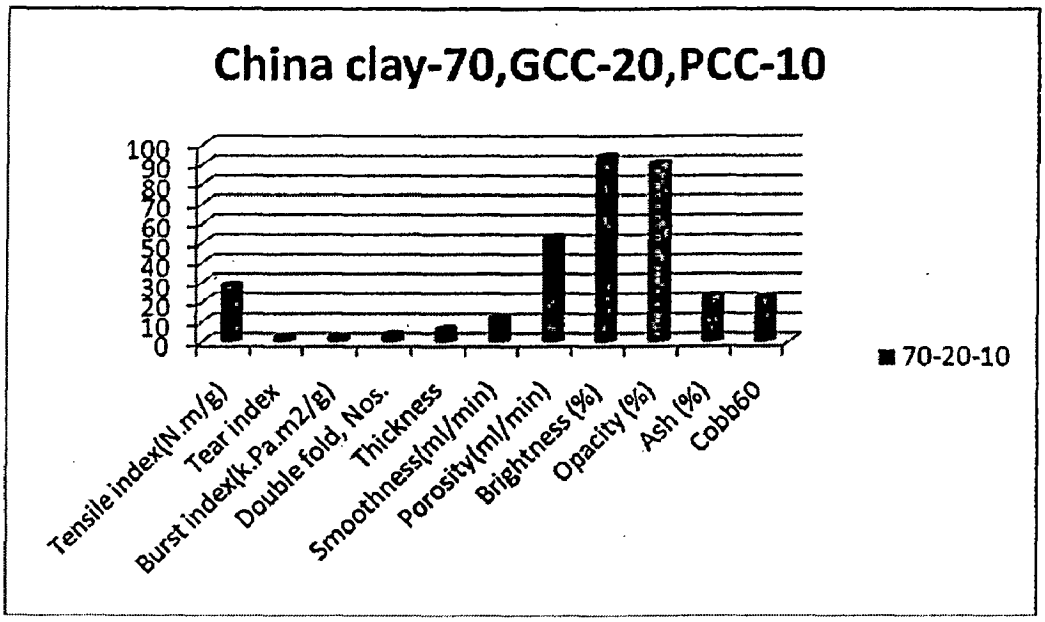
APPENDIX:

For Base paper One : The effect of pigment coating on the coated base paper -1

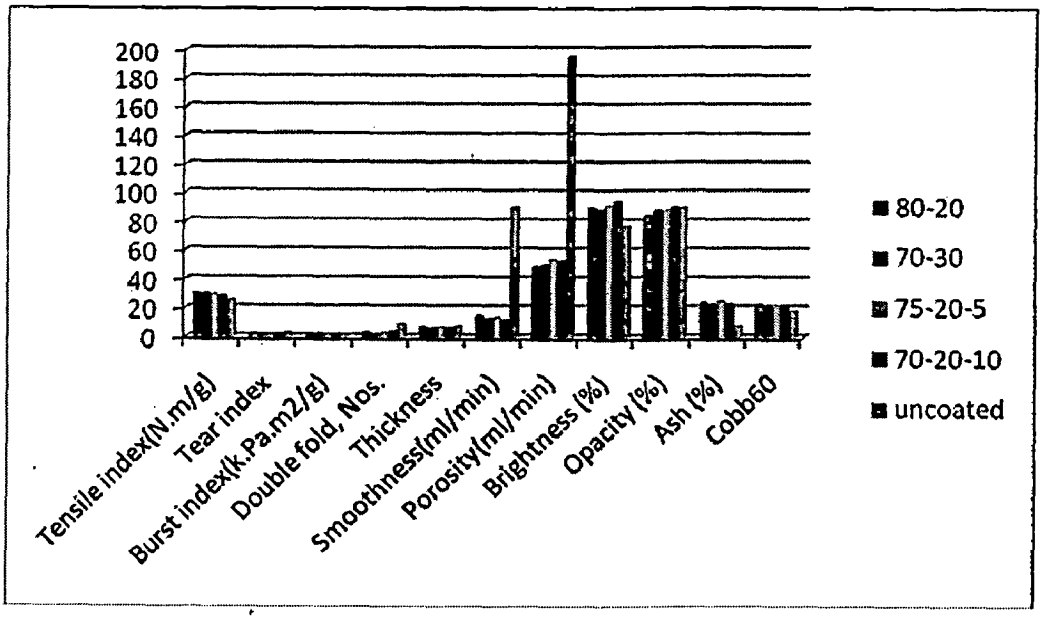




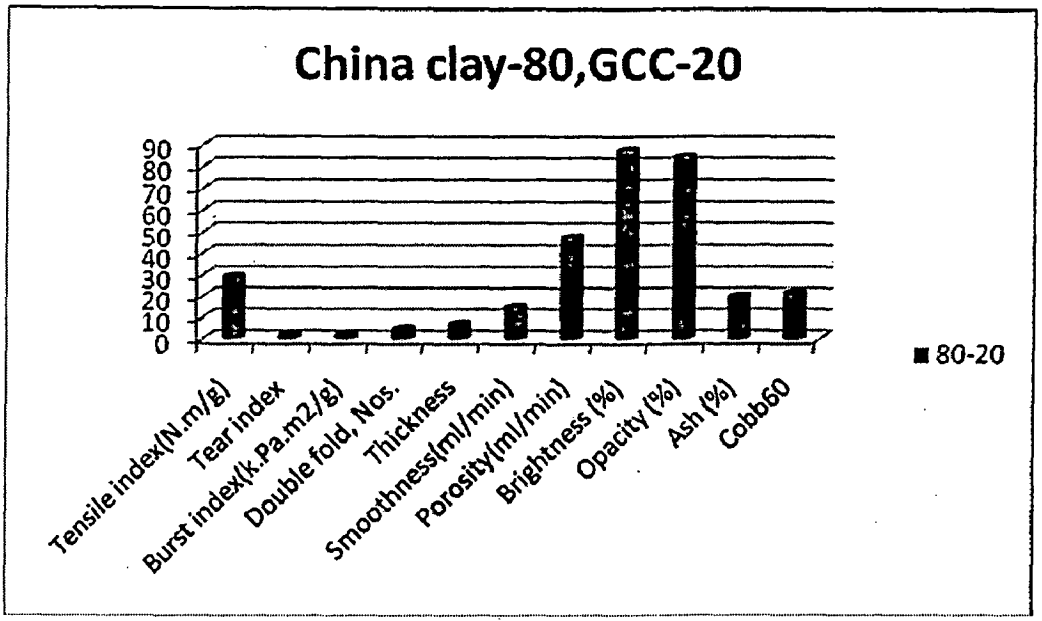

China clay-75,GCC-20,PCC-5
100
90
80
70
60
50
40
30
20
10
0
Tensile index(N.m/g)
Tear index
Burst index(k.Pa.m2/g)
Double fold, Nos.
Thickness
Smoothness(ml/min)
Porosity(ml/min)
Brightness (%)
Opacity (%)
Ash (%)
Cobb60
75-20-5

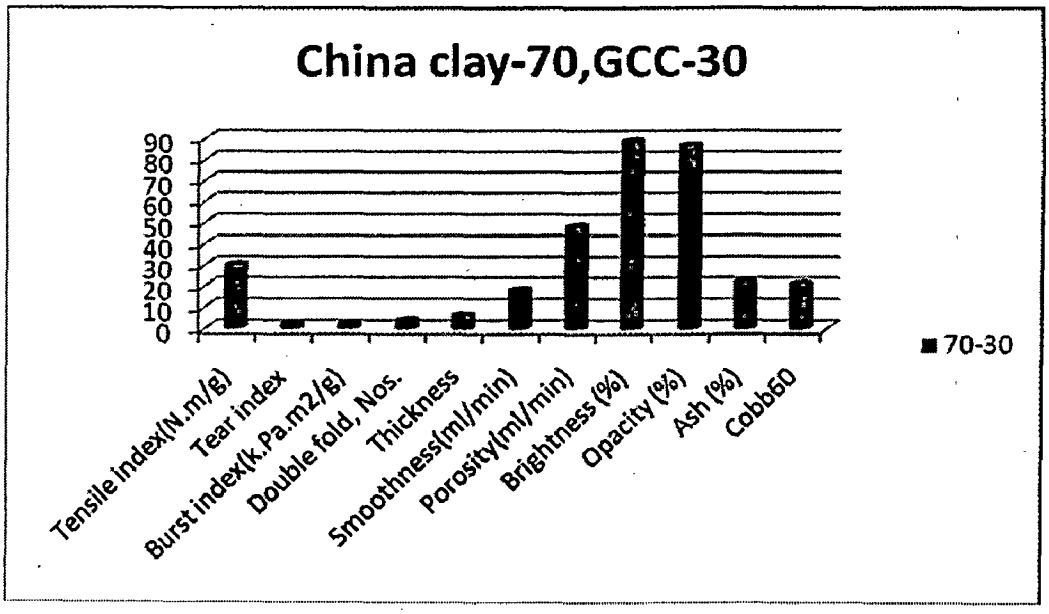

China clay-70,GCC-20,PCC-10
100
90
80
70
60
50
40
30
20
10
0
Tensile index(N.m/g)
Tear index
Burst index(k.Pa.m2/g)
Double fold, Nos.
Thickness
Smoothness(ml/min)
Porosity(ml/min)
Brightness (%)
Opacity (%)
Ash (%)
Cobb60
70-20-10

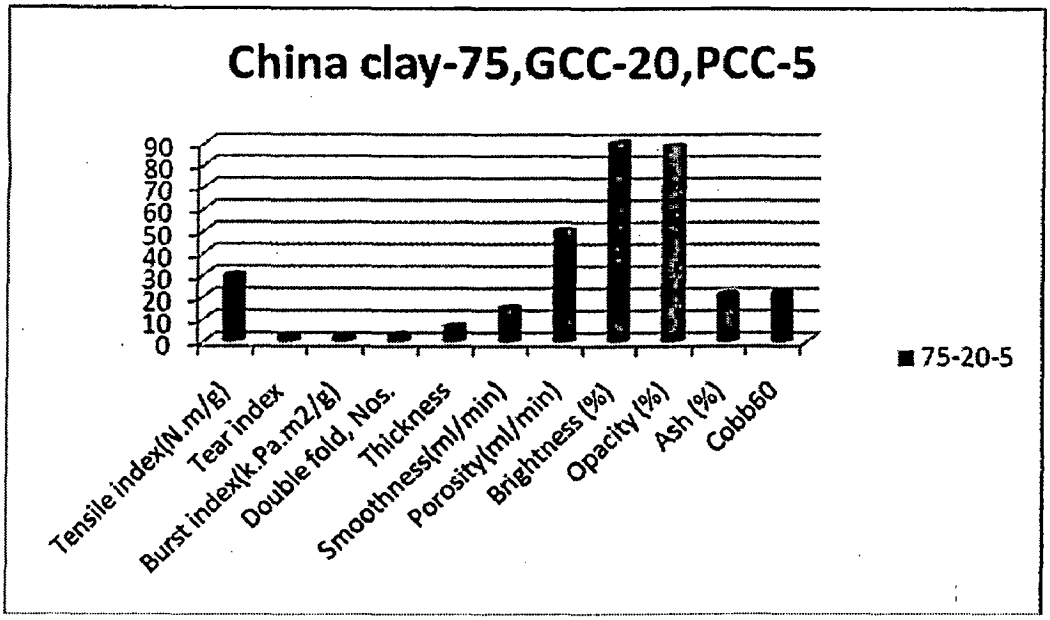
The effect of pigment coating on the coated and uncoated base paper -1 for different coating formulations.

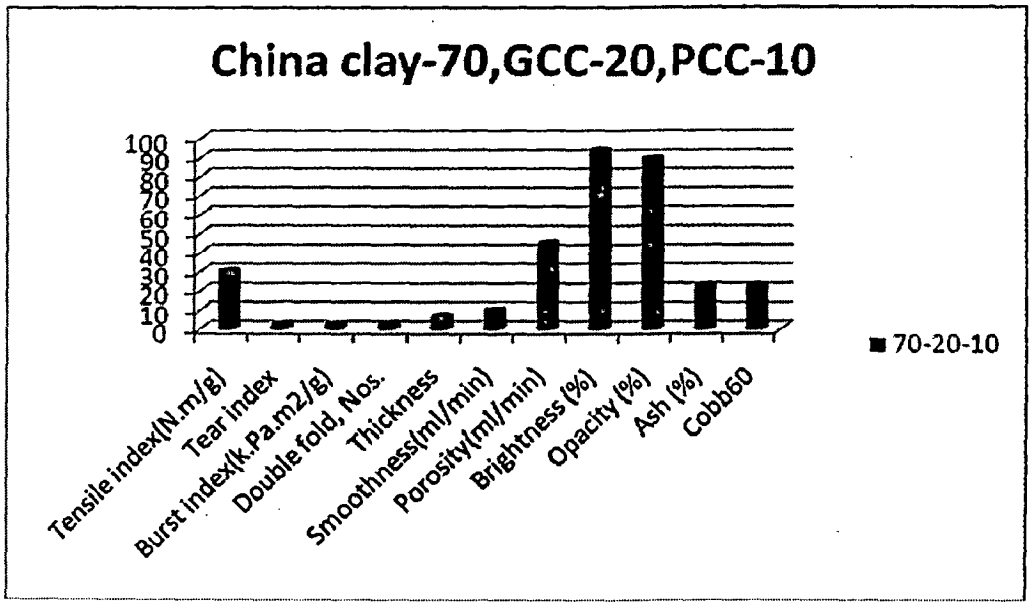


For Base paper Two : The effect of pigment coating on the coated base paper -2

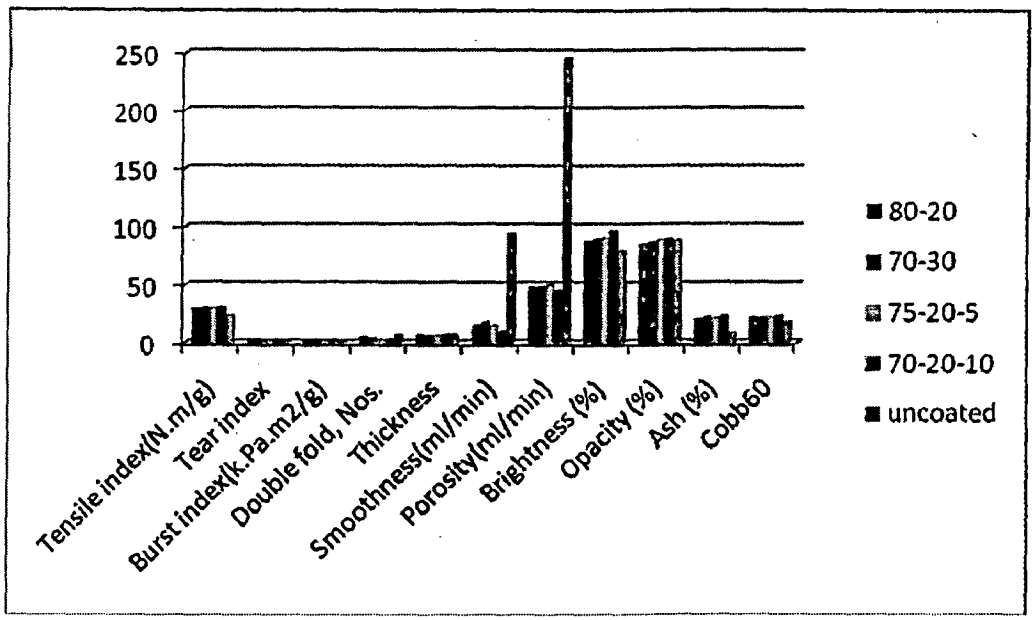



China clay-70,GCC-30
90
80
70
60
50
40
30
20
10
0
Tensile index(N.m/g)
Tear index
Burst index(k.Pa.m2/g)
Double fold, Nos.
Thickness
Smoothness(ml/min)
Porosity(ml/min)
Brightness (%)
Opacity (%)
Ash (%)
Cobb60
70-30


China clay-75,GCC-20,PCC-5
90
80
70
60
50
40
30
20
10
0
Tensile index(N.m/g)
Tear index
Burst index(k.Pa.m2/g)
Double fold, Nos.
Thickness
Smoothness(ml/min)
Porosity(ml/min)
Brightness (%)
Opacity (%)
Ash (%)
Cobb60
75-20-5

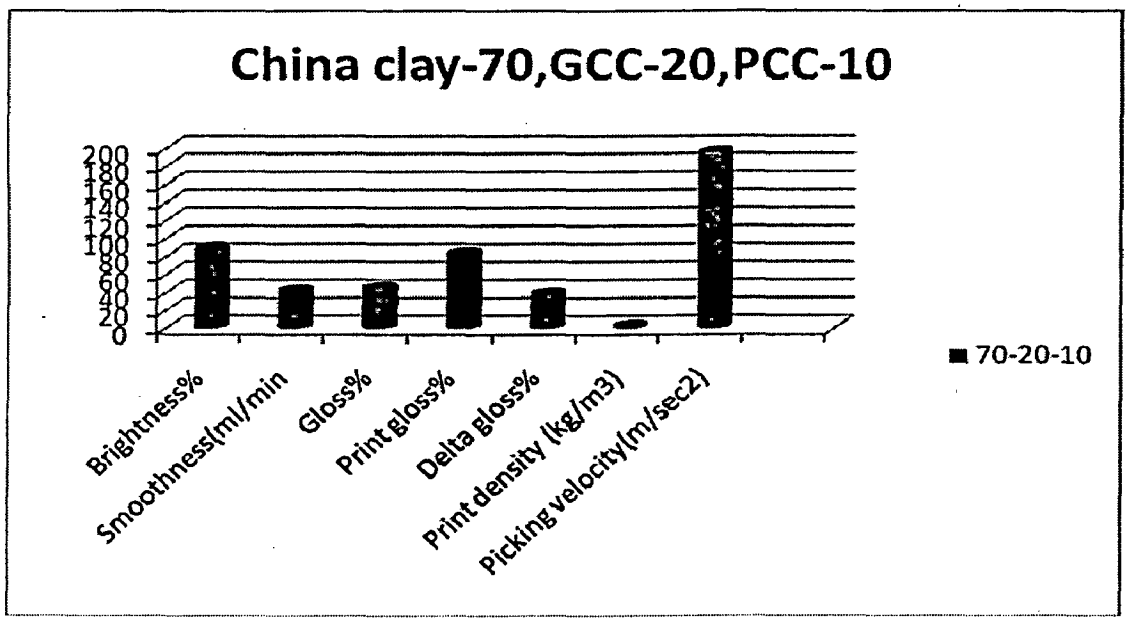


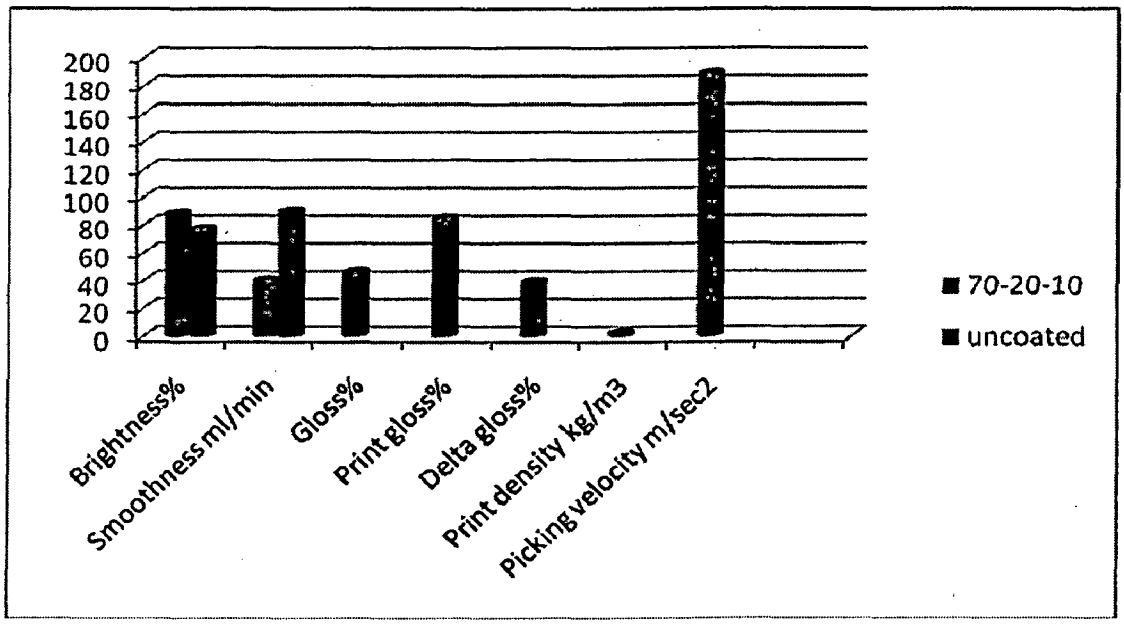
The effect of pigment coating on the coated and uncoated base paper -2 for different coating formulations.



For Base paper 1 and 2 : The effect of pigment coating formulation (china clay70,GCC-20,PCC-10) on the both base papers provides the better printing properties such as print gloss ,print density, print velocity, and also optical and mechanical properties such as brightness and smoothness. These properties are mentioned in table no.10 and11.

For base paper -1,The effect of pigment coating on the printing properties.





For base paper -2, The effect of pigment coating on the printing properties