A Review of the Developments in the field of Pigment Coating of Paper and Paper Board

G. C. Jain
Indra Mohan

Introduction :

Modern civilisation is a paper consuming process. Paper is one of the basic needs of modern life. With the advent of freedom and establishment of our welfare state, the recent years have seen rapid strides made towards economic development of the country. Paper can easily be termed as cultural barometer of a nation and being the primary medium of education and communication, has assured a vital role in the developing democracies of the world.

Role of Coated Papers :

Paper coating is an important branch of Paper Industry. It includes the application of different types of coating to the base paper. Uncoated papers and boards are, though, printed for many uses. lack, the type of surface needed for maximum print quality. The uncoated paper

G. C. Jain,
Works Manager
(Paper Processing)
Indra Mohan,
Superintendent (Coating)
M/s. Rohtas Industries Limited.
Dalmianagar.

Mechanised coating is almost 125 years old when first brush coater was installed, though at that time the production was very small. The appearance, feel and printing properties of coated paper had fascinated the printers, the advertisers and the customers. From the very beginning, the aesthetic appeal of coated paper has created the demand. As the demand picked-up, the improvements in quality of coated papers beeame inevitable. Till 1930, there was not much improvement except Calcium Carbonate and blanc fire had made inroads in Coating pigments and paper because brighter and glossier. Air knife coater replaced the brush coaters and spread shaft coaters. Cast coating had made its appearance in the field of pigment coating.

In last 25 years, the coating technology has drastically changed and some of the salient features of such changes are as follows :

1. BASE STOCK :

The use of ground wood pulp has opened a new page in the furnish of coating and has taken a prominent place since then. Selected quality of recycled fibre is emerging as a major component for base stock in the coming years.

2. PIGMENTS :

Beneficiated and delaminated china clays with higher brightness (88 to 91) and good dispersibility were introduced and accepted by the coaters. Titanium di-oxide was also available to coaters in 1950. Finer grades of precipitated Calcium carbonate is being marketed of late. Suppliers also introduced high-solids slurry of pigments to the mills.

presents a rough and uneven surface having many hills and vallies. Fine screen half-tone impressions on uncoated surface are consequently spotty and variable. Coating operations fill in the depressions and present a smooth, even, semi-absorbent surface for accurate reproduction and firm rate printing.

Depending upon the material applied during coating operations, the product can be grouped into two important heads :—

a) Pigment coated papers and boards
(water based coating)

b) Plastic coated papers and boards
(solvent based coating).

The scope of this paper is restricted to Pigment Coating only.

Basic Raw Materials for Pigment Coating :

There are three basic raw materials used in pape. coating.

1. The base paper or raw stock to which the pigment is applied.
2. The pigment
3. The adhesive used for bonding the pigment.

1. COATING BASE OR RAW STOCK

a) Requirement of base Stock

Uniformity of base paper is of greatest importance in the coating operation. The substance, thickness, finish, smoothness and porosity of the base should be as uni-

3. BINDERS :

Starch continued to be the most commonly used and cheapest binder, several grades of starch have been developed with low viscosity, high solids, better water resistance, and better binding strength in combination with the synthetic binders. Synthetic binder has opened a new chapter in the field of Coating Binders due to its manifold properties such as high gloss. smoothness, water resistance, ink receptivity and binding strength. The synthetic binders are available as per requirement of end product. The trend is towards 100% use of synthetic binders. Of course, casein continues still to be the main binder.

4. Coating Equipments :

Blade Coaters have changed the concept of coating with the installation of better, efficient and full width blade coaters. The subsequent developments in blade coaters have led to extended blade coaters for heavy coat weights. The idea of simultaneous coating of both sides has plagued the coaters in the past, but now it has become a reality, as few commercial units have gone into production successfully.

In the driving section, hot air, steam heated cylinders, air caps and infra and dryers, in combination with such other, are being used and will continue to be there. Air foil dryers is a new member to the hot air drying system in which simultaneous drying of both sides of the coated paper is made possible.

In the lost 25 years, super calenders have also not lapsed behind to meet the new dimensions in coating for higher gloss, smoothness, reduction in downtime and easy maintenance. Filling of fibre bowls with filmat paper has given added life to the bowls.

In India, pigment Coating Industry has made remarkable headway during last 25 years and now as many as nine units are there in commercial production. The latest addition being two cast coating units.

form as possible. Paper which is wild, tends to absorb coating unevenly resulting in a mottled coated surface. Two sidedness question is to be coated on both sides, in as much as the printing qualities of the coated surface will not be same on both the sides.

The strength of the raw stock is important because it is related to the strength of the finished product. A high degree of fibre bonding is desirable because it imparts to the coated surface power to resist rupture or spliting during the printing operations.

Sizing controls the penetration of adhesive from the coating colour into the body of the base stock. Too much sizing in the base paper is likely to produce curling. If the body stock is very absorbent, too much of the adhesive will enter the body stock, leaving a much lower ratio of adhesive to pigment, resulting thereby in a surface having very low wax pick.

b) Development in the furnish of base stock :

Previously the main furnish of the base paper was 100% Chemical bleached pulp and this hold till 1962. Then groundwood gradually replaced bleached pulp. This replacement by groundwood was made possible due to the better and efficient methods of refining groundwood, thermo mechanical groundwood process and screening and bleaching techniques. The old belief and thinking against the use of groundwood was discarded by the coating experts. They saw and realised the enormous benefits of groundwood used in the furnish (up to 75%). This has given additional advantage of opacity and internal bonding which is what printers are looking for high speed printing machines, such as web offset, gravure printing and multicolour printing.

Persistant demand by the customers for cheaper coated paper has motivated many mills to use a percentage of better quality of waste paper as one of the furnish. With better recycling of fibres, one can expect in the near future that recycled fibre may be a major component for the furnish of the base paper and board.

2. **Coating Pigments :**

a) **General Characteristics of Pigments :**

The pigment is a very important componant of coated surface.

i) to fill in the irregularities of the raw stock surface.
ii) to produce an even and uniformly absorbent surface for printing.
iii) to improve the appearance of the surface and
iv) to impart higher gloss and finish.
v) low adhesive demand.

b) Only two new developments in the field of pigments are briefly discussed here.

i) **Hydrated Alumina :** it is mostly used as filler in the paper but as coating pigment, it is gaining ground due to its high brighiness. It is used as titanium extender without affecting brightness, gloss, opacity and smoothness. It is available as pre-dispersed or non-dispersed of 1.0 micron particle size.

ii) **Plastic Pigments :** The latest approach in pigments is put forward by Dow-chemical. This is the application of an aqueous dispersion of a plastic pigment based on polystyrene. Since this plastic pigment has a specific gravity of only 1.05 (clay is 2.6) : it gives a good surface coverage at a significant reduction of cost weight (a good substitute for clay for LMC). Plastic pigment to binder ratio is less as compared to clay, refractive index is higher as clay. This plastic pigment responds exceptionally well to supercalendering for higher gloss due to thermoplastic nature,

smoothness, greater brightness, opacity and better ink receptivity as compared to clay. No doubt, in the coming years polystyrens will replace a part of Kaolin for coating purposes.

Wet Storage of pigments : China Clay, Calcium Carbonate and Titanium di-oxide are now easiliy available in high solid slurries of 65 to 68%. The slurry is brought in rail-road tankers, those tankers are emptied in large silo by pump and kept there in slow agitation. The main advantages of the wet storage of slurries are :

1) It comes in well dispersed from.
2) Less man power is required and less capital for make down equipment.
3) One step of preparing pigments is eliminated
4) Less space is required to store wet slurry as compared to dry pigments for example 1.0 ton of dry china clay occupies 2.1 m^3 as compared to 70% Clay slurry needs only 0.8 m^3.
5) Many blade coater experts have given to understand that by using wet storage slurries, the streaking problem in blade coaters is seldom encountered.

Many mills prefer to prepare pigment slurries themselves and storing the wet pigment slurry for a week or more, before consuming the same.

Physical prperties of various pigments are given below in the Table No. 1

3. **Coating Binders (Adhesives)**

(a) **Purpose of binder in Coating Solution:**

The properties of coated surface and coating colour are greatly influenced by the adhesive. The main functions of adhesives in pigment coating are :

i) to bond the pigment to the body stock
ii) to control the absorption of printing ink during printing of the coated surface and
iii) to serve as a carrier of the pigment.

It is desirable to use the minimum amount of adhesive for achieving the desired bonding of the pigment to the paper as excess of it increases the cost, reduces brightness and gloss of the coated surface, and effects the ink hold-out adversely. For an adhesive to be satisfactory, it should have high pigment bonding strength, good colour, should produce with pigment a surface which is highly receptive to printing ink, have strong filming properties to prevent excessive penetration of coating colour inks the paper being coated, and should have enough plasticity so that the coating film is not disturbed during super calendering.

(b) **Depending upon the process of obtaining binders, the same may be grouped into two types :**

i) Natural Binders
ii) Synthetic Binders.

Natural Binders : These are mostly in solid form, brownish-yellow in colour, form a viscous solution in water. The film formed by the natural binders is brittle and hard. Natural binders are subjected to put-refaction. Natural binders such as animal glue, gelatin count size protein are known to coating technologists. Starch synthetic binder & polyvinyl alcohol are briefly discussed here.

1. Starch : Corn starch is most commonly used and is the cheapest binder, previously the main disadvantage was that unmodified starch does not have sufficient binding strength and water resistance (15 to 20% Glyoxal is used to increase the water resistance). Oxidised starch, onzyme converted starch has provided a low cost and flexible way for coating application. Continuous jet cooking of starch and development of starch technology has further helped. Today starches meet all requirement of high solids low viscosity coating solution. With the development of cationic starches, water resistance and good binding strength has improved so much that the use of cationic starch along with synthetic binder has raised the quality and performance of coated paper for web offset printing press.

ii) Synthetic Binders : The syn-

Table 1 Physical Properties of Coating Pigments

Type	Chemistry	Refractive Index n	Whiteness (Elrepho) R 457	Particle size microns	Specific gravity	Special Features Advantages	Drawbacks
Silicates Kaolin (China Clay)	Al Silicate	1.56	70–92	0.3–5 90% 2	2.6	Whiteness Smoothness lustre, Printing ink absorptivity.	
Talkum	Mg Silicate	1.57	70–95	0.2–5	1.8	Lustre, smoothness glazing property (only for special papers).	
Sulphates	Ba Sulphate	1.65	96–98	0.5–2	4.4	Whiteness, binding power	Drop in lustre, printing ink absorptivity.
Satin white	Ca Sulpho-aluminate	—	—	0.1–0.2	Variable	Lustre, smoothness whiteness, binding power, printing ink absorptivity.	binding media requirement high PH: sensitive
Carbonates Chalk	Ca Carbonate (natural)	1.56	87–95	0.5–5 9. %2	2.7	Whiteness, very good printing ink absorpt., binding media req.	drop in lustre
Calcium Carbonate	(Precipitated)	1.59	90–95	0.1-0.2	2.7	Whiteness, printing ink absorpt. blister resisting.	difficult to disperse, binding media req.
Oxides Titanium dioxide							
Anatase		2.55	97–99	0 2–0.3	3.9	Whiteness binding power	Printing ink absorpt.
Rutile		2.70	97–98	0.2-0.3	4.2	Maximum binding power.	UV continuation
Hydroxides Aluminium Hydroxide		1.57	97–98	0.1–1	2.4	Lustre, smoothness printing ink absorpt binding power.	performance
Polymeric plastic pigment 37% solids	Polystyrene	1.59	95–97	0.5	1.05	high coating coverage, whiteness, high gloss due to thermoplastic, smoothness, printing ink absorbtivity ideal for high weight coating.	High cost

thetic binders are colloidal dispersions of the polymers in water together with various constituents such as soap (emulsifier such as Alkyl sulfates, Sulfenates and Alkylaryl sulp ates), electrolytes (Nacl, Kcl) to stabilise and to improve flow properties initiators (potasium persulphate, sodium or Ammonium persulphate) to initiate the polymerization process.

The svnthetic binders are produced by emulsion-polymerization i. e., by dispersing the mon omers (one or two) in water and adding a catalyst (initiator) decomposing into a free radical under certain conditions of pressure, temperature, time and concentrations. Synthetic binders overtook the natural binders in a very short period and have many advantages over the natural binders. In combination with natural binders, it improves the printing properties, smoothness, wetrub resistance ink holdout, flexibility and blister resistance.

It is evident that such type of individual binder has certain advantages and its selection depends mainly on the requirement of the finished product. The synthetic binder is uniform in quality, having uniform particle size (0.1 micron) having low viscosity and is able to form high solid coating.

Sole binder system : The trend using synthetic binder with starch is shifting towards sole binder system in which synthetic binder is the only binder used.

Sole binders are of two classes.

1. Primary Syn. binder plus separate thickner, either acrylic thickner type or CME, PVA etc.

2. Alkali thickenable binder (sensitivity to alkali results in Polymer solution or swelling) and general hydrophilic nature of similar to natural binders.

Coated Paper with sole binder exhibit all the advantages high calendered gloss, smoothness and good printing and pick strength. The advantages of various types of synthetic binders are given in table No. 2 below :

Syn. Binder	Advantages	Disadvantages	End Use.
Carboxylated S/B	Better Wetting of Pigments, water resistance, gloss, smoothness, flexibility in varnish holdout and binding power	Stiffness odor	Publication grade
Polyvinyl Acetate	Porocity, gluability, ink receptivity, stiffness, blister resistance.	Low gloss and binding power	Heat set paper and Board, Web offset
Acrylic (esters of acrylic and methacrylic Acid)	Stiffness, gloss low odor, smoothness, ink holdout, resistance to ageing heat, light	binding power	Art/Label Paper Board.

Polyvinyl Alcohol (PVA) : Polyvinyl alcohol is produced by Hydrolysis of polyvinyl acetate.

PVA shows highest bonding strength to pigments and cellulose. It is an excellent film forming and is having high resistance to oil, grease and organic liquids. It gives higher gloss, smoothness and good printability.

1. Part PVA is equal to 2.5 parts of Casein.
1. Part of PVA is equal to 4 parts of starch.
1. Part of PVA is equal to 2 to 2.5 parts of Syn. Binder.

Higher cost of PVA and the higher viscosity build up during mixing with clay (Pigment shock) restricted its use as binder. From recent literature this pigment

shock is due to dispersing agent. Untill some dispersing agent is found which does not give pigment shock, the use of PVA as binder will remain hindered.

Trend towards high solids coating:—

Total solids in the coating plays an important role and depends much on the equipment for Coating, method of application, flow characteristic of solution at the time of application.

Air knife needs around 35 to 37% solids content. It cannot run with 50% solids that will give operational problems.

With the advent of blade coaters the solids content of the solution has also increased to 58 to 62%. With subsequent development in the blade coaters, the more is towards still higher solids coating of 68 to 70%. This will lead to many advantages such as reduction in energy consumption, higher productivity without increasing the drying capacity. For example 30 % reduction in energy consumption is possible by increasing solid-content from 60% to 68%.

Types of Coating Process:

Coating is of two types,off-machine and on-machine coating,Off-machine coating is carried out as a separate operation independent of paper machine, whereas on-machine coating is carried on the paper machine itself. On-machine coating came into use after Massey and others demonstrated that coating could be done satisfactorily on on-machine. Thus on-machine coating eliminates winding and transporting of rolls from the paper machines to the coating machine. Also saves labour, less space is needed for the equipment. The opposing arguments are that off-machine is more flexible for production planning, change of grades is simplified. Downtime on either the coater or the paper machine does not stop the other, this is not true for on-machine coating. Many coating processes are using both on-machine and off-machine coating depending upon the end product.

Brush coaters, spread shaft coater and Air knife coaters are old versions of coating equipments. Few new developments in this field are described below.

1. Cast Coating:

The cast coated papers have ultra high finish like mirror finish. The cast coated papers are not supercalendered but dried against the highly polished metal surface which imparts the mirror like finish. Thus the cast coated paper has a much higher bulk and may have greater ink absorbency than paper made by the conventional methods involving super calendering which tends to compress and densify the coating. The cast coating operation involves application of coating to the paper web while the coating is still in a plastic condition bringing the web into contact with a chrome plated surface and removing the web from the chrome surface after the coating is dry. It is very essential for the coating to be easily and cleanly removable from the glazing cylinder surface after drying. To obtain release properties, the coating colour is added with (i) Oleaginous materials such as Oils, Fats, Fatty Acid-amines (ii) Use of coagulants for modifying the coatings mixture (Coagulants are Ca, Zn, Ba, Pb, Mg, Cd, Al. Salts of various acids when they contain protein adhesive.) (iii) and treatment of Chrome plated Coating drum surafce to impart passivity by applying dilute 2 to 10% Acetic acid or Nitric acid to the coating surface.

2. Blade Coaters:

There are three basic types of blade coaters. These are the puddle, the inverted, and the fountain blade coaters. The principal difference is in the method of supplying the coating.

With the puddle type coater, the side of the web to be coated is exposed to a puddle or pond of coating before it passes under the flexible blade which doctors off the excess coating.

The inverted blade has an applicator roll and the web passes through a flooded nip formed by backing roll and the applicator roll. As blade is inverted, the excess coating flows down and provides a flushing action on the blade-paper interface. With the fountain coater, coating is applied under pressure through an orifice to the web. The blade is inverted too.

Blade coaters are being successfully used both on the paper

machine and off-machine operations. Coating solution with high solid content upto 70% runs successfully on various trailing blade coaters with the rehelogical properties as that of thixotropy in order to maintain good finishing at the blade paper interface with the inverted blade. LWC (Light Weight Coated) paper of 34 gsm base are now being coated in Europe with trailing blade coaters

3. Bill Blade:

There is a good news for coaters, the new bill blade has now come with a differential device, which greatly widens its versatality. Qualities made with it can include label papers that could be coated with starch treatment on the back side. The new bill blade can also be used for producing coated M. G. Papers if bill blade is installed after the Yankee Cylinder, with extra drying after the coater. A typical label paper would be coated with 12–15 g/m^2 on one side, and 2 g/m^2 starch on the back side. For packing grades, the bill blade can produce a quality with a smooth blade coating on one side for good printability, and functional properties such as grease resistance built on to the back side. For water repellency wax emulsion can be applied to the back side.

However it is impossible to supply heavy coat weight with these conventional type blade coaters. This problem is caused by stiff and inflexible blades and the method of controlling blade pressure i. e., by loading the blade at the base.

4. Extended or bond blade coaters:

In last few years a new generation of flooded nip blade coaters has been developed capable of applying heavy coat weight. These coaters have extended, more or less flexible blades and an inflatable pressure tube at blade tip providing finger tip control of the blade pressure. This technique permits upto 32 g/m^2 of coating with high solids and at higher speed.

FEW CHARACTERISTICS OF BEND BLADE HEADS ARE

1. The blade is thin and clamped in a solid metal holder at the bottom to leave about 60–75 m.m. extension.
2. The blade tip is pressurized by means of inflatable tube This arrangement permits precise control of coat weight.
3. Due to improvement in clamping device and pneumatic operation, blades can be changed in just 45 sec., depending upon the wearing of the blade due to abrasiveness of solution, roughness of base, coat weight and speed.
4. Blade angle on the back-up roll can be varied while machine is on the run, thus regulating coat weight.

Another new development is combination of bend blade with metering bar, J. M. Voith's—Rollflex., Wartaila's–Rod blade., Beloit's—Belflex and Jagenburgs —Roll blade.

This blade/rod configuration can be also used on machine coating preferable for board coating. This blade/rod consist of small diameter rod mounted in a plastic housing near the tip of the blade. A change from bent blade/rod to bent blade only is also possible with some coating head but takes about 15 minutes time.

6. Twin Blade (Inventing AB Sweden):

It is simultaneously two side coating. It is still a baby in the cradle as only two commercial units are in operation. It is on-machine coating in which both the sides can be coated with some formulation or with different formulations simultaneously.Coat weight upto 15 g/m^2 and speed 300 m/m in.

The advantages are:

1. No curling problem due to simultaneous coating.
2. Very insensitive to sheet defects as holes.
3. It can run one side coated grades paper easily with water or adhesive applied on the other side for labels.
4. Simultaneous drying by air-foil or infrared rays.

5. Compactness & limited capital coats as compared to conventional coaters.

Voith has developed constacoat. This system can apply 8-25 g/m². As only one or two units are working, very little information is available at present on the performance of this.

Similarly Beloit's— S – Blade is also very new in the Coating field and its performance still need evaluation.

Drying of the Coated Paper :

After paper is coated, it needs heat to get the moisture removed from the coated surface. A variety of dryers are in use depending upon the appropriate type needed for.

A) Convocational Dryers :

Festoon, Chain-Conveyor, Floater, Arch dryers are most commonly used in coating drying. Hot air is impigned on the coated web. In this, the coated surface does not come in contact with the drying part. This type of drying is common with low solids, where length of drying chamber is longer and the hot air has sufficient time for removal of moisture.

B) Conduction Dryers :

These are steam heated drying cylinders similar to paper drying cylinders. Such type of cylinders are used in coated paper with high solids. These cylinders are followed before by the intraced battaries which remove the moisture before the coated surface comes in contact with drying cylinders.

C) Radient Dryers

These are gas fired or electrical fired infrared waves, which emit rediant energy. These are incorporated as auxiliary dryers for convection or conduction type dryers.

High Velocity Hoods or Aircaps.

These are hoods placed over the steam heated cylinders. High velocity hot air is blasted on the surface of the coated web while web is supported on the steam heated cylinder or drum. Many coaters support the view that high velocity dryers eliminate the migration of binders because of simultaneous drying of the coated web on both sides.

Air Foil Dryer : (Convection drying) :

The air foil floater is a two sided, non-contacting unit capable of high drying rates and comprises of a series of air foils, arranged above and below the sheet. All the air leaving the nozzle travels in the sheet travel direction. The two side air foil dryer, applies hot turbulent air on both sides of the sheet and controls fluid migration by evaporation from both surfaces of the coating layer. It is possible to operate with different air pressures in the top and bottom foils. This means total heat applied on top or bottom side, can be varied and controlled hence, the capillary migration into the base stock or evaporation from the coated surface can also be controlled.

The advantages are :

1. Regulation of the drying rates on the top and bottom side gives :
   a) Control of binder migration.
   b) Control of gloss ink.
   c) Higher drying rates.
2. Even drying and moisture profile across the web by full width nozzles.

Instant dryer

From USA comes an "instant" method of drying paper coating, inks and adhesives, using an electron beam accelerator. The electron beam effects chemical changes by direct action between electrons and molecular structure rather than, by heat application. It will be useful for the protective and decorative coatings which need curing as this will give instant curing.

Super Calendering

90% of water based pigments coated paper and board, are to be super calendered.

Super Calender is a stack of rolls. Chilled iron rolls alternating with fibre rolls except at the centre, where two filled rolls are positioned adjacent to each other permitting both sides of the sheet to receive the same calendering action in one pass.

Super calendering imparts gloss, smoothness, densifying the coated surface to make it suitable for printing and levels out all irregularities in the web.

To attain the aforesaid properties, 5 to 6% moisture in the coated paper, temperature of the rolls

and pressure applied on the rolls, crowning of the bottom roll, material of filled roll and its hardness, are the main parameter for good results.

In the past, lot of time was required to mount the coated reels and to change the damaged fibre rolls.

But number of design improvements have been made in supercalender recently with an effort to reduce downtime, maintenance costs and to increase the efficiency of the super calenders. Among them are continuous unwind stands similar to the ones on the coating machines (flying splice), any quick load release as low as 0 6 sec. (Rapidrop system of Bruderhaus). Introduction of the Kusters rolls in the super calender have furtner helped to maintain any deflection in the supercalenders and to regulate the crowing of the king roll as needed. A Bruderhause design suggests a distribution of the supercalendering stages over the whole of the drying section. In each case a filled roll is pressed against a drying cylinder by a stiff support roll. Still it is to be seen how this proposed system of co-machine supercalendering of paper and board will develop in the coming year.