Dimensional Stability - Factors for Consideration with Special Reference to Bagasse Paper Making

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ABSTRACT

Dimensional stability of paper is dominantly governed by the nature of pulp and method of fibre orientation. Bagasse pulps have very high degree of hydrophilic nature and possess short fibres resulting in low dimensional stability. Improving the hydrophobicity and optimizing the fibre orientation appear to be the key parameters to improve the dimensional stability.Synthetic polymer resins improve the bonding sterength resulting in improved dimensional stability.

INTRODUCTION

One of early end uses of paper, namely letter press did not require many of the characteristics that are today expected from printing paper. Later generation printing processes such as offset and its variations and the modern non-impact printing and copying processes require many requirements in the substrate which is paper. One of the most desired properties of paper is Dimensional Stability (1). In simple terms it can be explained that it relates to the change in the shape and size of the paper during the intended job. When the paper is put into its end use the importance of dimensional stability is realized only when it comes under drastic atmospheric changes in contact either with water, water vapour or heat. Dimensional stability and its relevance in different end-uses are shown in the Fig. 1.

In the present Indian scenario, to meet the environmental pressures and with the desire to maintain the eco-friendliness, paper industry has started showing keen interest in the development of non-wood papermaking. This presents a novel challenge namely using non-wood raw materials and at the same time achieving the same quality of wood based papers and satisfying the ever-growing customer demands. One of the foremost among the non-wood raw materials is Bagasse which has found its own established place in the papermaking field. This paper discusses some of the factors that determine the dimensional stability of bagasse papers and its direct application in end-uses.

Importance of Dimensional stability

In Offset printing water is added as the medium to prevent inking of nonimage areas which necessitates the dimensional stability in the paper, which in turn means that paper should not change its original dimensions neither by shrinking nor expanding. In offset printing, especially in a multi-colour system, water is applied in series at least for 4 times on to the paper in a very short time. Paper suffers dimensional change when subjected to water either as a liquid or as vapor. This has been dealt in depth by various authors (2). The Dimensional changes may also lead to runnability problems. Paper dimensions increase with higher moisture content and decrease with lower moisture content. When paper size change occurs between press passes during multi-colour printing, mis-register can result.

This applies to notebook making also where a thin layer water-soluble gum is applied to keep the binding cloth in the spine of the notebook in tact. Size change

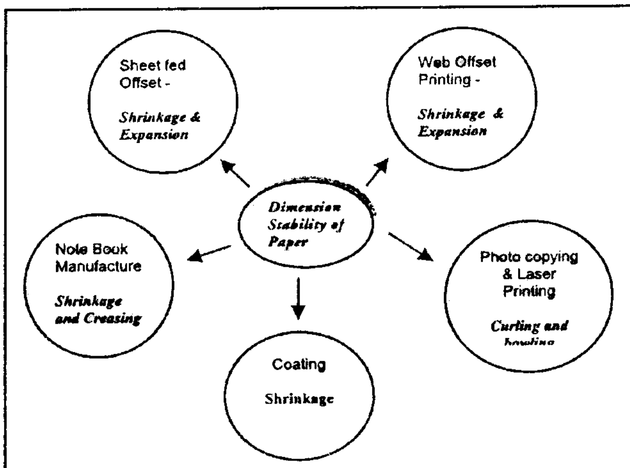

Fig. 1 : Role of dimensional stability in various end uses of paper

Tabe 1 Characteristics of bagasse paper with respect to dimensional stability in comparison the wood papers

Parameter	Bagasse Paper	Wood Paper
Density, Kg/m3	830-850	600-650
Cobb60 g/m2	25	16-18
Shrinkage, %, CD	4.0	1.0-1.5
Degree of Curl, deg/cm	4.5	2.0-3.0
Taber stiffness	2.2	3.0-4.0
Drooping stiffness, mm, MD (Bending stiffness)	112	120

after binding into notebooks can create undersirable appearance and can cause creasing or wrinkkling. It has been reported that flatness of paper may be altered if paper is exposed to an environment in such a manner that a nonuniform moisture profile develops. (3). Water penetrating into the fibre-to-fibre contact can cause fibre swelling which can result in dimensional instability (4). Therefore in all these instances, wetting mechanism requires dimensional stability in paper.

On the contrary, in a photocopier, the paper is subjected to extremely high temperature (190 -200 deg C) for fusing the toner particles on the surface of the paper. The dimensional retention is required from the paper in drying mechanism, when the moisture leaves the sheet during the drying and reabsorption as soon paper leaves the fusion compartment in the Photo copier or laser Jet printers (5).

From the foregoing we can conclude that the fundamental criteria for Dimensional stability is the characteristic of the pulp used and its association with moisture or water. In the context of this discussion, Bagasse pulps are known to contain very short and heteropgeneous fibres and are highly hydrophilic in nature and have very dense structure with very low porosity. Figs. 2 and 3 depict the nature of bagasse papers towards absorption and evaporation of moisture or water. As it can be observeb from Fig. 2. even though the final dryness is almost similar for both papers, the drying rate is significantly faster in the case wood papers. Like wise in a given unit of time bagasse papers absor 60% more water than wood papers and the capillaries in the case of bagasse papers are more non-uniform. This results in a paper having predominantly low dimensional stability. High density, hygroscopic nature combine to result in a sheet having low dimensional stability. This is shown in Table 1.

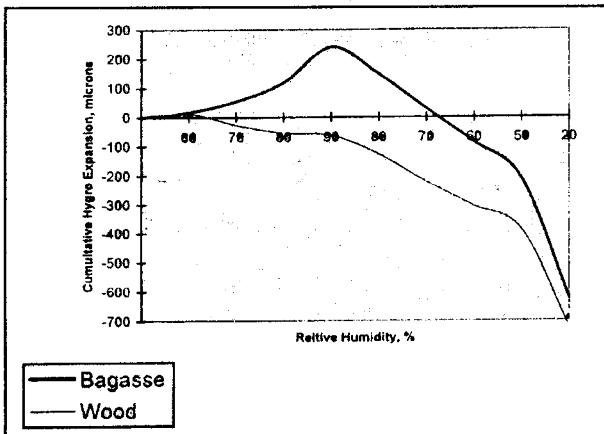

Fig. 1 Effect of moisture of hygro expansion

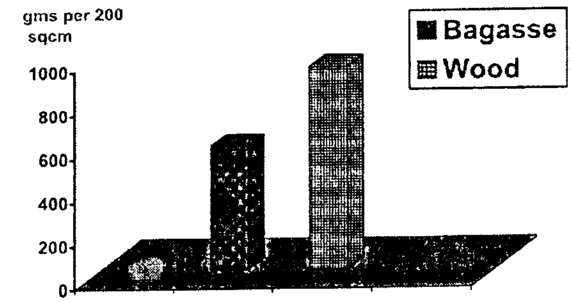

Fig. 2 Water uptake in 60 minutes

EXPERIMENTAL

Testing

Determination of Cobb

One minute Cobb testing was performed with standard ISO method after conditioning the samples.

Determination of Hygro Expansion

The dynamic hygro-expansion caused by water vapour

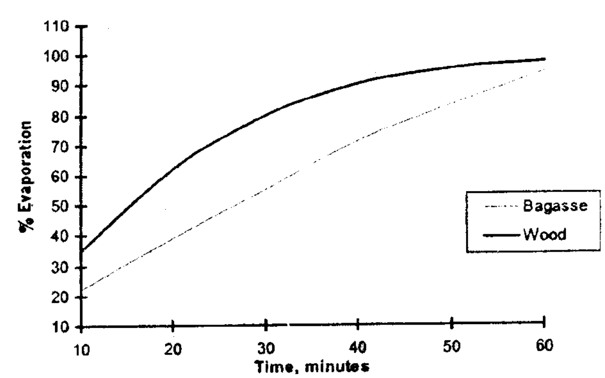

Fig. 3 Evaporation rate of bagasse and wood papers

was measured from a sequence of images captured at short time intervals in a climate chamber Fibro DST 1210, manufactured by Fibro Systems, Sweden . Initially the specimens were pre-conditioned at 50% RH to reach equilibrium. Then the climate was changed from 50 to 80% RH and images of the expanding surface were captured at the interval of 15 minutes.

Tensile Strength

Tensile Strength was determined according to ISO procedures, in the Alwetron Tensile Tester.

RESULTS AND DISCUSSION

Moisture absorption and water uptake

Cellulose is hygroscopic in nature. A material that is hygroscopic, absorbs moisture from a damp atmosphere or release moisture to a dry atmosphere and after sufficient time will come into equilibrium with its atmospheric environment. Therefore many basic properties of paper are greatly affected by its initial moisture content. These paper properties, especially dimensional stability, can be very critical for the performance of paper in the aforementioned end uses. It is reported that the moisture content of a final dried paper depends on the paper making pulp (6).

The moisture level of paper is routinely referred to in relation to the moisture level of the environment, which can be measured as Relative humidity (RH). Fig. 1 illustrates the extent of hygro-expansion of Bagase based paper in comparison to wood based papers at the different levels of relative humidity. At a typical dosage level in conventional rosin sizing, bagasse papers, exhibit more hydrophilic nature than wood papers. Bagasse pulp contains more amorphous hemicellulose which contains more OH groups, readily available for water molecules for bonding, unlike crystalline cellulose. it is reported that at 100 % RH, moisture conent of lignin is 10%, Cellulose is 30% while hemicellulose is 80% (7). The presence of amorphous hemicellulose and parenchyma cells (pith)in bagasse pulps promotes more water absorption and incidentally this is the reason for low freeness (ie)-poor drainability.

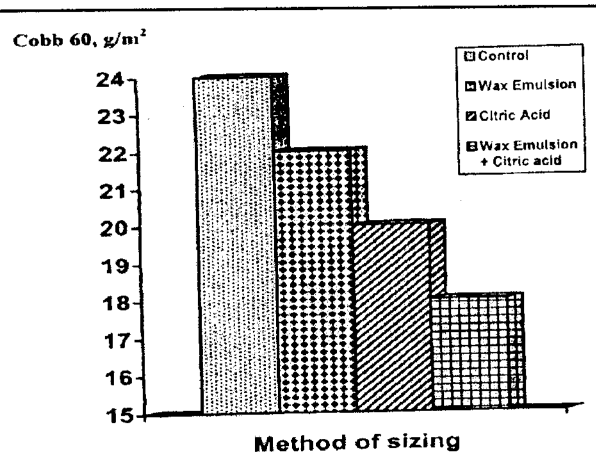

Fig. 4 Effect of modification in sizing

Controlling moisture absorption and water uptake

The most commonly used method to determine the extent of water absorption by paper is Cobb Testing. Conventional sizing with Fortified rosin normally results in a cobb of 25+ in bagasse predominant papers. This is very high when compared normal wood based paper where the cobb with a similar dosage of Fortified rosin is about 16-17. Therefore the first step to improve the dimensional stability is to reduce the Cobb value. There are various methods, already in current practice that can be modified to enhance the hydrophobicity of bagasse paper.

Modified Rosin sizing in bagasse Pulps with a Polyanion

Studies were carried out to improve the sizing with further reinforcement in association with Rosin. In this regard, the addition of wax emulsion along with fortified rosin resulted in a cobb value of 22. In continuation of improvement in rosin sizing, literate survey showed that, in the past, reserchers have achieved significant improvement in sizing with the addition of coordinating poly anions along with rosin with recycled pulps (7). The effect of the Polyanions was to reduce the sintering point of the rosin size precipitates. As the precipitated aluminimum rosinate melts, additional opportunities are provided for beter size distribution and for better size orientation to give hydrophobicity and uniform size film. The addition of 0.1% citric acid along with rosin in the bagasse furnish resulted in an average cobb of 21. The synergetic effect of the combination of Wax Emulsion + Citric acid is shown in Fig. 4. This resulted in 30% improvement in sizing compared to the conventional rosin sizing.

Internal Sizing of Bagasse Pulps with Reactive sizes

In various parts of the world, mills are changing to Alkaline Sizing from acid sizing for various reasons such as Paper permanency, Shade stability, better runnability and less corrosion. Therefore, reactive sizes such as Alkyl Ketene Dimer (AKD) or Alkenyl Succinic Anhydride (ASA) are more and more being used since Rosin sizing is not possible in alkaline pH range. In the present context of sizing efficiency, reactive sizes have superior sizing capability when compared to Rosin sizing. Fig. 6 illustrates the achievement of cobb sizing with a commercial reactive size (AKD) on a plant scale with bagasse paper. In addition, it is possible to extend the sizing efficiency with increased dosage to much lower Cobb with reactive sizes which is

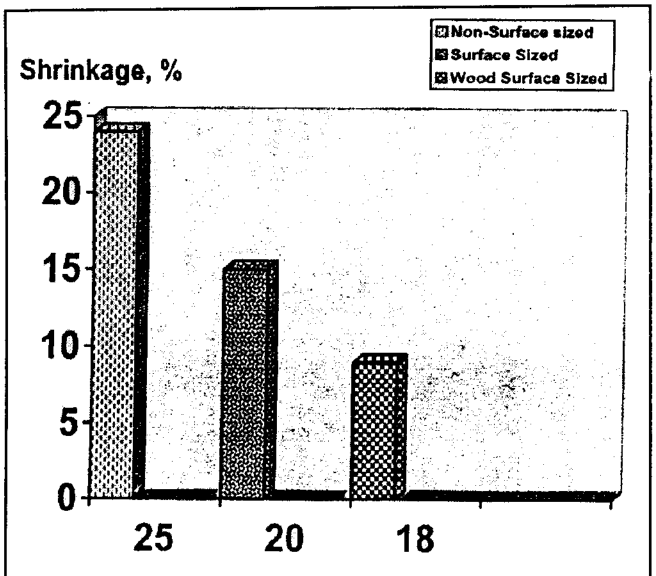

Fig. 5 Effect of surface sizing in shrinkage after coating

not possible with rosin sizing.

External or Surface Sizing of Bagasse Papers

It is very difficult to achieve lower cobb values with internal sizing alone in the case of Bagasse pulps. In general, the rate of water absorption depends upon the apparent contact angle of between the surface and water. Hence, Surface sizing with Starch increases the contact angle, which results in enhanced hydrophobicity in paper surface. The increase in hydrophobicity helps in dimensional stability in the end use applications such as paper coating (8,9) . When the paper is surface sized it pre-shrinks the paper which prevents further dimensional shrinking during coating. Fig. 5 illustrates the effect of surface sizing on surface coating with respect to shrinkage of in Cross direction. The surface coating was carried out in a commercial air knife coater. The non-surface sized bagasse paper showed highest shrinkage (24%) against the surface sized paper showed only 15% and wood based paper showed only 9% after drying. This is because when the paper is surface sized it had already undergone rapid shrinking in the final group of paper dryers. Even surface application of water itself could initiate the process of preshirinking, which would reduce further shrinking in coating applications. Modern high -speed Surface coating provides additional opportunities for further improving the hydrophobicity. Plant trials held with ethoxylated starch instead of normal thin boiling starch showed increased water repellency in the baggase paper. Further plant trials held with additional synthetic polymers such as acrylic copolymers or latex emulsions along with starch soup further retarded the water penetration in the bagasse paper.

Fibre orientation and its effect on dimensional stability

Fibre orientation describes the alignment of fibres during the sheet formation,. Fibre orientation has also significant role in the Dimensional stability of paper. In fact, it appears that cobb value alone does not help to predict the paper behaviour. When a trial was conducted in a high speed 4 colour sheet fed offset machine with Newsprint where there is no sizing at all, there was no creasing or cockling or buckling of paper observed while severe cresing was observed when printing was carried out with a well sized printing and writing bagasse paper. The same trend was observed even in notebook making. Therefore, besides the ability of paper to repel moisture, the extent of fibre orientation also appears to be a dictating factor in the case dimensional stability of paper during printing. Consequently, in the case of bagasse papers, it has frequently been noted that creasing of paper during high speed offset printing occurs with Cut Sheet Fed machines rather than Reel Fed Web Offset Machies where the web is always kept under tension.

Orientation magnitude

In the case of bagasse pulps, which have very short fibres when compared to soft wood or hardwood pulps, orientation during sheet formation is more profound in Machine direction than in Cross direction. In other words, number of fibres per unit area will be more in Machine direction than in Cross direction. Even though this can be changed in the paper machine, by nature this only occurs during papermaking. The fibre orientation could be monitored by the factor called MD:CD ratio of Tensile strength. This is other wise called orientation magnitude. Too high MD:CD ratio results in dimensional imbalance during the printing or notebook making or photo copying operations. Fig. 7 illustrates the effect of MD:CD ratio on hygro expansion of bagasse paper. The positive side indicates the expansion and negative side indicates shirinkage in the Cross direction at a given relative humidity. As the humidity is increased we observe a sharp rise in expansion with high MD:CD ratio in the Cross direction of the paper and as ratio is decreases we observe increase in shrinkage.

Expansion of paper in Cross direction when paper comes into contact with water results in increase in the width in turn resulting in mis-registration and ghost images. Further, more the expansion more it will lead to shrinking. This is why printers want to avoid mainly the initial expansion of paper. Therefore, in order to get good dimensional balance, optimum MD:CD ratio has to be determined. Different furnish have different tendencies under similar condition of shear, turbulence, concentration (10). In order to optimize the orientation

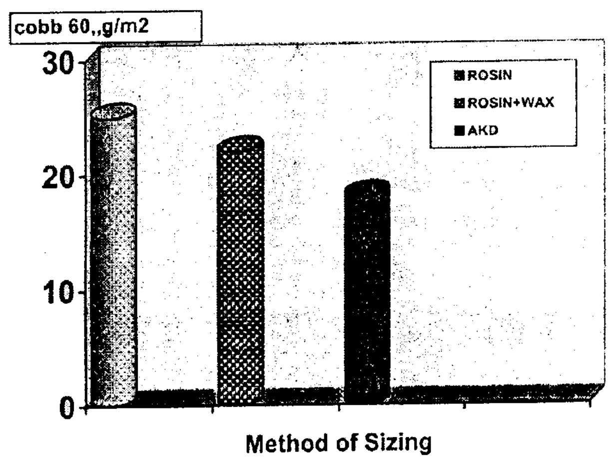

Fig. 6 Sizing method Vs. Extent sizing

magnitude in bagasse papers, the jet velocity and Wire velocity have also to be greatly balanced. Since, bagasse fibres readily fall and align themselves in the Machine direction it is necessary to have some kind of disturbance during the formation time itself to put them in the Cross direction also. Experiments carried out in this regard appear to suggest, that it is always better to keep the jet velocity at higher side in order to have turbulence or disturbance that will force more number of fibres align themselves in CD thus resulting in improved dimensional stability.

Demensional stability in Notebook making

Reducing Cobb value and optimizing the MD:CD Ratio will help to mitigate the buckling problems during the production of notebook making. Normally during the process of notebook making, a water-soluble gum is applied in the spine of the notebook and then the calico cloth is pasted. In the course drying the bound edge of the paper can not move as freely as the unbound edge. This difference in movement of the paper as it changes its size is manifested by wrinkles or waves or grooves in paper. The wrinkles that develop in the paper radiating outward from the bound edge are commonly referred to as buckles. In order to control this effect, an experiment was conducted in a commercial notebook manufacturing industry, which uses bagasse paper. In the notebook making process, generally the ruling is done along the machine direction. Hence, during the notebook production, the machine direction always comes perpendicular to the spine of the notebook. The water present in the gum propagates along the Machine direction during drying process and thus leaving grooves or waves along the Machine direction.

In order to alleviate the creasing or buckling during drying the notebook, the paper was cut in such a manner that the Machine direction fell parallel to the spine of the notebook. In this way the formation of waves or grooves along the Machine direction greatly reduced. This improves the production at the notebook making plant. Thus the Fibre orientation plays a significant role in notebook making also.

The effect of fibre orientation was further explored in another experiment. A Bagasse paper produced in a high speed vertical twin wire former was compared with a bagasse paper produced in a high speed hybrid former where the forming conditions and turbulence are entirely different and low MD:CD tensile ratio. With the similar pulp furnish and filler conent the paper made from twin wire former and hybrid former were used in a modern coating plant. There was 50% reduction in shirnkage of paper. Thus we can conclude that the fibre orientation has to be optimized to improve the dimensional stability.

Dimensional stability in non-impact printing equipment

As already mentioned, in the case of photocopiers and LaserJet printers dimensional stability is required when the substrate is subjected to very high temperature and continuous bending movements in a very short duration. Here also the orientation magnitude plays very important role. The extent of dimensional stability in the case of papers meant for these type of end-uses can be studied with bending Stiffness. The drooping tendency of the paper is very important in the photocopiers. The drooping tendency can be measured with a tester where the paper is suspended through a fixed slot to bend on a scale. The drooping distance is measured in mm in both MD and CD. Even though this is a very simple test, it helps greatly to measure the stiffness of the paper in the Machine floor for control. Although droop is a functional property, it helps to predict the behaviour of the paper when it is subjected to high temperatures inside the photocopier

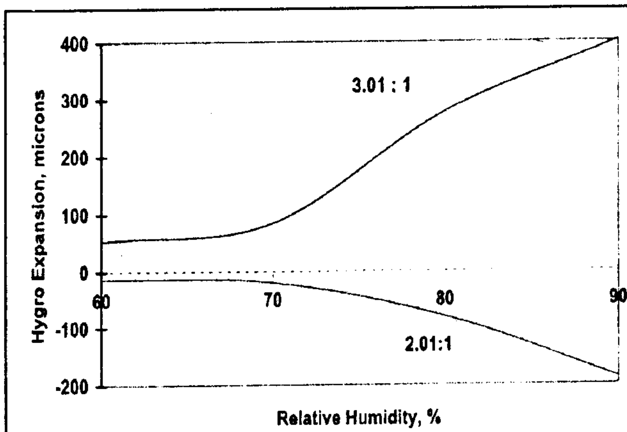

Fig. 7 Effect of MD:CD ratio on cumulative hygro expansion in bagasse papers in a Twin Wire former

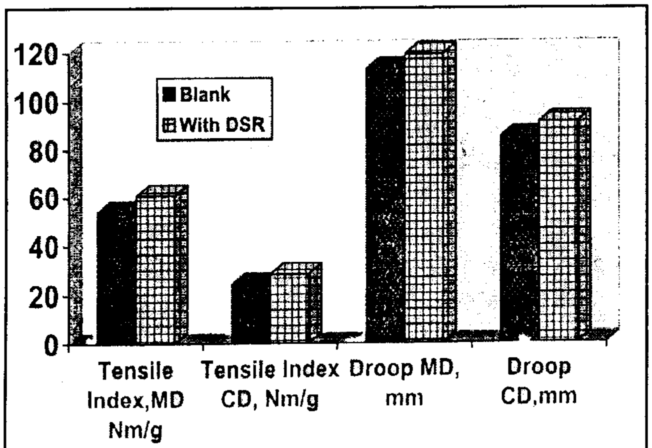

Fig. 8 Effect of dry strength resin in bagasse paper

Machine. If the droop values are lesds, curling or bowling occurs as the moisture is driven out from the paper on heating. This results in heavy jamming inside the Machine. The dimensional stability of bagasse paper is low when compared to other wood papers for reasons already discussed. In order to improve the performance of the Bagasse paper another approach is now discussed. Increasing the bonding also strength results in better dimensional stability.

The strength of the paper can be increased by providing bonding in the paper with synthetic polymer resins. This prevents dimensional change in the paper to a large extent when the paper surface is exposed to high temperature.The strength can be maintained even when the surface of the paper comes under heat. This can be accomplished with the addition of Dry Strength polymer resins. These polymer resins enhance the bonding strength, which helps paper to some extent to keep its dimensions in tact when subjected to heat. Fig. 9 shows the results obtained in the bagasse paper with a dry strength resin made in high-sppeed twin wire former for the photocopying end-use. 10-15% improvement in Tensile strength particularly in Cross direction was observed where we need more orientation in the case of bagasse papers.

This is very much important especially in bagasse pulps where it is not possible to increase relative bonded area with the help of refining. Because in the case of bagasse pulps high refining,as it is done in the case of hardwood pulps, results in excessive fibre cutting which in turn results in reduction in domensional strength in Cross direction. Surprisingly, the various plant trials held revealed that Wet Strength resins were not promising as dry strength resins. Therefore dry strength resins could be effectively used to improve bonding strength thus resulting improved stiffness and dimensional stability

Further the lack of dimensional stability in bagasse papers could be effectively overcome by keeping the machine direction parallel to the axis of the printing rolls in the LaserJet printers and Photocopiers will reduce the creasing tendency.

CONCLUSION

Improved Sizing helps to retard moisture absorption resulting in better dimensional stability. External surface sizing with starch and other additives helps to decrease expansion and shrinkage in coating end-use operations. Optimizing the orientation magnitude results in ideal hygro expansion thus improving the runnability of high -speed offset printing machines with reduced dimensional stability problems. Maintaining the correct cutting direction in notebook making helps to reduce creasing and buckling. Addition of synthetic polymer resins improves the fibre bonding and stiffness and helps to overcome the dimensional instability problems encountered in high-speed photocopiers and laserJet printers.

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