Retention – Drainage – Formation

Mittal Saurabh & Joshi Ravi Shankar

Mittal Saurabh

Joshi Ravi Shankar

ABSTRACT

As the matter of fact that the first line of action where Paper makers increase the overall FPR%, FPAR% & drainage (water-removal) values on the wire till the point of machine runnability & final formation is not affected. Once a fibre mat begins to form, the mat itself usually can act as a much more effective and finer sieve than the forming fabric. Using this process will also increase/improve the fines retention of the machine which in some cases might not be desired by the paper makers. In the cases where FPR% & FPAR% values of the machine are optimum, this approach doesn't provide much benefit for FPAR% & FPAR% increase but when we increase the amount of filler & short fibers then it is must to optimize the selective RDF program suitable to wet-end chemistry.

INTRODUCTION

There are several kinds of paper are made across the globe and each paper maker having one common desire to make the paper at lowest cy% with high retention, drainage & off-press dryness to save the steam which has become a costly affair now a days. This is because of the stiff targets they have to run their paper machines at optimum machine speed so that's why it has become more challenging to achieve the optimum water removal at with maximum FPR% & FPAR%. Retention can occur by various mechanisms. The simplest of these is mechanical sieving by the forming fabric. But even then, particles less than about 10 micrometres in size are not effectively retained by sieving. Rather, retention of fine particles requires the action of colloidal forces, including polymeric bridging or a charged patch mechanism which can easily achieved by effective RDF Program. Retention & Drainage aid chemicals can be effective either by attaching fine particles to fibre fines or fibres or by agglomerating them so that they can be sieved more effectively but at the same time we need to ensure fast drainage & ash retention with the help of bentonites & Organic Micro Particulates. So in this paper, we are going to put some light on basic polymer chemistry, its need & mechanism along-with troubleshooting guide-lines.

Ivax House, 6-3, 248/B, Road No.1, Banjara Hills, Hyderabad

CHARACTERISTICS THAT DEFINE A POLYMER:

- Monomers in the Polymer
- Charge of the Polymer
- Molecular Weight
- Configuration
- Natural or Synthetic

GENERAL CLASSIFICATIONS OF MOLECULAR WEIGHT

Classification	:	M. W. R.
Low	-----	<100000
Medium	-----	<1000000
High	-----	>10000000

Three Steps of Retention and Drainage

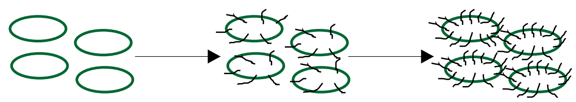
1. COAGULATION

Coagulation reduces the repellant forces between fillers and fines by developing of charge Patches (charge neutralization). Charged patches are created with products classified as coagulants. Two types:

- Inorganic
  - a. Alum
  - b. PAC
- Synthetic - low molecular weight, high - charged cationic polymers
  - a. Polyamines
  - b. PolyDADMAC's
  - c. PEI

2. FLOCCULATION

Combining or forming a bridge between particles with a polymer to produce discrete agglomerates – Flocculation by particle bridging:



a. High level of hydrodynamic volume favors bridging - long loops and tails
b. Bridging influenced strongly by molecular weight of the polymer
c. Bridging also influenced (to lesser extent) by the amount of polymer charge
d. Generates large diffuse floc structure (macro flocs)
e. Shear sensitive; higher the charge, the stronger the bond

3. FILTRATION/DRAINAGE

The papermaker's goal is to produce the most uniform product (formation) at the highest speed (drainage) and at the lowest cost. These factors are interrelated and must be balanced to meet the customer's needs. Basically, there are four stages of water removal/drainage:

- Gravity drainage
- Vacuum assisted water removal
- Mechanical pressure (table and press
- Drying (heat energy)

Example: Volume of Water Removal

Given: 25.00 ton/hr @ 7% reel moisture & Calculation - 23.25 ton/hr Bone-Dry Fiber:

@40% Press Section Solids	@42% Press Section Solids
60% water	58% water
Ratio 1.5:1	Ratio 1.38:1
34.9 ton/hr water	32.1 ton/hr water

2.7 m3/hr less water to be evaporated in the dryers

Theory – Rule of Thumb

- 1% increase in press solids correlates to: –11-13% increase in wet-web strength
- 4-5% machine speed increase (directly related to production increase) on drying-limited grades
- 4-5% reduction in steam consumption

FACTORS AFFECTING RETENTION, DRAINAGE, FORMATION & RDF PROGRAM

a. Furnish & Additives Composition – solid & liquid phase:
b. Impacts program selection
c. Relatively stable for any given machine and grade
d. Pulp – type, amount
e. Bleaching - type and brightness level
f. Filler – type, amount
g. Other additives – type, amount

Short Fiber

It contains shorter fibers compared to softwood and typical fiber length remains from 1.5 - 2.5 mm, typical fiber diameter 15 - 20 um with high fines contents than soft wood. It is more difficult to retain smaller fibers with more fines can plug voids between fibers and impede drainage. On the other hand these fines provide smoother surface and better formation but these short fibers/fines will not give the sheet strength of longer softwood fiber. Further, hardwood fines used to provide smoother printing surface by filling voids between longer softwood fibers.

Long Fiber

It contains longer fibers compared to hardwood, agro residue & waste paperand typical unbroken fiber length is size 3 – 5 mm, diameter 30 – 45 um. Softwood fibers can easily be retained. Long fibers imparts high sheet strength and high percentages of softwood tend to give a rougher surface and can be susceptible to over-flocculation (poor formation).

Mechanical Fibers (TMP, CTMP)

It contains high level of fines, high extractable content & low brightness but having high yield & inexpensive fiber source.

Strength of fibers depends upon process and high surface area but its lignin content relate to high cationic demand and high soluble cationic demand. High fines content results in low retention which provides opacity and drainage can also be impaired by high fines content.

UNCOATED BROKE

Chemically and fiber-wise, similar to the original furnish but broke has gone through the process once so the structure of the fiber has been altered depending on the degree of refining. Typically a higher level of fines than the original furnishes and most of the negative sites on the fibers have been neutralized with charge near zero. Broke is always less reactive than virgin furnish with slight increase in fines level may adversely affect the retention and drainage and ash levels in broke also contribute to filler content of system.

COATED BROKE

Coating broke includes pigment ($CaCO_3$, Clay, TiO_2) with a latex or starch binder alongwith unneutralized charged sites (anionic). Small particle size of coating pigments makes retention difficult and unneutralized charged sites create high (cationic) retention aid demand in some furnishes and much more adverse effect on retention than uncoated broke.

FILLERS

Inorganic fillers are utilized to provide improved sheet properties like Opacity, Brightness, Smoothness, Formation & Dimensional Stability . Filler loading has become a no-ending process and every paper wants to win the race of higher ash loading at optimum machine speed. High filler loading not only reduce the furnish costs through filler for fiber substitution but also reduce the steam demand. But particles less than about 10 micrometres in size are not effectively retained by sieving. Rather, retention of fine particles requires the action of colloidal forces, including **polymeric bridging** or a **charged patch mechanism which can easily achieved by effective RDF Program.** Retention & Drainage aid chemicals can be effective either by attaching fine particles to fibre fines or fibres or by agglomerating them so that they can be sieved more effectively but at the same time we need to ensure fast drainage & ash retention with the help of bentonites & Organic Micro Particulates. On the other hand, low filler retention can also cause poor wire life due to abrasive nature of filler and lead to high back water turbidity which can further cause fouling/deposition in the approach-flow-system.

pH impact conclusions & pH importance

Understand fundamental importance of pH & stability factor in acid pH and hardness/brightness in neutral pH mechanical grades. Target 0.1 pH unit variation & selection of pH control chemicals (sulphuric acid, caustic, phosphoric acid, CO_2, sodium bicarbonate, soda ash, other). Understand the system's buffering capacity (alkalinity, acidity) & determine sources of pH variation.

Impact of Conductivity

All cationic starches are negatively affected & only very high DS (0.073) starch showed good resistance as only amphoteric waxy maize starch shows good stability at higher conductivity levels. At high conductivity levels higher DS of starch should be recommended to improve retention, Sizing, Strength and surface strength.

Impact of Anionic Trash

Anionic Trash Sources are washing, bleaching, dispersants, and bio dispersants. Dispersion:

- Negative impact on coagulation - deposit control, retention (fillers, pitch and stickies, dyes, etc.)
- Increased and unstable retention polymer usage
- Difficulty to reach expected retention level
- Problems with filler retention and its benefits (opacity, brightness, etc.)
- Impact on sizing – through impact on retention and/or surface properties
- Dispersed fillers difficult to retain, pre-treatment with coagulants may lead to retention increase
- Interaction of anionic trash with cationic starch leads to bad runnability and decreased quality

so treating stock with cationic donor before starch addition recommended.

Charge Neutralization

Coagulants are traditionally used to reduce/neutralize the cationic demand or anionic trash. EPI/DMA – Poly (DADMAC), PEI, PVAm, Inorganic coagulants. The strategy is to use inexpensive, high charge materials to absorb the anionic trash and protect the functional additives

Typical Strategies of RDF Program Application:

A. Pre and Post Screen Addition

- Global trends and preferences
- Impact on dosage and sheet properties
- Facts and myths

- Polymer mixing vs. adsorption – importance in optimizing cost and quality

B. Dual polymer program

- Impact on performance, cost and formation
- Premix addition
- Benefits, testing, establishing synergy

C. Filler Pre-Treatment Application

Pre & Post Screen Addition:

- Post Screen Addition: Formation and runnability concerns drive pre---screen addition
- Polymer preparation best practices
- Proper mixing and dosage

Pre Screen Addition - Exposure of floc to shear stress in the screens

- Larger flocs – more hydrodynamic stress
- Exact location of an addition point before screens important
- Addition point close to the screens – limited flocculation and less floc disruption in the screens
- Systems with addition point far before the screens – highest loss of flocculant efficiency

Pre – Screen – Addition – "it is good for efficiency and formation"

- Typical savings from going to after screens addition – 15 - 30%. Different based on polymer, furnish, pre---screen addition and post – screen addition
- Source of concerns about efficiency loss for post screen addition – Bad experience in the past – Polymer solution, gels, inversion, bad filtering can be overcome formation – dosage level, white water consistency target, mixing can be optimized
- Application post screen should be an ultimate goal – best practices in polymer preparation, feeding and program control

Cy (%)	Reflocculation Time (Sec.)	Distance Traveled On Wire @2000 fpm (ft)
0.5	0.5	16
1	0.1	3.3
2	0.04	1.3
3	0.01	0.33
4	0.0001	0.000.33

Dual-Polymer-Program

- Look for synergy in coagulant addition
- Look for additional benefits of coagulant addition – drainage, sheet properties, formation, two - sidedness, printability, linting.
- If no synergy in terms of retention level or other benefits application could be sensitive for cost reasons
- Benefit of each component of retention program must be well established and documented

Filler – Pre – Treatment

- Treating filler stream with additive maximizing interactions with retention program
- Non – flocculative pre – treatment helps to reduce zeta potential & coagulant addition along with sensitizing filler particles for flocculant addition (Phenol formaldehyde resin additon)
- Flocculative pre – treatment – Increasing filtration component of filler retention.

Filler – pre – treatment – lab testing

- Prepare furnish without filler
- Make filler addition a part of retention experiment
- Determine dosage of coagulant needed to destabilize filler slurry
- Keep dosage of retention polymer constant
- Vary dosage of pre---treatment applied to the filler
- Measure FPR% & FPAR%

Drainage Mechanisms - A Closer Look

- Shear Patterns within a forming web

Factors Influencing Dewatering Paper Machine

Headbox conditions– (turbulence and shear)	Table Design & Drainage Elements
➢ Slice geometry and profile ➢ Jet angle ➢ Machine speed ➢ Wire speed ➢ Jet/wire ratio	➢ Wire (fabric mass, width, drainage properties, permeability) ➢ Forming board position ➢ Blade angles along table ➢ Gravity elements ➢ Vacuum devices ➢ Formation devices (i.e. top formers)

- Independent of former type, the control of turbulence and shear combined with drainage rate ultimately decides retention and formation
- Slower drainage = better retention = poorer formation due to lack of turbulence and the formation of fiber flocs
- Goal is sufficient drainage with the best formation to give the highest retention

Fiber Reflocculation

- In the absence of active turbulence the following table is applicable
- Poor early turbulence or sheet sealing on a table and late turbulence often results in poor formation due to formed flocs not breaking apart:

Forming the Initial Wet Web - When the head-box jet impinges on forming fabric generally ahead or on the forming board – Rapid Drainage Happens

- Forming fabric is the only resistance for drainage
- Low retention
- In some milliseconds a wet web is formed dominating drainage
- The wet web is the surface of the final paper and the conditions where it was formed defines the paper surface characteristics

Response of initial forming

- J/W ratio defines amount of MD shear force imparted on the fiber surface
  a. Surface orientation
  b. Curl
  c. Shear force breaks flocks => formation, impacts retention and drainage
- Headbox jet has turbulence => shear forces
  a. Jet turbulence aides in restricting fiber flocculation however turbulence decay down the forming section allows reflocculation to occur
  b. Jet turbulence reduces surface orientation

CONCLUSION

Now, we should have to understand that when we operate with large flocs with high retention of fines then we face fast gravity drainage. Large void areas between flocs causes slow drainage over the vacuum units due to thin spots caused by heavy flocculation because this increases the openness of the sheet and allows vacuum to be lost/disappear through the sheet. Large, high fines content flocs remains quite dense and makes it difficult to remove water by pressing and drying. On the other hand if we operate with dispersed, unflocculated system with low retention of fines then we face slow gravity drainage due to high fines level of system & cause two sidedness. Also, we get good drainage over vacuum units due to uniform sheet providing high vacuum and good drainage in the press and dryers unless a high level of fines causes severe two sidedness. So it is always better to operate on uniform microflocs with good fines retention because small/micro flocs provide paths for water drainage and fines controlled at low equilibrium level. Uniform micro-flocs gives good vacuum drainage and well-distributed fines give good pressing and drying. So while selecting the RDF Program it's better to define the exact need – Is it retention or drainage or formation?

REFERENCES

1. J.C. Alfano, P.W.Carter and Gerli, A., NPPRJ, 13(2): 159(1998)

2. P. Pruszynski and Jakubowski, R., Appita Conf:211---218 (2003)

3. P. Pruszynski and R. Jakubowski, Appita Journal, 59 (2), 115, 2006

4. A. Sundberg, et.al., Nord. Pulp Pap. Res. J. 9 (2):125---128 (1994)

5. M. Rundlof, et.al. Nord. Pulp Pap. Res. J. 15(4): (2000)

6. X. Zhang, et.al., J. Pulp pap. Sci. 25(6):206-211 (1999)

7. J. Thornton, et.al., J. Wood Chem. Technol. 14(2):177-194

8. (R. Beaudoin, R.Grahon and R. Turcohe, 80th CPPA Meeting (February 1994)

9. Pulp and Paper Chemistry Symposium, Stockholm 2006

10. Thornton, J., Tappi J. 77 (3) 161-167 (1994) Sundberg, A., et.al. J. Wood Chem. Technol. 20(1):71-92 (2000)