Water-Soluble Polymers as Retention Aid in Papermaking

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The papermaking process involves three basic operations. First, a wet web of fibers is formed from a fiber – water slurry and drained on a continuously moving wire. Second, additional water is removed by pressing the web between felts. Third, the web is dried on a series of steam–heated drier drums. The water systems surrounding this basic process will be described in more detail below, as will the complete papermaking system.

Papermakers use water–soluble polymer flocculants in papermaking for two main reasons :

1. To improve retention, within the sheet, of fiber fines, inorganic fillers, and other small particulate matter.

2. To improve liquid–water removal, or drainage, during the papermaking operation.

Historically, improved retention of titanium dioxide in the sheet has been the primary reason for using filler retention aids (1,2). This is because of the high cost of titanium dioxide, compared to other components in the system. The expanding use of other relatively expensive pigments has increased the need for use of a filler retention aid. Also, recent increases in pollution control measures have made the papermaker more interested in improved retention of the cheaper materials such as clay and fiber fines. Papermakers also have become more aware recently of the potention economics in improved retention of fiber fines.

Even through most of the water drained from the wire during papermaking is recirculated to the wire, optimum operating standards require the "first pass" retention to be as high as possible. When inadvertant spills or leaks occur, or when the machine is shut down and drained, the loss of expensive filler and fiber is directly related to the concentration of these materials in rhe recirculating "white water" (so called because the pigment build–up gives it a white colour). Typical papermaking practice calls for frequent change in the grade of paper being produced. Often a grade of paper which requires a high level of titanimum dioxide is followed by a grade which does not require TiO_2. In such case, the TiO_2 buildup from the first grade will be bled into the second grade until a new equilibrium is built up. In this case the price obtained for the TiO_2 being used in it, so the papermaker would operate at a reduced profit. On the other hand, if the grade without Ti02 was made first, the system would have to be "slugged" with large amounts of Ti02 so that the sheet followihg would conform to specifications This would also cost the papermaker money. Use of a retention aid would minimize Ti02 buildup in the system and avoid these losses.

The use of flocculants to improve drainage, or water removal, in the papermaking process is a relatively new development compared with filler retention. Papermaksrs are primarily interested in drainage aids because they improve machine speeds. Increased machine speed gives increased production for a given amount of equipment which, in turn, makes more money for the papermaker. It is common for a papermaker to get a production increase of ten percent or more. In a typical case, a production increase of ten percent resulted in a net profit inciease to the mill of about 3250,000 per year (3).

Increased drainage rates also improve sheet formation and increase sheet strength The improved formation (distribution of fibers throughout the sheet) results from increase dilution of the fiber slurry going to the papermaking process and from removal of excess water by the improved drainage rate. The strength improvement is obtained by increasing the mechanical refining on the fiber itself, which improves strength but decreases drainage. The loss in drainage is compensated for by the increased drainage rate made possible by the polymer. Action of the polymer does not reduce this strength improvement.

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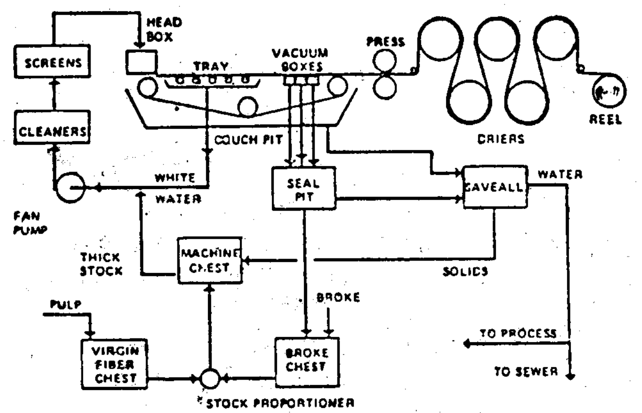
THE PAPERMAKING SYSTEM

A typical papermaking system is shown in the attached Diagram. The stock input system is comprised of the virgin fiber used and the broke (or scrap) from the papermaking operation. It also includes many other ingredients such as fillers, chemical additives, dyes, etc. which are used in the sheet. These materials are all run through stock-proportioning device and stored in the machine chest to be drawn on by the paper machine.

Paper Machine Wet End System



Schematic Diagram of a Typical Papermaking System

POLYMERS USED FOR DRAINAGE AND RETENTION IMPROVEMET

Many different types of polyelectrolytes are used by the paper industry for drainage and retention improvement. They are of both the anionic and cationic type. Molecular weights range from intermediate to high. Dry Products are sold, as well as liquid products ranging from 5% solids to about 35% solids. The most commonly used polymers may be classified into the following types :

1. **Polyacrylamides** (anionic and cationic liquid and dry products available).
2. Polyamines (cationic, liquid products).
3. Cationic Starches (dry products derived from various sources, e. g. corn, potatoes, etc)

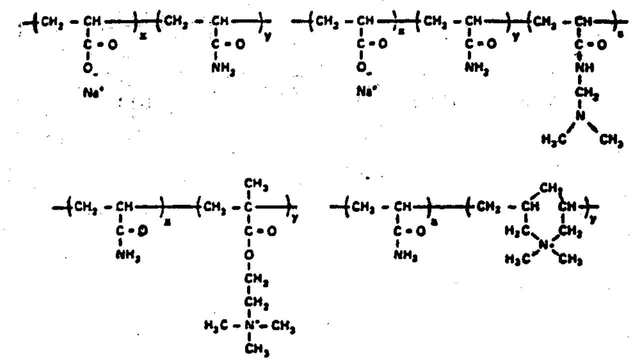
Addition of Drainage and Retention Aids to Papermaking Systems

The main guidelines for adding flocculants to the papermaking system are :

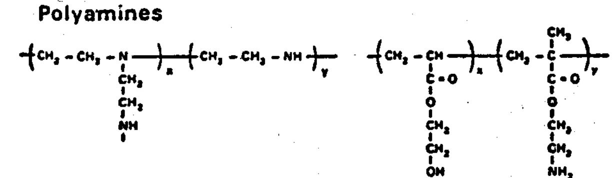
1. That they be added to the system after the thick stock has been added to the recirculating tray water. The tray water contains a large part of the fines and fillers which have to be retained.

2. That they be added to the system after points of high shear, but for enough ahead of the headbox to give a good mixing.

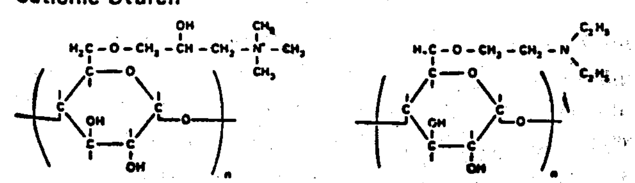
Polyacrylamides



Polyamines



Cationic Starch



Structures of Water-Soluble Polymers Used for Drainage & Retention Improvement

SHEAR EFFECT

Since flocs formed by different polymers have different sensitivities to shear[4], the common practice when testing a flocculant on a paper machine is to try different points of addition and see which works best. An addition point in current favour is the outlet of the centrifugal screens, In this case, however, it is necessary to have sufficient mixing between the screen and the headbox If sfficient mixing is not allowed, "stratification", or localized over-concentrations will occur causing streaks in the sheet. The immediate inlet side of the fan pumk also can be used as an addition point. Here the fan pump is the in-line mixer. The flocs probably do not form until the stock and polymer have passed through the pump When a fan pump addition point is used, however, flocculants should be used which give flocs less susceptible to breakdown by the shear forces in the cleaners and screens. When two or more polymers are used in combination, the last polymer is added as described above. The preceding polymers (s) is added at a point further back in the system. The first polymer often is added to the thick stock[4]. In such cases the first polymer often functions as a conditioner for the second polymer.

Generally, it has been observed that for any given polymer larger amounts need to be added for drainage improvement than are necessary for improved retention. With the synthetic polyelectrolytes, addition levels for retention are usually in the range of 0 01% to 0.06%, based on dry paper solids and dry polymer solids.

Flocculants are often used at the saveall when improved retention is the objective. When used in this manner, the flocculants are normally mixed with the incoming water as it enteres the saveall. Often, however, the use of a flocculant on the paper machine itself gives a sufficiently improved saveall operation In some cases, a small fraction of the polymer used on the machine is added immediately before the saveall, and is in addition to that used on the machine. A polymer of opposite charge to that used on the paper machine also may be used on the saveall. There is no set rule on how to best use a flocculant at the saveall. Each mill has its own point of view, Unfortunately, the saveall operation is still governed largely by guesswork. Furthermore, it often receives a disproportionately low share of attention from the machine technical crews.

Other Factors Affecting Performanee of Drainage and Retention Acids

Papermaking fibers have an anionic surface charge. This is largely due to the uronic acid (carboxyl) groups of the hemicelluloses portion of fiber. These hemicelluloses exist as a coating around the cellulose fibrils which comprise the fiber. Therefore, the fiber surfaces which the flocculants see are mostly hemicellulose Anionic polyelectrolytes would act as dispersants rather than flocculants for the anionic fibers if they were not used in conjunction with some multivalent metation. In the paper making process this cationic charge is supplied by alum. In the case of the cationic polyelectrolytes, direct interaction with the anionic fibers is possible.

In many cases, the anionic charge on the fibers can be diminished or even reversed by the effect of preceding chemicals[5,6]. The best drainage and retention performance generally occurs near the point of zero net surface charge. At this point the ionic repulsion forces are at a minimum. This maximizes the inherent flocculation tendency. It also minimizes the effect of ionic repulsion forces reinforcing the shear forces which tend to break down the flocs that have already formed. In addition, a low surface charge will result in a lower tendency for repeptization of the fines and fillers which are detached from t e fibers by the shear forces.

When the charge on the fiber–fines system is sufficiently diminisned, but still anionic, a weaker cationic charge on the polymer is desirable, since more polymer can be absorbed on the system fiber–fines system is used and little neutralivation has occurred a strongly cationic polymer is more desirable. If the charge has been completely reversed, an anionic will probably work best. Unfortunately, because of the complexity of the system it is usually difficult to predict whether the surface charge on the system will be anionic or cationic on any given papermaking machine A practical approach to deciding which polymers(s) should be tested on the machine is to evaluate a sample of headbox stock in the laboratory for drainage and retention values using a series of different type of polymers.

Machine dynamics is another factor affecting the performance of a drainage and retention aid. Shear forces in the diluted stock system preceding the wire, and shear forces in the stock on the wire itself can both adversely affect the distribution of particles in the web structure. These forces have been discussed to some degree above. Britt[4] has developed a laboratory technique for measuring and retention under shear which correlates well with observed mill results. As discussed earlier, he has shown that combinations of anionic and cationic polymers give flocs that are less sensitive to shear than flocs formed by single polymers, either anionic or cationic. Single polymer systems are currently being used successfully, but further increases in machine speed will give approaches such as Britt's greater importance.

Problems and Side Effects When Using Drainage and Retention Aids

Overflocculation is probably the biggest problem associated with the use of drainage and retention aids.

When a retention aid is used to retain titanium dioxide, for example, some loss in optical efficiency will result. This is caused by the Ti02 particles being agglomerated with a resultant loss in optical scattering surfaces. Increased resention of Ti02 will usually offset this slight loss in optical efficiency. At higher levels of retention aid, however, the loss of efficiency will surpass the incremental increase in retention and the opacity will deccrease Different polymers or polymer systems can be expected to have different ratios of retention to loss of optical efficiency. Pummer[7] has given a good illustration of the technique of Brecht and co-workers[8] for relating the various optical properties of paper. They plot scattering power, absorption power, opacity and brightness on a chart which they call the "plane of optical status". The scattering and absorption power of the sheet are determined using the well-known Kubelka-Monk theory. Becht's technique is an excellent one for showing the relevant optical properties of a sheet of paper on a single graph. Pummer evaluated diffe ent types of polymers for their effect on the optical properties of the sheet. He concluded that the lowe -molecular-weight polymers have less effect on optical efficiency of fillers than do polymers of high molcular weight. However, lower-molecular-weight polymers uiually require substantially high addition levels to obtain good retention.

Some polyelectrolytes (polyamines, for example) have a deleterius effect on optical brighteners[7]. They presumably complex with the optical brighteners and cause them to lose efficiency in absorbing and re-emitting light.

SUMMARY AND CONCLUSIONS

Improved retention is achieved by agglomeration of fines and fillers to the whole fibers. Redistribution of fines and fillers and collapse of the hydration shell on the fibers and fines gives better web permeability. This can increase drainage through improved water removal at the web end, and improve steam escape on the dryers. Drainage and retention aids work best at the point of zero net surface charge on the fibers. Combination anionic and cationic polymer systems are less shear-sensitive than single polymer systems. Evaluation of any retention aid system should include an analysis of optical properties.

A key point to remember when considering flocculants in papermaking is that these water-soluble polymers are tools that the papermaker can use to give him more flexibility in operating his system. He can achieve many advantages by efficiently using these materials, but they generally involve readjustment of his operation to take full advantage of them. This is an aspect of the use of polymers that papermakers often do not fully realize. This implies a need on the part of the supplier industry for rather large amounts of technical service to accompany introduction and profitable use of water-soluble polymer flocculants.

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