Current strength requirements on corrugating medium are escalating whilst recovered paper qualities tend to deteriorate. At the same time, papermakers are confronted with a growing demand for ever lower basis weights. Both trends call for countermeasures to compensate for strength losses. Based on the innovative product class of polyvinylamines, BASF has developed a chemicals system allowing papermakers to respond to varying and basically deteriorating raw material qualities. The knack is to make combined use of a cationic and an anionic polyvinylamine – a viable approach to targeted solution concepts for the strength problem concerned. BASF is marketing polyvinylamine under the brand name of Luredur®. This article presents a dry strength system called BASF Carrier System which is successfully being applied in the Smurfit Kappa Hoya Paper papermill.

The Carrier-System

Paper strength is of paramount importance in corrugated manufacture and all the more so if production is based on 100% recycled fiber. The majority of papermakers agree that recycled fiber qualities are steadily declining so that it is becoming increasingly difficult to meet strength specifications. This experience has been confirmed in systematic studies. Tests conducted by Hoya Paper revealed that the average SCT levels of raw materials for both high-grade qualities (kraft liner) and inferior qualities (testliner 3) decreased over a 4-year period (Fig. 1).

Problems of internal starch used as strength agent

For European packaging papers, size presses and metering size presses are usually employed to enhance paper strength. Surface starch is currently the most popular strength agent employed. If this treatment proves insufficient, internal starches may additionally be introduced. As a rule, however, traditional cationic internal starch can only be dosed in amounts of 1 – 1.5 %. Frequently, papermakers are having difficulty to keep the performance of internal starch unchanged over protracted periods of time.

Synthetic dry strength agents – a more powerful alternative to cationic internal starch

Synthetic dry strength agents – and primarily cationic polyacrylamides of medium molecular weight – suggest themselves as a viable alternative. Recently, the range of options has been extended by cationic and anionic copolymers on a polyvinylamine (PVAm) basis. Synthetic dry strength agents provide strength by bridging gaps on a molecular level. Without them, the interspaces would be too large to permit effective looping of the fibrils of different fibers. In the case of polyvinylamine and below a specific dry content, the vinylformamide group forms hydrogen bonds with cellulose (Fig. 2). Compared to starch, the polymer chain of PVAm is far more flexible and, in relation to its molecular mass, provides a distinctly higher number of potential binding sites. This benefit is also reflected in the ratio of the specific performance of cationic internal starch to that of a synthetic dry strength agent. In other words: synthetic dry strength agents considerably outperform cationic internal starches (Fig. 3).
Strength agent dosages vs. strength increase
A drawback of synthetic dry strength agents is their high cost. However, this is more than compensated for by the productivity increase obtained—a fact that has been underlined by recent new developments.
There exists a relationship between strength increase and strength agent dosages (Fig. 4).

Additions exceeding 0.5% of a PVAm-based cationic dry strength agent fail to give a further strength increase. For dosages above 0.5%, this saturation is accompanied by a saturation of the polymer level adsorbed on recycled pulps.

If dosages of less than 0.5% are added, 100% of the polymer adsorbs at the recycled pulp which results in a largely linear rise in strength values. When the 0.5% mark is exceeded, a steadily growing part of the polymers is no longer adsorbed at the fibers so that the strength increase comes to a stop.

Functions of the Carrier System
The saturation of polymer adsorption is chiefly charge-driven—a phenomenon that has been confirmed in adsorption tests of polymers with different levels of cationicity. If the saturation point of polymer adsorption is reached owing to a charge reversal, thus preventing a further strength increase, a dry strength agent in the form of a polymer carrying an opposite—i.e. anionic—charge can quantitatively adsorb at the cationic fibers, thus contributing toward higher strength levels. This mechanism has been demonstrated in pertinent studies (Fig. 5).

After adding 0.5% of a cationic dry strength agent on a PVAm basis, an anionic PVAm is dosed into the stock. Up to a maximum dosage of 0.7%, this agent is quantitatively adsorbed so that the total polymer dosage (cationic plus anionic) at this point comes to 1.2%. The more the anionic polymer is adsorbed, the more the zeta potential drops from its originally positive to distinctly negative values. However, in the presence of a cationic carrier, the anionic polyvinylamine is additionally retained on the fibers. This explains why this combination of cationic and anionic dry strength agents is called Carrier System.

Synergy effects of the Carrier System
Theoretically speaking, every cationic polymer can adsorb an anionic dry strength agent (Fig. 6).
As expected, polyamine—which is not a dry strength agent—fails to contribute appreciably to paper strength. However, when used in combination with an anionic dry strength agent—here anionic polyvinylamine—it clearly produces a strengthening effect. The performance of this combination is poorer compared to the sole use of cationic PVAm. On the other hand, two polyvinylamines combined achieve more than twice the performance of a sole PVAm, which suggests a kind of synergistic complexing between anionic and cationic products.

Industrial test at Smurfit Kappa Hoya Paper
Hoya Paper, a member of the Smurfit Kappa group, has benefited from the BASF Carrier System: as early as the 1990’s, paper strength had been improved to a point where two-side operation of the size press could be switched to one-side mode with all its particular
advantages including a productivity increase. However, as raw material qualities deteriorated over the years, it became ever more difficult to meet strength specifications. Though mill managers felt themselves compelled to run the size press once more in two-side mode, they kept searching for possibilities of returning to one-side operation without compromising the SCT standards achieved.

Mill-scale tests
To begin with, one-component synthetic dry strength agents were tested. However, they frequently failed to keep strength levels reliably constant. In view of the favorable results obtained with the Carrier System in the laboratory, mill tests were initiated (Fig. 7).

At first the cationic component Luredur® PR 8095 (cationic PVAm) was dosed into the outflow of the machine chest before the anionic component Luredur® PR 8276 X (anionic PVAm) was added immediately ahead of the stock dilution stage. A number of single tests were performed to identify the appropriate dosing sequence and dosing points.

If the Carrier System is applied in optimal dosages, the SCT value keeps within specified limits even if the size press is run in one-side mode. The higher strength contribution of the internally added synthetic dry strength agent offset the losses resulting from one-side starch application. This system has already proven effective over extended periods of time (Figs. 8 & 9).

Rules of Carrier System application
There are a few points to be remembered when applying the Carrier System. For example, papers tend to develop a certain degree of wet strength already before entering the drying section so that web breaks may lead to problems in the pulpers. For the time being, these problems have been alleviated to a tolerable level by fine-tuning the cationicity of the cationic product. In the case of fluctuations in raw material inputs and in the charge household, the proportion of the two single components has to be suitably adapted. Disproportions might increase the gas content in the whitewater and thus also the foaming tendency.

When used in the size press, the Carrier System has a positive side effect: reinforcing the sizing degree, it helps reduce the consumption of synthetic sizes.

Online charge measurements are strongly recommended to master charge variation and its effects on an optimal dosage ratio of the two components of the Carrier System.

If polyvinylamines are applied, particularly high strength increases are obtained by adding a combination of cationic and anionic polymers. Their combined use achieves more than twice the effect of a sole chemical, which suggests a kind of synergy effect.
Benefits of the Carrier System

For two paper grades (kraft liner and fluting), Smurfit Kappa Hoya Paper achieved annual cost savings of 1 million euros by applying the Carrier System. The BASF Carrier System significantly enhances the quality and productivity of fluting manufacture. The target SCT levels are safely attained and kept constant. The most important advantage is one-side operation of the size press with a number of favorable effects: owing to smoother machine running and higher machine speeds, productivity is raised by 14%. Surface starch consumption is decreased by 50% and size consumption by 40%. At the same time, the complaint rate because of inadequate gluability in the corrugator is reduced to zero. No internal starch is needed, which lowers the drying energy requirement. Similarly, retention aids become superfluous and steam consumption is reduced. Variations in anionic trash loads can be successfully compensated for by suitably adapting cationic polymer dosages.

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