FLOQUIP is the engineering division of the SNF Group. It has a long experience in manufacturing polymer dissolution equipment, emulsion storage and handling, and has recently designed the Dynamic Handsheet Former closely following SNF’s paper application laboratory team recommendations on performance and ergonomics.

**Market and Technologies**

Papermakers have felt an increasing pressure over the last few years coming from production imperatives and the market environment. Many driving forces have contributed to drastic changes. These changes include:
- Demand in brightness (change in type of filler, increase of filler content).
- Demand in paper production (high speed machine up to 2000 m/mn, higher filler content (up to 30%) easier to dry but more difficult to retain).
- Demand in new machinery (short wire section formation, short loops and very short recirculation, closed loop control).
- Environmental demands (water consumption, water quality, less virgin pulp more recycled fiber).

All these demands require systems with a higher sophistication:
- Retention-drainage systems
- Dry strength resin systems
- Enhanced sizing systems

Some of these systems are already in place, others to come are based on polyacrylamide chemistry (new technologies, new patents...)

**Dry Strength Resin Trends**

The increase of strength requirement, the demand for lower basis weights associated to deteriorated recovered paper quality, require imagining measures to compensate the strength losses. Over the years, higher machine closure and quality challenges made starch performance more difficult to be obtained due to its poor affinity with “tired fiber”.

As a result of its charge, high dosage may create an over flocculation and leave free starch in the wet end. The side effects are visible on the paper process: formation issues and breaks as well as higher energy consumption due to binding water, and on the water & effluent process: biological activity, slimes and DCO increase.

Among the synthetic polymers, the most commonly used dry-strength additives are polyacrylamides. The polymer structure (linear or branched) can be manufactured under different conditions combining different type of monomers, ionicity and form.
- The cationic PAM resins are directly substantive to fiber,
- The anionic PAM and amphoteric resins require the separate addition of alum or other cationic promoters to allow its fixation.
The new design of the FLOQUIP Dynamic Handsheet Former enables paper makers, R&D centers and chemicals suppliers to:

- Try out new technologies
- Test new concepts without taking any risks on machine by simulating chemicals/filler addition and their impacts on mechanical and optical properties.

The FLOQUIP Dynamic Handsheet Former has been designed by hands-on paper lab technicians and engineers to have an easy to use equipment that simulates paper machine conditions every time all the time.

The main benefits are:

- Compact & ergonomic for space constraint requirements
- Maximum operational safety both for electrical protection and moving parts
- High reproductibility in automatic mode on the full speed range
- Easy data entry and clear displays using a graphic interface on a tactile screen

The FLOQUIP Dynamic Handsheet Former brings innovative solutions to edge effect, vibration reduction and high speed levels (up to 1500 m/mn) and multiplies application.

**Opportunities**

Based on the steady focus on Polyacrylamide by the paper industry and the use of FLOQUIP Dynamic Handsheet Former, service partners have promoted over the years various technologies allowing to:

- respond to papermaking process (Acidic to Alkaline)
- address quality challenges
- integrate runnability & strength priorities

This paper presents various aspects of this dry strength system combining the use of highest substantive cationic polymer with or without anionic DSR but also some amphoteric PAM and GPAM grades.

**DSR Benefits**

**Costs efficiency**

- Reduced furnish costs by allowing fiber substitution with filler or higher filler level with improved strength properties
- Reduced basic weight
- Increased productivity balancing refining and drying requirements
- Reduced COD and BOD due to optimization of starch dosage
- Improved machine runnability

**Process improvements**

- Optimized chemical additives such as drainage aids, sizing agent and starch,
- Reduced steam consumption
- Reduced mechanical or enzymatic refining
- On machine cure

**Quality improvements**

- Increased burst and tensile strength
- Better Scott Bond, better CMT, RCT, SCT
- Constant paper production MD & CD
Combining effects

The strength properties on packaging grades are generally enhanced through wet end starch and size press application. Due to water retention requiring higher energy to dry, DCO issue and conductivity sensiveness, cationic starch is limited to 10-15kg/t to keep internal properties. Cationic polyacrylamide or in a better extend primary amine or PVAm proved to be an effective alternative when associated with anionic DSR. The high substantive cationic polymer, issued from Hofmann synthesis or NVF process, allows boosting strength to a point where operation of size press can be partially switched off. In spite of this higher cost (limiting addition rate), dry strength resin is far more efficient than starch and less sensitive to conductivity build up and poor recycled fibers.

Starch vs Multicomponent System Strength Comparison

High runnability performance and cleaner paper machine are obtained with synthetic dry strength technologies. Additional benefits such as productivity (5-10%) associated to the reduction of retention aid (10-100%) and sizing chemicals (15-50%) have been recorded with lower drying energy than when starch is needed.

Charge Control

The ionic nature is one of the most important properties of chemical pulp with regard to the action of Polymer or starch. Due to the anionic character of the fibers, most chemicals additives (PA, PAE, PAC, Starch,...) added to the wet end are cationic. In this example we decided to treat an OCC furnish with a coagulant to neutralize pitch and stickies while maintaining good runnability. Among key process parameters we selected FPR, FPAR and coagulant dosage. With the addition of a polyamine coagulant the FPAR and FPR remain good as long as the ionic nature of the furnish stays anionic. If cationic additives are over dosed, the ionic nature of the system, measured with PCD equipment, will over pass the iso-electrical point and become cationic. This is characterized by an increase in the chemicals consumption and frequently as poor runnability.

Note: all values in this brochure are presented in active polymer content
Ionic Charge

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Charge density (meq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cationic Starch D.S. 0.035</td>
<td>0.2</td>
</tr>
<tr>
<td>Polyaluminium chloride (PAC)</td>
<td>3.0</td>
</tr>
<tr>
<td>Polyacrylamide 40% Mole</td>
<td>3.3</td>
</tr>
<tr>
<td>Polyethylene imine (PEI)</td>
<td>5.1</td>
</tr>
<tr>
<td>Polydadmac</td>
<td>6.2</td>
</tr>
<tr>
<td>Polyamine</td>
<td>7.4</td>
</tr>
<tr>
<td>Primary amine-Hofmann</td>
<td>8.0</td>
</tr>
<tr>
<td>Polyvinyl amine</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Charge control is influenced by the chemicals & dosage applied, furnish composition, water recirculation and the amount of anionic trash present. The charge density of a cationic polymer used for DSR is by far higher than cationic starch. Table presents a comparison of the charge density of various cationic polymers.

Colloid titration is a common method of measuring ionic nature and a reliable indicators of changes that have occurred in the system. The polymer adsorption on fiber, measured with SZP equipment, allows to multiply hydrogen bonding and thus enhance DSR properties.

PCD and Zeta Potential

Zeta potential and the cationic demand on white water are the key parameters that control the wet end balance, machine runnability and strength performance. The potential describes the potential surrounding fiber surface while the cationic demand corresponds to the ionic nature of the stock.

In a case of multi component process (primary amine combined with anionic DSR), we can control very efficiently polymer adsorption on the recycled furnish and predict a linear rise of strength properties even with a multiple addition points, see graph below.

An excess addition of anionic DSR will be accompanied by a non saturation of the fiber, a release of anionic charge in the wet end and a poor strength increase. A return to normal for the cationic demand will be managed by a subsequent addition of primary amine.

Similar behavior will occur when primary amine is added in excess without anionic counter measure. Above a certain level of saturation (0.12-0.15 %) which may vary from furnish to furnish, the polymer will not be adsorbed anymore and the strength properties will stop improving and foaming may occur.
Although many papermakers are interested capitalizing speed increase with single or multi components DSR, FLOQUIP Dynamic Handsheet Former performance is independent of DSR molecular weight.

The average molecular weight of the PAMs can vary from a few thousand to several millions. In general, medium to high molecular weight PAM’s (>6 million up to 20 million Daltons) are used as retention aids, while PAM polymers with relatively low molecular weight (100 k to 1 M Daltons) are used as dry-strength agents due to their tendency to avoid flocculation.

Even if the same general dosing instructions are applied for retention aids and DSR, addition points and operating procedures for dissolving DSR have to be adapted to cope with mechanism and MW difference.

Compared to standard retention system dosed at 0.15-0.40 kg/t (active), DSR programs (single or dual) may require globally 1.5-4.0 kg/t ie over 10 times retention aids usage.

### DSR Programs—Primary Amine Neutral pH

The two complementary effects in a DSR program are runnability & strength enhancement. These can be achieved with a single primary amine addition or a combination effect with a high substantive cationic primary amine associated to an anionic DSR. Overall dosage rate may vary from 0.7-1.2 kg/t (active) for a single to 3-4 kg/t (active) when we consider a multi components addition program.

It is clear however that both expectations (runnability & DSR) may coexist depending on grade structure or market requirements. The selection of each component, the nature and dosage rate will allow to maximize customer satisfaction and make the treatment cost affordable.
The main challenge selecting a DSR in powder form versus a liquid is driven by the dissolution equipment size and the investment associated. Once sorted out, drainage enhancement can be capitalized due to higher MW contribution. Some increase on DSR properties can be recorded as well.

**Primary1** = Primary amine first generation, **Primary2** = Primary amine second generation.

*All the products on the second graph are dosed at 1.5 kg/t on OCC furnish.*
DSR Program-Amphoteric with Alum-Acid & Pseudo Neutral Media

In acidic & pseudo neutral pH, DSR enhancement with an amphoteric resin, has to be activated with a cationic charge: Alum or PAC. The response follows a Gauss curve. The second generation of Amphoteric resin (Amphoteric 2) has allowed boosting strength properties while reducing Aluminum dependance versus old generation (Amphoteric 1). This new grade will be applied on pseudo-neutral condition where as the previous one was in acidic condition.

Optimal Strength Performance with Alum Addition

Runnability & DSR properties can also be maximized through higher molecular weight when the Alum/PAC dosage is optimum.

Molecular Weight Influence on Drainage

Even if the Amphoteric program delivers lower performance compared to primary amine associated to anionic DSR resin, it offers to paper maker a friendly use especially when Alum/Pac is added in large quantity.

Due to environment legislation (requiring less Al ion released in the effluent) and the increased use of recycled waste made in alkalin media, this system will be over time replaced progressively by multicomponent system (Primary amine + anionic resins or cationic acrylamide based + anionic resins) less demanding or requiring no Aluminium to make them work.
GPAM imparts absorbency and temporary wet strength characteristics which are required for tissue industry. Depending on process condition, up to 50% of the initial wet strength may be lost after 30’ of soaking time.

Compared to PAE, GPAM’s develops a fast on machine curing which eliminate paper ageing requirement before testing or converting. Utilizing these inherent strength gains allows for fine tuning of refining levels to achieve bulk and softness.

When we have to consider the use of a glyoxylated resin, pH optimization can be simulated with FLOQUIP Dynamic Handsheet Former handsheets to assess optimum wet and dry strength performance. As reported on these graphs when the GPAM is dosed at 5 kg/t active, the lower the pH, the better would be mechanical properties.

Further lab study can be initiated with the FLOQUIP Dynamic Handsheet Former, combining modified starch with GPAM. As for other technologies higher efficiency is gained as a result of such addition. This synergy in the case of GPAM & starch, usually improves retention & drainage but allows to improve repulpability process time, bulk properties and strength while reducing refining.

In the case of tissue application, the use of temporary wet strength – GPAM can boost mechanical properties with or without starch.
Program Design: Fiber Substitution by Filter

**Business Case**

In order to address mill objective: to reduce cost over its current 90-130 g/m² grade structure, a service partner has investigated various options using FLOQUIP Dynamic Handsheet Former unit.

While the mill, specialized in testliner production, has experimented several strength programs, it was not capable to meet burst targets and sufficient cost reduction. In addition to this priority, the mill wanted to introduce a new grade higher once economy recover.

**Analysis**

Following a machine & wet end survey including cationic charge analysis, a laboratory program was scaled up capitalizing chemicals sequence, shear factor & fiber orientation while using high reproductibility of the FLOQUIP Dynamic Handsheet Former equipment.

As a result of these evaluations a multi component program (Primary amine + anionic DSR) was selected among various technologies.

Strength Performance with GCC Addition

A very positive feedback was received from the papermaker concerning this trial.

The addition of DSR in a multi component addition system keeps the physical properties of the sheet while increase charge.

- Quality improvement with higher burst index and higher smoothness and opacity
- Cost reduction by substituting 3% fiber by filler without losing strength property
- Increase printability

Additional benefits was clearly highlighted to justify the multi components system through sizing optimization (-15%), drainage enhancement and retention increase.

As a result, trial agreement was obtained.
Program Design: Virgin Fiber Substitution by TMP

- **Business Case**
  A producer of fine paper grade needed to respond to market pressure by developing new grades with basis weight of 80-100 g/m² at lower cost. Adding to the papermaker’s concern was runnability. The drainage reduction and poor retention may lead to lost machine production.

- **Analysis**
  In concert with papermakers and service partner, several chemicals and furnish options were investigated to improve cost reduction without impacting productivity.

The mill finally set its priority to use partially TMP instead of virgin pulp. Based on service partner survey, it was determined that retention & drainage can be managed with the existing system (cationic polyacrylamide combined with PAC for porosity and anionic trash control). The goal over their current grade structure, was to select a DSR program able to compensate strength loss with different amount of TMP.

Prior to chemical evaluations on lab, key parameters were defined: Burst, Ratio Virgin Fibers/TMP, cobb sizing, cost performance. As a result of these evaluations a multi component program (Primary amine+ anionic DSR) was selected.

**Strength Performance with GCC Addition**

It clearly demonstrates capability to enhance mechanical performance and reduce fiber cost:
- Increase Burst Index combined with 10% fiber substitution
- Substitute about 20% of virgin fiber by TMP at equal performance

As for all application met with multi components, the addition of highly substantive cationic polymer will allow to reduce AKD sizing cost by 12%.

On machine evaluation has been agreed.

This program carried out using FLOQUIP Dynamic Handsheet Former unit has allowed to develop new grades without taking any risks simulating chemicals or fiber substitution.