A new approach to wet-end drainage, retention, and formation technology

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ABSTRACT

The drive to improve sheet quality, increase paper machine productivity, and control rising furnish costs continues to escalate the demands placed on wet-end chemistries. Progress in one area often requires sacrifices in quality or performance in other important areas. This paper offers a new approach to wet-end drainage, retention, and formation technology that offers performance alternatives to this paradigm. This easy-to-use technology combines a cationic, high molecular weight dispersion or emulsion polymer and a modified lignosulfonate. The technology works in acid and alkaline papermaking conditions.

Application:

Laboratory and pilot paper machine data show the benefits of customizing a new wet-end drainage, retention, and formation technology.

THE ART OF PAPERMAKING OFTEN requires compromises of one benefit to gain more of another benefit. The use of single, high molecular weight polymer drainage and retention (D/R) aids on paper machines is one example of this paradigm. D/R aids have had decades of use as a technique to adjust stock freeness chemically for increased machine productivity and to improve the retention of various additives—particularly fillers *(1, 2)*. Figure 1 shows that these improvements in D/R unfortunately come at the expense of sheet formation. This is also a desirable quality. At low treatment dosages, however, one can realize significant improvements in drainage with a small loss in formation.

The problem with this situation is that significant reserves of potential drainage improvement and machine productivity remain untapped because of escalating fiber flocculation and the consequent loss of sheet formation. The key to improving D/R with minimal loss of formation is to find some means of associating filler, fines, and other additives with the fibers without having the fibers associate with each other. The lack of reaction site specificity of D/R aids makes uncoupling D/R and formation in this ideal situation impractical. There are consequently two practical choices for minimizing the loss of formation:

- Limit improvements in D/R by using low treatment dosages
- Moderate the increased tendency for fiber flocculation at higher dosages with applied shear.

The introduction of microparticle systems over the last 15 years to improve D/R in highly filled, wood-free, alkaline furnishes has changed this traditional paradigm *(3–5)*. Alkaline stock drainage and sheet formation are still inversely coupled, but the improvement in drainage provided by microparticle systems is sufficient to allow dilution of the headbox stock. Therefore, one may recover some expected loss in sheet formation with lower headbox consistency.

This paper reports a new drainage, retention, and formation (D/R/F) program using a synergistic combination of two, water-soluble products:

- A high molecular weight, cationic synthetic polymer
- A modified lignosulfonate.

The high molecular weight, cationic polymer may be an inverse emulsion product or a high solids, dispersed polymer product. The combination of the cationic polymer and modified lignosulfonate products provides improvements in acid and alkaline furnish drainage, retention, and sheet formation exceeding microparticle technology. It also provides flexibility to uncouple these parameters under specific conditions and permit independent improvements in each. This feature is particularly important for paper machines limited by fan pump capacity or line shaft speed.

Through laboratory and pilot paper machine studies, the author examines the impact of changes in controllable variables of this new program. This includes product dosages, ratios, and feed points on acid and alkaline furnish drainage, retentions, and sheet formation. The paper also compares the performance of the new D/R/F program with those of a single polymer, D/R aid, and a polymer and bentonite clay microparticle program.

EXPERIMENTAL

Laboratory test methods

Alkaline furnish preparation. All the laboratory tests used synthetic alkaline or acid furnishes prepared with the ingredients listed in Tables I and II, respectively.

Stock freeness test. Table III outlines the sample preparation and test procedure for measuring stock freeness or drainage rate under various simulated treatment conditions.

Handsheet formation test. A commercial sheet former produced the handsheets for formation testing from stock samples prepared using the procedure described in Table III for the stock freeness test. Measurement of sheet formation was in the transmittance mode using a commercial formation tester.

Pilot paper machine test conditions

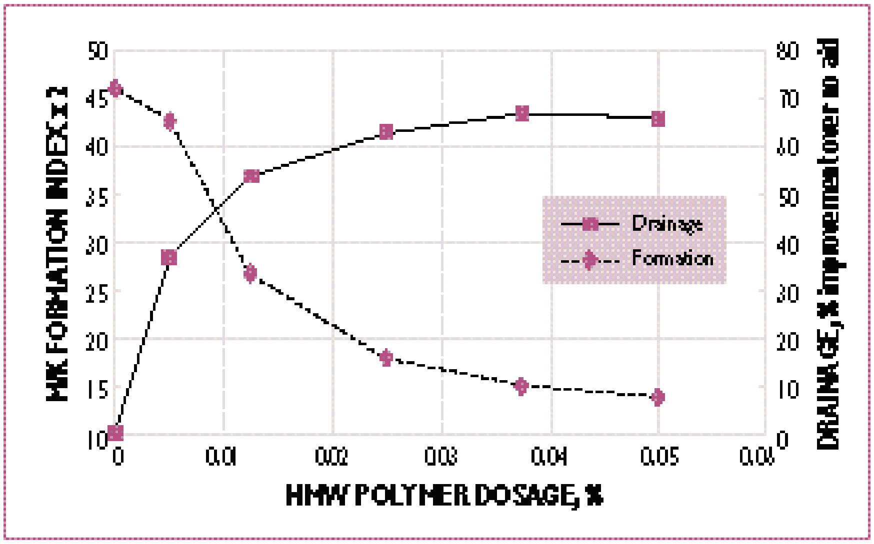
A series of experiments used acid and alkaline fine papermaking conditions on a high-speed, pilot paper machine. These experiments sought to test the predictive capabilities of the laboratory test methods and to compare the performance of the new D/R/F program to that of a cationic polymer D/R aid and polymer and bentonite clay microparticle technology for drainage, retentions, and sheet formation. Table IV describes the test conditions used for these pilot paper machine evaluations.

RESULTS AND DISCUSSION

Impact of chemical feed points and shear on alkaline furnish drainage in laboratory studies

The objective of this laboratory study was to determine the impact on alkaline pulp drainage performance of changes in feed location or applied shear for the high molecular weight (HMW) polymer and the modified lignosulfonate D/R/F aid. Using a range of paper mill approach system designs, the mixing times at 1200 rpm shown in Fig. 2 correspond approximately to post-screen (t = 0 s), pre-screen (t = 5–15 s), and pre-fan pump (t > 15 s) feed point locations. As Fig. 2 shows, subjecting the HMW polymer to increasing mixing time or shear has dramatically different effects on drainage when using this product with the modified lignosulfonate D/R/F aid than used alone. Increasing shear on a single-polymer D/R aid leads to a marked loss in drainage performance. For the new two-product D/R/F program, increasing shear on the HMW polymer component improves drainage performance.

In contrast, when the modified lignosulfonate component of the new two product approach is subjected to increasing mixing time or shear, Fig. 3 shows that drainage performance progressively worsens before finally flattening out.



1. Alkaline drainage vs. sheet formation for HMW polymer only with post-screen feed

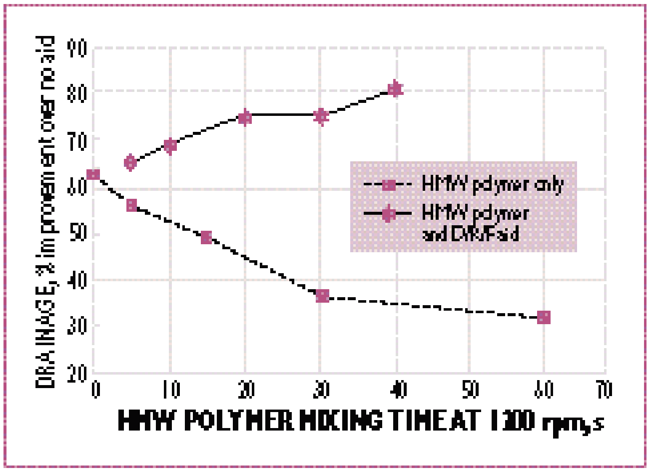
Fiber:	50/50 HWK/SWK refined to 350 mL Schopper-Riegler freeness
Filler:	Ground calcium carbonate (GCC)
Loading:	15%
Other additives:	0.5% cationic starch, 0.25% AKD size
Consistency:	0.7%
pH:	8.0

HWK = hardwood kraft
SWK = softwood kraft
AKD = alkyl ketene dimer

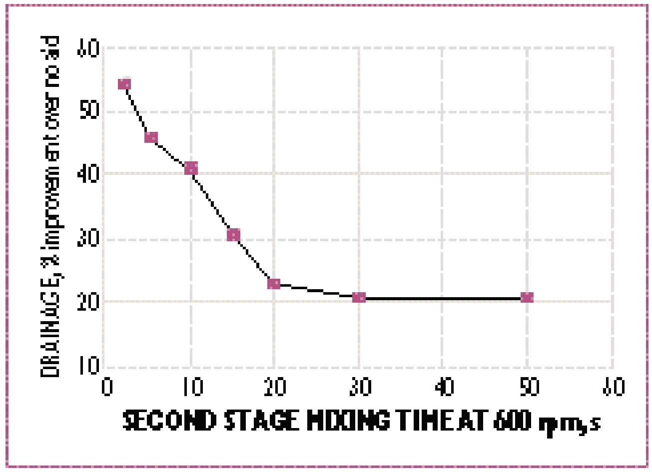
I. Synthetic alkaline furnish composition

Fiber:	50/50 HWK/SWK refined to 350 mL Schopper-Riegler freeness
Filler:	Kaolin clay
Loading:	15%
Other additives:	1% rosin size, 2% alum
Consistency:	0.7%
pH:	4.8

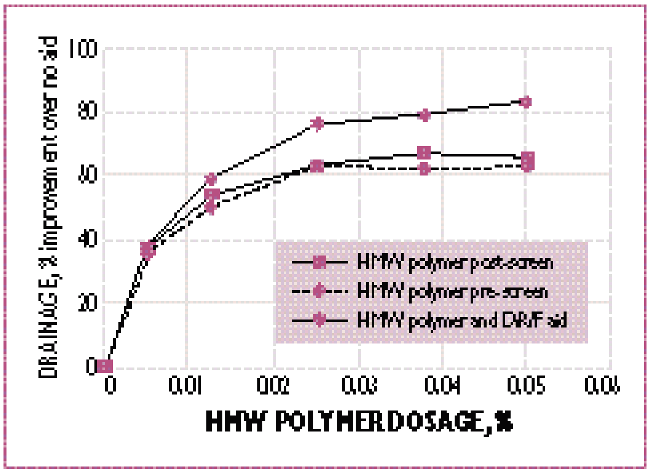
II. Synthetic acid furnish composition



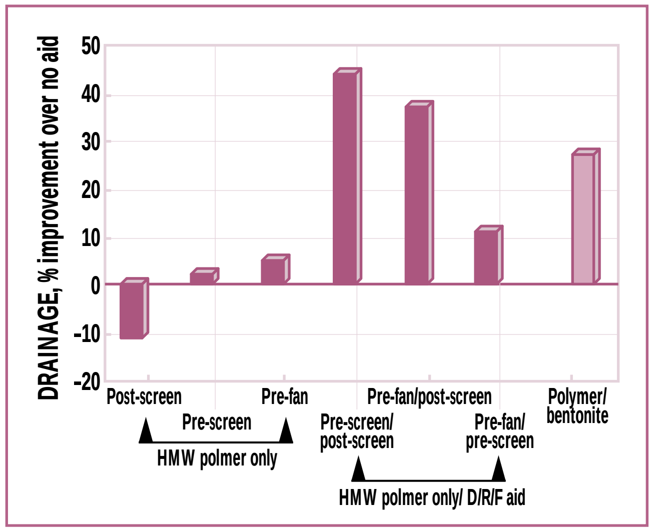
2. Effect of applied shear on alkaline drainage for 0.1% active HMW polymer with 0.05% active D/R/F aid



3. Effect of mixing time (shear) on D/R/F aid performance for 0.1% active polymer with 0.05% active D/R/F aid for alkaline drainage



4. Alkaline drainage vs. feed point and dosage



5. Alkaline drainage vs. feed point in pilot paper machine study

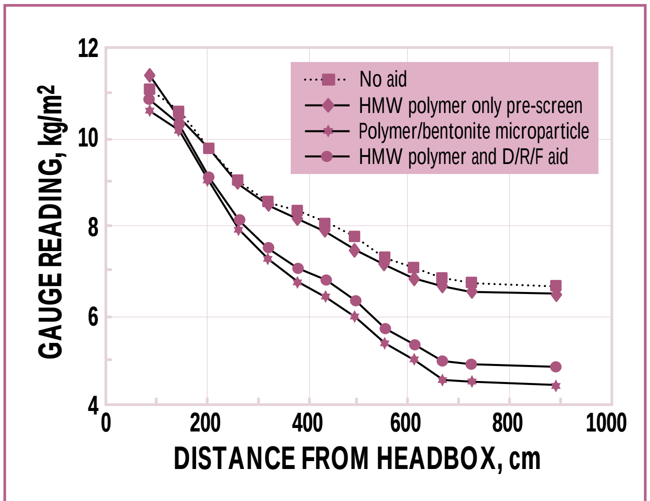
A 500 mL stock sample is transferred to a 1 L rectangular mixing jar equipped with a marine propeller stirrer and variable speed controller. The stock is then treated according to the following chemical addition, mixing time, and mixing speed sequence:

Mixing time, s	Simulated chemical feed point	Mixing speed, rpm	Comments
t_0	—	1200	Begin mixing stock
t_5	Pre-screen	1200	Add HMW polymer
t_{30}	—	600	Reduce mixing speed
t_{40}	Post-screen	600	Add D/R/F aid
t_{60}	—	—	Stop stirring

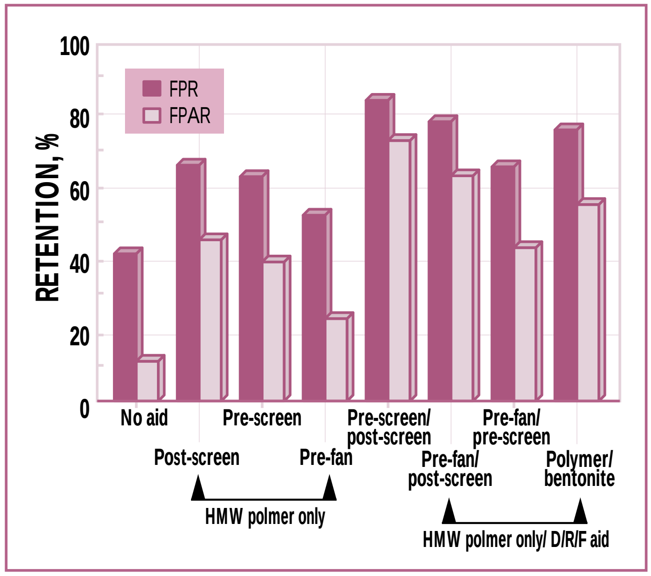
Transfer the stock sample to a 500 mL drainage tube fitted at one end with a 100 mesh screen and rubber stopper. Invert the drain tube five times. Open the bottom plug and measure the drainage rate as a function of elution volume.

III. Laboratory sample preparation for drainage test procedure

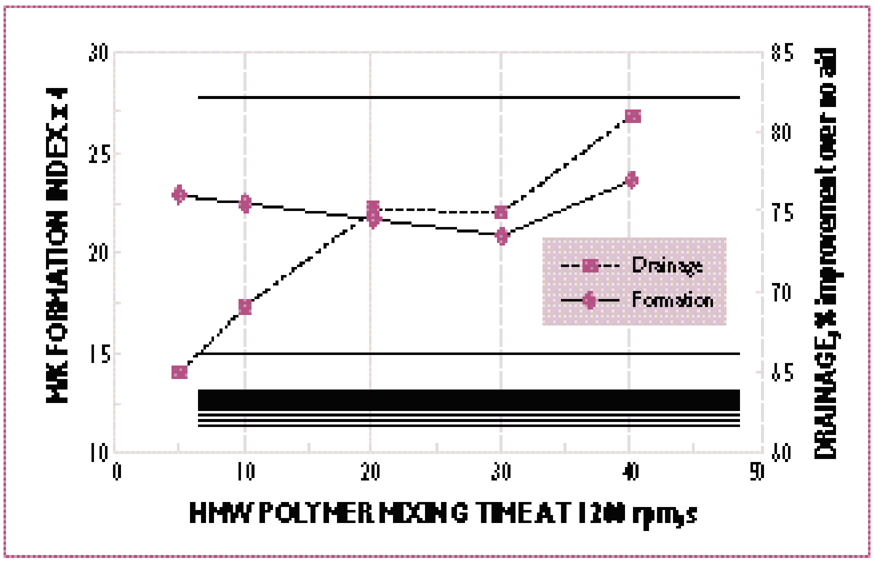
One may manipulate alkaline drainage performance with the new two product D/R/F program to the desired degree by adjusting the amount of shear to which each component is subjected. For best drainage performance, the HMW polymer component should be fed to the outlet of the fan pump. The modified lignosulfonate D/R/F aid should be fed between the outlet of the pressure screen and the headbox. Figure 4 shows the alkaline drainage performance of the new two product D/R/F program compared to post-screen and pre-screen



6. *Alkaline drainage profiles for pilot paper machine showing fourdrinier drainage measurements with NDC Gamma Gauge*



7. *Alkaline retentions vs. feed point in pilot paper machine study*

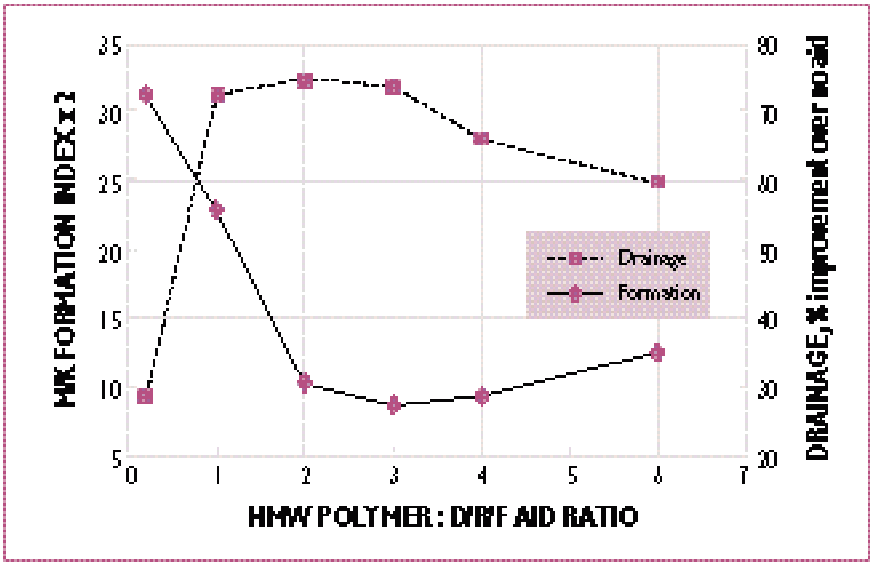


8. *Uncoupling drainage and formation with shear for 0.1% active HMW polymer with 0.05% active D/R/F aid*

feeds of a cationic polymer D/R aid. The improvement in drainage performance with the new two product approach really begins to take effect at an active product dosage of 0.0125%. The greatest differential occurs at dosages of 0.025% and higher.

Alkaline furnish drainage in pilot paper machine studies. The impact of changes in chemical feed points or applied shear on the pilot paper machine drainage differed from predictions based on the laboratory test data. Figure 5 shows that moving the single-polymer D/R aid feed point from post-screen to pre-screen to pre-fan locations increased drainage. Although this unexpected result is contrary to practical experience on commercial paper machines, it is possible to explain it. Drainage performance depends on thorough distribution of the D/R aid through the stock. With the short mixing times and lower degree of applied shear produced on a small machine, there was less mixing energy imposed on the very high molecular polymer used in this study than expected. For the new two-product D/R/F program, drainage performance decreased with increasing shear on the HMW polymer component. As predicted by the laboratory data, increasing shear on the modified lignosulfonate D/R/F aid did lead to a loss in drainage performance.

Even with this mixing energy limitation, however, Fig. 6 shows that the new D/R/F program outperformed the single-polymer D/R aid and the polymer and bentonite clay microparticle program in alkaline fine paper drainage.



9. Uncoupling drainage and formation by product ratio with total dosage constant at 0.15% active

Paper machine configuration:	Pilot fourdrinier equipped with a Bel Bond CB unit, Concept IV-MH headbox, Tri-Vent with fourth press section
Clothing:	Top Wire: Appleton #1156, 152 X 133, 448 ft^3/min Bottom Wire: Appleton #1076, 162 X 125, 392 ft^3/min
Speed:	3000 ft/min
Grade:	60 g/m^2 alkaline fine paper
Alkaline Furnish 1:	
Fiber:	75% HWK, Riverdale (Alabama), 450 mL CSF 25% SWK, Albacel (Eastern White Pine), 500 mL CSF
Filler:	GCC
Loading:	20%
pH:	7.2 ± 0.2
Alkaline Furnish 2:	
Fiber:	60% HWK, Riverdale 20% SWK, Albacel 20% Recycle fiber, Ponderosa post consumer waste
Filler:	GCC
Loading:	20%
pH:	7.2 ± 0.2
Acid Furnish:	
Fiber:	60% HWK, Riverdale 20% SWK, Albacel 20% Recycle fiber, Ponderosa post consumer waste
Filler:	Kaolin clay
Loading:	20%
pH:	5.0 ± 0.2
Other additives:	0.75% alum (thick stock addition)
Chemical feed points:	
Cationic polymer D/R aid:	Post-screen, pre-screen, pre-fan, as indicated
New D/R/F program:	HMW Polymer: Pre-screen, pre-fan Modified lignosulfonate: Post-screen
Polymer and bentonite microparticle:	Polymer: Pre-fan Bentonite clay: Post-screen

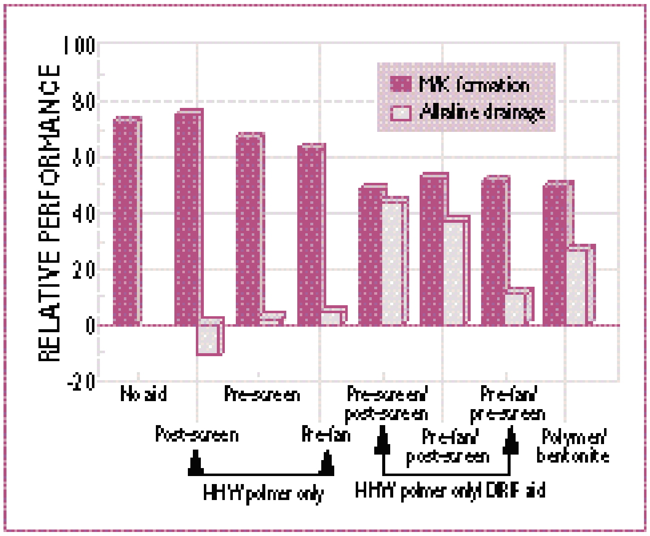
IV. Pilot paper machine test conditions

Total and filler retentions in pilot paper machine studies. In contrast to the drainage results, Fig. 7 shows that total first pass retention (FPR) and filler first pass ash retention (FPAR) on the pilot paper machine varied as expected in response to changes in applied shear. For the single-polymer D/R aid, both FPR and FPAR decreased with increasing shear on the polymer. The same general trend also held for the new two product D/R/F program, although retentions were again significantly better than the single-polymer D/R aid or the polymer and bentonite clay microparticle program.

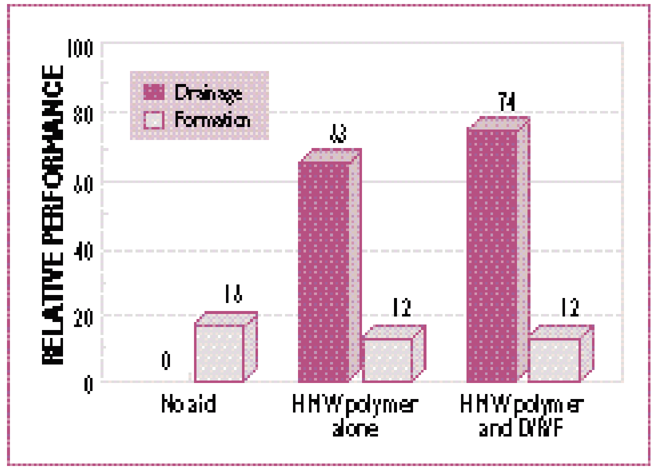
Uncoupling drainage and sheet formation

In many fine paper applications, D/R and sheet formation are inversely coupled. Under laboratory test conditions, however, this author found it possible with the new two-product program to uncouple these parameters and allow independent manipulation. The experimental conditions under which this phenomenon occurs are functions of applied shear and the ratio of HMW polymer to modified lignosulfonate with D/R/F aid.

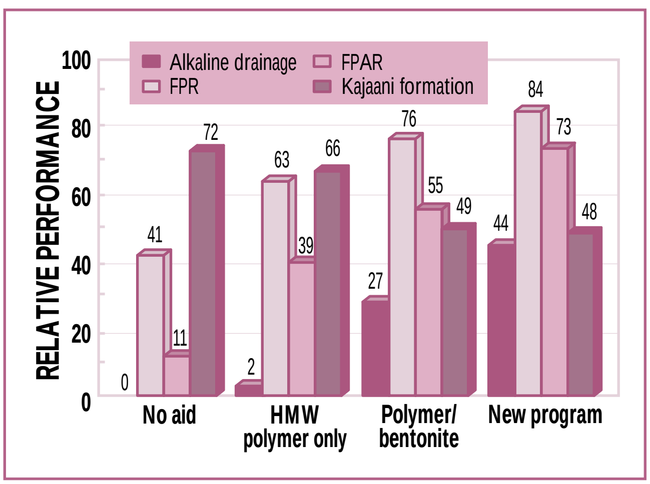
As Fig. 8 shows, increasing shear applied to the HMW polymer component improves drainage performance by 15% while maintaining sheet formation. Figure 9 shows that under constant applied shear conditions it is also possible to manipulate drainage and formation independently through changes in product ratio. In this lab study, optimum drainage performance occurred between 1:1 and 3:1 active product ratio of HMW polymer to D/R/F aid. At active product ratios of 2:1 and higher, drainage and sheet formation are coupled. Here an increase in drainage yields a corresponding loss of formation. At a 1:1 active product ratio, however, drainage and sheet formation become uncoupled. It



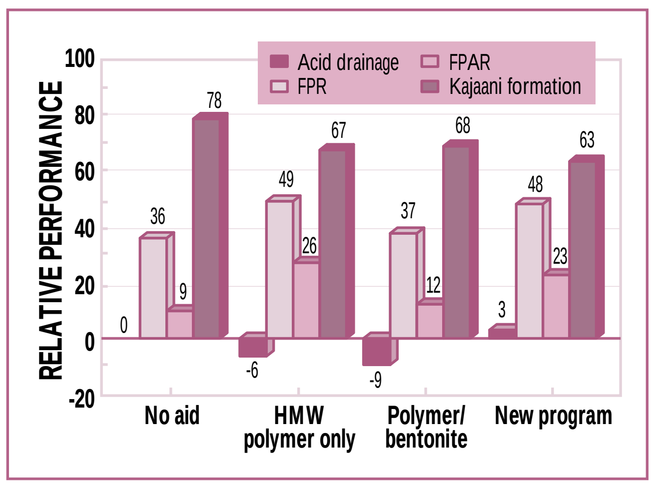
10. *Uncoupling alkaline drainage and formation in pilot paper machine study*



11. *Acid furnish drainage and formation in laboratory study for 0.1% HMW polymer with 0.05% D/R/F aid*



12. *Pilot paper machine study showing comparison of alkaline D/R/F treatment programs with drainage shown as percentage improvement over no aid*



13. *Pilot paper machine study showing comparison of acid D/R/F treatment program with drainage shown as percentage improvement over no aid*

KEYWORDS

Additives, drainage aids, formation, lignosulfonates, particles, polymers, retention aids, sufonates, wet end additives.

then becomes possible to increase sheet formation significantly compared to the 2:1 active product ratio while maintaining the optimum drainage rate.

In the pilot paper machine studies, the coupling of drainage and formation for the single-polymer D/R aid and the new two-product program at a 2:1 active product ratio is evident in Fig. 10. At a 1:1 active product ratio, however, it was possible to uncouple D/R from sheet formation at a higher total product dosage as Table V indicates.

Impact of recycled fiber on performance

This study examined the impact of recycled fiber from post-consumer waste on the new D/R/F program under the alkaline conditions on the pilot paper machine. All the other machine and chemical treatment parameters remained constant. As Table VI shows, this dramatic change in fiber source had a small impact on D/R/F.

Product ratio*	Dosage, lb/ton	Kajaani formation	Drainage**	FPR, %	FPAR, %
2	3	47.2	37	83	71
1	3	51.4	40	81	65
1	1	51.6	21	65	39
4	1	53.0	19	68	44

*HMW polymer with modified lignosulfonate
**Drainage shown as percentage improvement over no aid

V. Uncoupling drainage/retention and sheet formation

Product ratio*	Recycled fiber, %	Drainage**	FPR, %	FPAR, %	Kajaani formation
2	0	44	84	73	47.9
2	20	37	83	71	47.2

*HMW polymer with modified lignosulfonate
**Drainage shown as percentage improvement over no acid

VI. Impact of recycled fiber on performance

Impact of acid fine paper conditions on performance

This work also explored the impact of acid papermaking conditions on the effectiveness of the new D/R/F program. Laboratory testing used a synthetic acid furnish. As Fig. 11 shows, the new program provided significant improvement in drainage over the cationic polymer D/R aid at comparable sheet formation.

Alkaline and acid furnish D/R/F performance comparisons

Figures 12 and 13 show graphical comparisons of D/R/F performance data for the new HMW polymer with modified lignosulfonate program, a cationic polymer D/R aid, and the polymer and bentonite clay microparticle program. These figures use data generated in pilot paper machine studies conducted with the alkaline and acid furnish conditions shown in Table IV.

Under alkaline papermaking conditions, the new program clearly provides significant improvements in drainage, FPR, and FPAR over the polymer and bentonite clay microparticle program at comparable formation. The single-polymer treatment fed pre-screen provided better formation, although it was at a lower drainage rate than the other treatment programs.

Under acid papermaking conditions, the new HMW polymer with modified lignosulfonate program improved drainage over the pre-screen feed of the single-polymer D/R aid and provided significant gains in FPR and FPAR over the polymer and bentonite microparticle program. Sheet formations with these treatments were roughly comparable.

CONCLUSIONS

This report discusses a new D/R/F program using the combination of two water-soluble products. One is a cationic, high molecular weight polymer, and the other is a modified lignosulfonate. This new program is effective under alkaline and acid papermaking conditions. In pilot paper machine studies, this new program has shown significant performance advantages in D/R over conventional single-polymer D/R aids and a polymer and bentonite clay microparticle program. By manipulating product dosages, product ratios, and feed points (applied shear), it is possible to uncouple alkaline pulp drainage and formation with this program and permit independent improvements in each. TJ

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Received for review Nov. 29, 1995.

Accepted March 19, 1996.

Presented at the TAPPI 1996 Papermakers Conference.

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