Crepe Adhesive Modifiers Improve Tissue Runnability, Product Quality

Under today's low sheet moisture and high temp conditions, use of modifier chemistry in a tissue crepe coating package can slow adhesive hardening, greatly expanding its useful life.

— By Greg Rose

Tissue creping is defined as the controlled breakdown of fiber-to-fiber bonds by impingement of a high-velocity traveling web onto a stationary doctor blade. Creping continues to be the preferred way to create the soft absorbent tissue sheet that consumers desire.

The differences in base sheet properties between an uncreped and well-creped sheet off of a Yankee dryer can be dramatic. A comparative example of typical properties is given in Table 1 for a thru-air-dried (TAD) base sheet before embossing. Note the significant differences in water absorption and hand feel values.

PROPERTIES	FLAT SHEET (NO CREPE)	CREPED SHEET
GMT/BW*	20	10
Bulk	2.3	3.2
MD Stretch	4.0	20.0
Water Absorbency (g/g)	4.0	10.1
Handfeel (Quality)	25	80

*MD Tensile *CD tensile/Basis Weight

Table 1. Comparison of TAD Base Sheet Properties (29 g/m2 Bath Tissue).

CONDITIONS	1984	2004
PM Width	2 - 3 m	3 - 7 m
Reel Speed	800 - 1000 m/min	1000 – 1500 m/min
Speed Difference (Yankee - Reel)	100 - 200 m/min	150 - 300 m/min
Crepe Moistures (Betu Gage)	4% - 7%	1.5% - 5.0%
Sheet Temperatures, °C	90° -110°	100° –160°

Table 2. Typical Tissue Machine Conditions, 1984 versus 2004.

Unfortunately, as every papermaker operating a tissue machine knows, creping is the source of many runnability problems. It is where most sheet breaks occur, and is the amplifier for any wet-end or on-machine problem.

Furthermore, demands put on a successful creping program grow each year. Robustness of the chemical coating package and mechanical requirements of the Yankee and doctor blade system are being tested as never before. State-of-the-art tissue production making high quality brands of bath, facial, hankies, and kitchen towels has changed considerably during the past 20 years, as shown in Table 2.

Tissue machines are wider on average, and run considerably faster. The base sheet being produced today tends to be weaker, softer, have more short fiber, and creped at higher heat conditions, than it once was. The average speed difference between the Yankee and reel has increased more than 50% as the need for very high stretch products has grown. All of these changes make it more difficult to maintain acceptable runnability at the crepe blade.

Crepe Coating Formulations

Most tissue machines making product for the high-end consumer quality market utilize a chemical coating package for their Yankee creping. These coating formulations are the key to balancing the dual goals of high quality while maintaining good runnability.

The crepe coating provides necessary tack adhesion to the dryer surface. Essentially, it functions as a type of water-based pressure sensitive adhesive. The coating must transfer the sheet from the felt or fabric onto the Yankee at the press roll, hold it onto the dryer sufficiently to be decelerated into the crepe blade, then allow it to release cleanly from the crepe blade—all in about one second or less.

There is a wide variety of coating formulations practiced today, and these tend to be proprietary in nature. They generally consist of a crepe adhesive and usually a crepe release or modifier. Crepe adhesives are typically formulated with water-soluble or water dispersible polymers such as polyvinyl alcohol (PVOH), polyaminoamide-epi (PAE) being predominate, with occasional use of such materials as polyacrylamides (PAM), carboxymethyl cellulose (CMC), and polyvinyl acetate (PVAC).

Historically, most of the research focus from both chemical suppliers and tissue producers has been on development of the crepe adhesive part of the coating formula. Far less thought has gone into the crepe release component of the recipe. The release component, whether it comes directly as part of the spray boom coating or indirectly from a fabric release or tissue softener added prior to the Yankee, provides an extra control tool. The release is used to determine the sheet tension and stretch, lubricate the blade/dryer interface, and optimize sheet properties such as caliper.

EFFECT	OIL-BASED RELEASE	WATER-BASED MODIFIER
Softening of the Crepe Adhesive	No	Yes
Reduce Blade Wear	Yes	Yes
Reduction in Dust and Static	Slight	Moderate
Effect on Sheet Water Absorption Properties	Generally reduces both rate and capacity	Variable – can sometimes improve
Tactile Hand Feel Improvement	None to slight	Generally improves
Typical add-on rates	0.1 – 0.4 kg/ton	0.3 - 1.5 kg/ton

Table 3. Comparison of Crepe Release and Modifiers.

Crepe Release *versus* Modifier Chemistry

Crepe release chemistry can be broadly divided into crepe "release" products and a term used more frequently of late, crepe "modifiers." The traditional release products are oil-based. The majority of the composition (50% to 95% w/w) is some type of water insoluble oil, either petroleum or vegetable derived.

Because these oils need to be water dispersible, a surfactant emulsifier package is added. Wide varieties of surfactants are used, mostly non-ionic type, with lesser amounts of cationic and anionic surfactants utilized. The oil-based releases have been used since the start of creping. They are a widely used, low cost way to control machine runnability, provide dryer/blade lubrication, and optimize sheet properties. For practically all commercial away-from-home (AFH) and many consumer tissue grades, the oil-based crepe release works well and is the product of choice.

Crepe modifiers are evolving from the traditional crepe releases, as creping requirements become more demanding. Modifiers perform a similar function to releases in controlling runnability and quality, but there are some key differences that set them apart and make them the product class of choice for many of the newer tissue making technologies.

A comparison of crepe release and modifiers is given in Table 3. The most important difference between them is that modifiers do just that—they chemically modify or interact with the crepe coating on the hot dryer while releases do not. Modifiers alter the mechanical properties of the crepe adhesive and become part of the polymer. The oil-based releases have no to very little effect on the resident crepe adhesive film.

Table 4 shows how coating film properties are impacted by the addition of modifiers.

Figure 1 is a schematic diagram comparing the mode of action of releases versus modifiers. This representation is somewhat simplified, but shows what happens to the coating film as the add-on levels are increased. The salient point is that modifiers will form primarily a single discrete water miscible phase while the release forms two to three distinct phases. Thus, the mode of action of how releases and modifiers function in the coating is quite different.

COATING FILM PROPERTIES	CURE TIME @ 140°C (hrs.)			
Adhesive Only (low x-link PAE)	**0**	**1**	**2**	**4**
% Insolubility	32	50	62	70
Tack Adhesive [1]	4	2	1	0
Hardness [2]	6	7	8	>8
Adhesive (+ 20% Modifier)				
% Insolubility	30	37	47	55
Tack Adhesive	4	3	2	1
Hardness	6	6	7	7

[1] Tack Adhesive: Scale 0 – 5 (0 has no tack, 5 is totally tacky).
[2] Hardness: Pencil harness scale 0–8 (0 is dead soft, 8 is very hard).

Table 4. Effect on Coating Film Properties by Addition of Modifier.

As release is added to the coating, most of it floats to the top of the coating layer, acting as a boundary lubricant. With increasing add-on, the emulsified release starts to surround pockets of the adhesive and disrupt the continuous adhesive film. Now, with a modifier added, it combines with the adhesive to significantly alter it. With continued modifier added, depending on the specific formula, eventually a saturation point will be reached and the excess modifier will form a second phase similar to an oil-based release.

Figure 1. Schematic cross section of coating layer.

Unlike releases, modifiers influence the Yankee coating in two positive ways. The modifier may act as a polymer plasticizer for the coating adhesive. As such, it can drastically change the properties of the adhesive film. A plasticizer is chemically bound with the polymer. It lowers the glass transition, hardness, and increases water absorption capacity of the adhesive film.

Crepe Modifier Options

There are a wide variety of candidate modifier chemistries. These can be used as single component products, or formulated with multiple components into a product tailored towards a specific grade or machine.

Crepe modifiers must possess some degree of solid solution miscibility with the crepe adhesive polymer(s). They should be heat stable and have low vapor pressure at typical dryer temperatures. Furthermore, modifiers must have minimal potential toxicity for obvious reasons. Some possible modifier options include various simple and poly glycols, ether glycols, and ester glycols, certain phosphates and phosphonates, tertiary and quaternary nitrogen compounds, lower carbohydrates, and oligomers of polyamines and polyamidamines.

Unfortunately on the hot dryer surface, bad things happen to good coatings. Over time and with heat, most coatings eventually change chemically into the familiar insoluble "baked-on" coating (in appearance). Generally, once this occurs the only way to remove what has become a hard brittle layer with little remaining tack adhesive is to strip it off the surface with a new crepe or cleaning blade. However, use of the correct crepe modifier can greatly slow this process.

One way to simulate this in the lab is to measure the extent of polymer insolubilities. To function as an effective crepe adhesive, there must be a balance between that portion of coating that remains soluble/dispersible and can absorb water to remain a tacky resin and that portion that is insoluble and forms the base coat at the dryer interface. By determining the ratio of soluble to insoluble coating, in concert with other simple adhesive tack and hardness tests, a reasonable lab screening procedure can be established.

These tests can be run at different times and temperatures to mimic crepe conditions on the dryer. Typical conditions for most dry crepe and thru-dried applications might vary from a surface temperature of 100°C to 170°C and a duration of 15 min to 4 hours. Of course, any and all lab crepe tests are limited by being static in nature, whereas the actual crepe conditions on the machine are very dynamic and constantly in equilibrium between that coating added on each dryer revolution versus that stripped away by the blade.

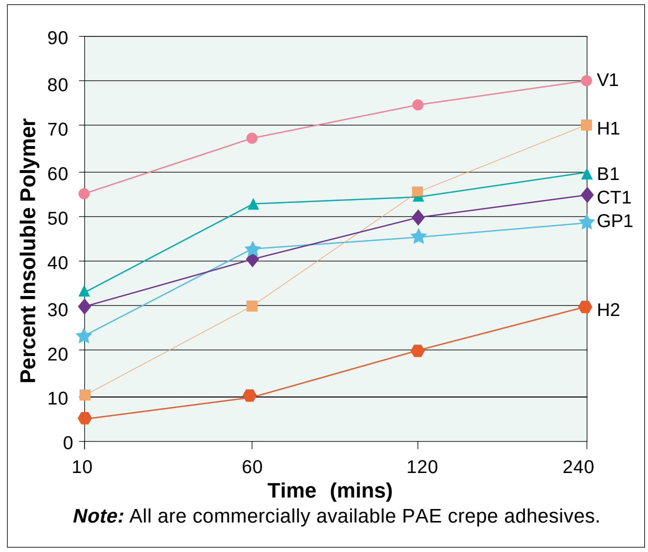

Figure 2. Crepe Adhesive Insolubility as a function of Time.

Figure 2 compares several commercially available crepe adhesives in terms of their respective insolubilization properties as a function of temperature. As seen, there is considerable variation in the extent of insolubilization (cross-linking) of the various products tested. Also, note the wide variation in the rate of change of each.

Products that have the largest rate of change are thought to be reacting in-situ on the dryer surface, while those with less rate of change fall into the category of polymers sometimes called the "dead-cat" adhesives. These products tend to be partially cross-linked in the drum and prior to applying in the Yankee. All of the products tested undergo some level of insolubilization with prolonged time/temperature exposure. Any suitable chemical modifier that can slow the rate of the reaction would benefit the coating since it extends the open-time or useful life of the polymer adhesive on the dryer surface.

The tendency to become insoluble depends on both exposure time and dryer surface temperature. Figure 3 plots the percent insolubilization as a function of temperature of a typical commercially available PAE-type of crepe adhesive with either an oil release or water-based modifier added. Note that the release material has no benefit in preventing the polymer from becoming insoluble, while the modifier has a definite positive impact on the reducing extent of insolubilization. The modifier reduced the degree of insolubilization by nearly 50% at 350°F (170°C).

These data show that there is definite applicability in utilizing a crepe modifier strategy, especially in applications exposed to the higher than normal creping temperatures, such as in high dryness crescent former and thus–dried tissue machines.

PM Applications

Real world paper machine comparisons of a traditional oil release and a water-based modifier have been carried out on pilot machines and one commercial tissue machine. In general, the runnability of the water-based modifier has been very good and equal to or better than when using the oil release.

Somewhat surprising has been the fact that blade wear tends to be lower with the modifiers, despite no lubricating oil being present. Sheet handling properties are far less sensitive to modifier add-on rates compared with oil releases. One drawback, however, is that total add-on levels of the water-based modifiers are two to three times greater than an oil release.

Figure 4 compares base sheet properties generated using an oil release versus a water-based modifier for MD stretch at different crepe moistures, and Figure 5 for panel hand feel. By use of a modifier, higher MD stretch and hand feel were obtained. In addition, the modifier has a broader working range compared with the oil release, as a function of add-on ratios.

Why the modifier usage gives better properties is not certain, but the best guess is that it is able to keep the crepe adhesive in the "open" or tacky phase longer. This leads to a softer coating into which the crepe blade can work more effectively. Also, the modified coating tends to build a less thick layer on the dryer and has better heat transfer properties.

Summary

With the continued trend towards creping at very low sheet moisture and increasing temperatures, the need to slow the rate of crepe adhesive hardening becomes more necessary. The addition of modifier chemistry to the coating package is one way to accomplish this. Unlike the traditional oil-based crepe release, a properly chosen crepe modifier formulation can greatly improve the useful life of any of the commonly used crepe adhesives.

In most cases, the benefits of additional control tools to better optimize the runnability needs of the papermaker and quality issues of the consumer far outweigh the added chemical cost and feed equipment requirements to implement a crepe modifier system. As with most things in the tissue paper world, the true proof of the applicability of adding or replacing a chemical on the paper machine depends on a successful long-term trial evaluation. Any mill practicing state-of-the-art Yankee dryer crepe making in the production of high quality, lightweight, tissue at low sheet moistures and at high speed should consider this approach.

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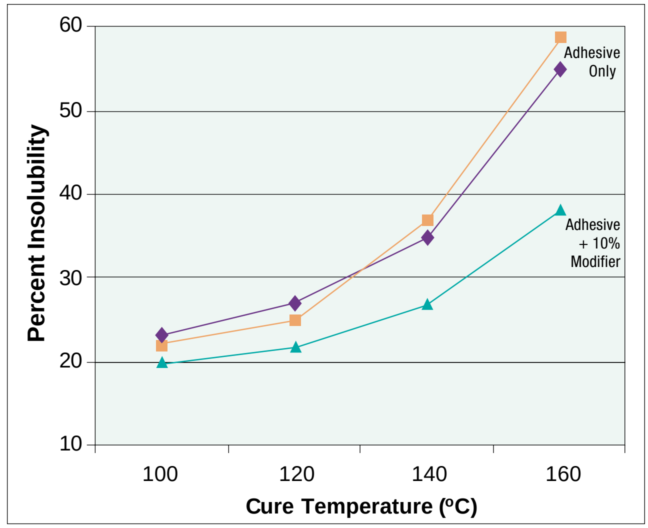

Figure 3. Percent Insolubility of Crepe Adhesive as a Function of Temperature.

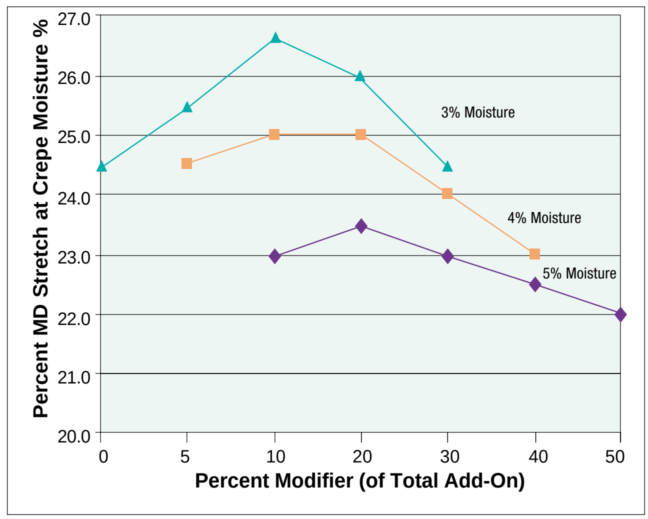

Figure 4. MD Stretch at Different Crepe Moistures as a Function of Modifier Addition.

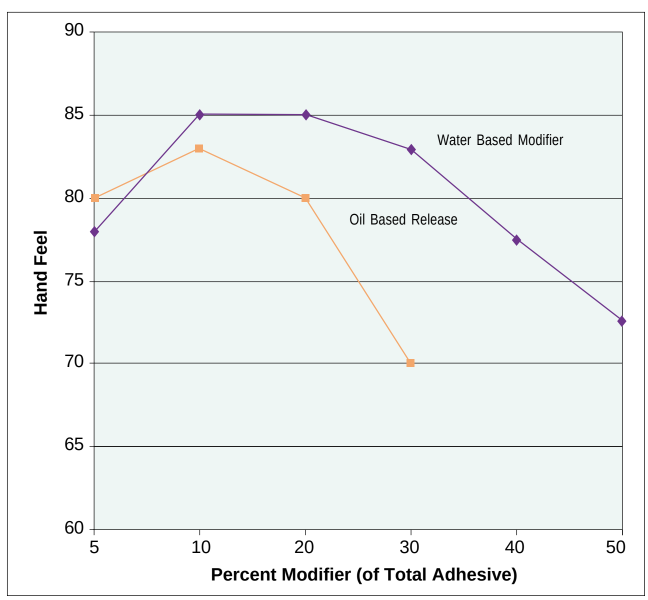

Figure 5. Hand Feel Quality with Oil and Water Based Crepe Release/Modifiers