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ADVANCED ADHESIVES REPORT

Your corrugating newsletter from Harper/Love Adhesives Corporation

Rheology vs. viscosity

It takes more than a thickening agent to improve adhesive performance with lower solids

By John Kohl

The most common measurements for corrugating adhesive are the viscosity and its corresponding temperature. Viscosity of any liquid is defined as a measurement of the fluid's resistance to flow. Starch viscosity is measured with either a Stein-Hall cup or a Love cup and is simply a measure of the time for a fixed amount of adhesive to pass through an opening in the bottom of the cup.

Viscosity of starch adhesive is easily altered by varying the amount of carrier starch or water used in the formula. In a box plant, viscosity is determined by the needs of the machine due to the glue rolls and the rate they pick up and transfer starch to the medium. The higher the starch viscosity, the higher the end application rate is on the combined board due to the film thickness being carried on the glue roll.

Rheology modifier—really?

A current buzz word in the corrugating starch adhesive industry is *rheology modifier*. In order to understand what is being modified, we first must understand what rheology is and how it pertains to starch based corrugating adhesives. Rheology is not a measure of viscosity but an area of physics focused on the study of a substance's change in flow characteristics under applied stress or force. The term *rheology modifier* is being used erroneously to refer to chemicals that modify the viscosity of any material. They are also known as thickening agents.

The carrier starch used in an adhesive can be considered a thickening agent, since increased amounts of starch in the carrier portion of an adhesive increase viscosity. The amount of carrier also controls water holdout to keep water in the glue line so it is available for proper gelatinization of the raw starch during bonding. The borax used in the adhesive also gives some additional viscosity but primarily improves adhesive tackiness for proper pickup on the glue roll and transfer to the flute tips.

Rheology is not a measure of viscosity but an area of physics dealing with the change in flow characteristics of a substance under applied stress or force.

In the science of rheology, a fluid's changes are measured when there are actual forces (mechanical shear or pump pressure) induced. This is not simply resistance to flow, as in viscosity measurement. There are two basic types of fluids, Newtonian and non-Newtonian. Newtonian fluids are those, such as water and oil, that follow the basic laws of physics and always act as liquids regardless of the forces acting on them. Non-Newtonian fluids are those that are shear thinning or leave a hole in them when stirred like pudding. The shear stress is measured with a Brookfield viscometer and the unit used is centipoise (cps).

Starch adhesive is a non-Newtonian fluid

Starch adhesive is an interesting fluid that is often studied since it is classified as a non-Newtonian fluid: it changes under pressure or induced stress. The forces that starch adhesive has to deal with occur during mixing, pumping, and application on the corrugator. Its viscosity drops when stirred but when agitation stops viscosity goes back up. It also gets thick quickly when there is enough force applied to it as in the nip between the glue roll and metering rolls. This rapid rise in viscosity in the nip of the glue mechanism causes the amount of adhesive being applied to increase as speed on the corrugator increase. This phenomenon has led to the development of automatic glue gaps that decrease with speed increase.

So if you are offered a *rheology modifier*, with claims to improve your starch adhesive *and* reduce your solids simultaneously, think it over. Remember, the only thing that can be accomplished with a thickening agent is to increase the adhesive viscosity. That can be accomplished by simply increasing the amount of carrier starch in the formula.

However, just thickening the adhesive will not improve bonding with lower solids. That requires a completely different chemistry.

Finessing the glue roll speed ratio

The goal is to adjust the speed ratio so the glue is deposited symmetrically on the crest of the flute tips.

By Rex Woodville-Price

Conventional wisdom says glue roll speed should be set at 98 percent of paper speed. Many OEMs recommend this number. This is a good starting point, but one that can certainly be optimized to accommodate the characteristics of the machine and the adhesive.

When I first came to the corrugating industry I wondered why it wouldn't make more sense to run at a one-to-one ratio, i.e., 100 percent. Why any speed differential at all? Well, not so fast (pun intended). We first have to understand the dynamic of adhesive pickup.

In operation, the surface of the glue roll is flooded with a thin film of adhesive. The tip of the flute is dipped in this film and dragged along the surface of the roll because the flute tip is traveling faster than the glue roll. This dragging action causes a small wave to build up on the leading edge of the flute tip. *The adhesive is sticky and has what some call tack—demonstrated by the tendency of adhesive to form a little string between your fingers when you pull them apart. When the flute tip and the glue roll separate, this tack causes the adhesive to be pulled backwards toward the center of the crest (photographs).*

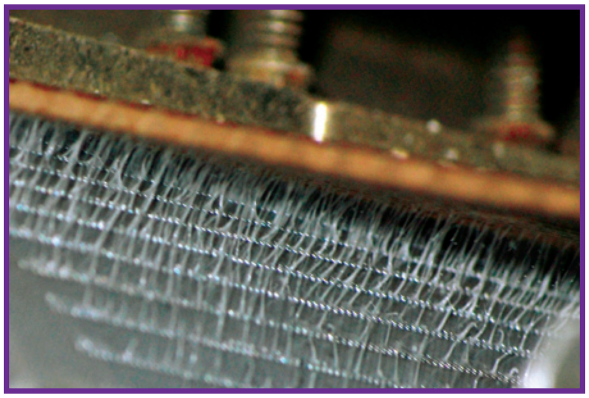
Put the adhesive where you need it

Adhesive must be applied where it will do the most good and that is on the crest of the flute tip, the place where the bond with the liner will occur. Adhesive anywhere else increases consumption and adds moisture but it does not improve bond strength. It can also cause washboarding and warp. (One exception to this rule is running wet strength board. Enough adhesive must be applied so that a small shoulder is built up on the sides of the bonded area, but in all cases the adhesive must be applied symmetrically to the flute tip.)

Machines are not all the same

There are several factors that affect the ideal glue roll to paper speed ratio. These can be divided into two categories: those intrinsic to the machine and those that are characteristics of the adhesive itself. Machine attributes such as the cell pattern of the glue roll will affect how much force is required to release the adhesive. A roll with large deep cells is going to behave differently than one with a sand blasted (or random pattern) surface. We must keep in mind that there is a different dynamic going on in a glue machine than a flexographic printer. In a flexo the applicator roll is wiped clean by a doctor blade and the only liquid (ink) left to transfer is that which remains in the cells.

In a glue machine, we don't wipe the roll clean, we run a metering roll in close proximity to the applicator roll and remove (meter off) some of the adhesive. However, a film of adhesive still remains on the surface of the roll, so we actually run the roll in a flooded condition. It is this film, the thickness of which is determined by the gap between the two rolls, plus some of the adhesive in cells, that gets transferred to flute tip.



Other features of the machine that affect adhesive transfer are:

- Angle that the paper exits the glue roll—for example the top station vs. the bottom station.
- Wrap—how many flutes contact the roll. With increased wrap, the flutes remain in contact with the glue roll (and the adhesive) longer, so they drag further and pick up more adhesive. The limit to this is when a flute tip drags so far forward that it now has contact with the area already wiped.

Make the adhesive suit the machine application

Aspects of the adhesive such as viscosity and tack affect how it transfers from the glue roll to the flute tip and subsequently onto the liner from the medium. Remember that adhesive is applied only to the medium by the glue mechanisms and is transferred from there onto the liner. It is these qualities of flow and transfer that will determine the ideal speed ratio. It is possible to tailor formulation to suit a specific machine application.

How can we tell how accurately our equipment is applying the adhesive? Iodine stained soaks are the ideal tool for determining adhesive placement. Look at the medium because that is where the adhesive is applied. Compare how the glue lines look when viewed from the front and from the back to see if application is uniform. Ultimately our goal is to adjust the speed ratio until a soak test shows that the glue is deposited symmetrically on the crest of the flute tip.

The low-solids breakthrough

New polymeric technology yields unprecedented cost and quality benefits

By Bill Kahn

Several years ago Harper/Love launched an R&D project in our Charlotte laboratory to understand more fully the bonding process as it relates to an adhesive formula with a lower level of total overall solids. This was driven partly by the rising costs of pearl starch due to the ethanol situation but also by the need for more definitive data and research in this area. In those days it appeared that the corrugated industry was enamored with the high-shear mixers and their ability to make starch-based formulae with a high solids content of around 30 percent.

We experimented with numerous types of starch as well as a large number of starch additives, both natural and synthetic. After a number of optimistic outcomes and a few failures we developed an additive that allows us the option to formulate adhesives in the field with solids ranging from 18 percent to 30+ percent. The polymeric additives employed in this approach contain no Volatile Organic Compounds (V.O.C.)

ADHESIVE SOLIDS COST ANALYSIS

	Current solids	Reduced solids
Corn	560 lbs	430 lbs
Water	1,375 lbs	1,375 lbs
% solids	28.9%	23.8%
Corn cost	$100.80*	$77.40*
Reduced solids saving		$23.40
Batches per day		20
Saving per month		$10,296
Saving per year		$123,552

*assuming corn starch at $0.18 per pound

Early in 2008 we began using this new technology and incorporated field testing that was required for such a controversial approach. One of the largest impediments was the general belief in our industry that high solids-low viscosity is the only path for success. In 2009, a new product, which is a blend of both natural and synthetic polymers, was ready to exit the lab for a controlled series of box plant trials.

Current adhesive technology now allows lower solids to outperform high solids

Harper/Love's technical team ran solids as low as 18 percent in one application with no degradation of board quality or top-end run speed. A more normal situation was solids level between 21 percent to 23 percent, with the machine running at its top rated speed on both lightweights and 56 lb liner. We have seen no change in the warp profile or flatness of the combined board. Additional improvements resulted in increased dry pin adhesion and higher combined-board moisture which helps reduce score cracking in colder climates.

These results were not limited to a particular flute or board combination. Flat E-flute was produced at speeds over 1000 fpm with adhesive solids of less than 22 percent.

As part of the experimental design, the Harper/Love research team was able to incorporate our success in developing five generations of bond-enhancers with the newest polymer technology. The result of this approach allowed reduction of starch adhesive solids and also helped to increase machine speeds and quality. The combined savings of a much lower dry pound consumption, as well as increased speed on heavyweight board, easily recovered the cost of the polymers and also provided the plant with a return on investment. These hard savings experienced by the plant, were in addition to savings from reduced warp, washboarding, and energy consumption.

Another significant attribute of the polymer technology was the ability to increase the glue line footprint while actually lowering the amount of starch consumed. In most cases the plant experienced a corresponding increase in both pin adhesion and fiber tear.

In our assessment with high-speed digital photography we observed that the polymer-based formula had less elasticity; it snapped back to the glue roll rather than create a stringy leg, which promotes slinging and overspray. This characteristic also allowed for exact placement of the adhesive directly in the center of the flute tip.

Optimal solids level is in the range of 21percent to 23 percent

As mentioned earlier we have pushed the limits on starch solids to operate in the ultra-low solids range of less than 20 percent. This level was achievable but our initial results predict the more effective and profitable payback comes from working in the 21percent to 23 percent solids range. At levels lower than 21 percent we saw no further improvement in quality attributes or strength of bond and felt the small amount of additional savings didn't justify the risk of bad board.

The versatility of the product we developed lets us approach the solids reduction from a very conservative position if that is what the customer requires. With the addition of the polymer technology, starch adhesive solids can be reduced initially by a percent or two and then fine-tuned over time to fit the actual mix of the individual plant. In the fine-tuning process, solids can be reduced by as little as one-half percent and the resulting board tested in the Harper/Love lab facility, while documenting at the machine that there is no loss of speed. This allows crews to become acclimated to the new levels without the shock of changing the levels all at once and upsetting the traditional benchmarks and centerlines.

Leaders in the science of making good adhesives better™

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