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Adhesive strategies for high-speed corrugating machines

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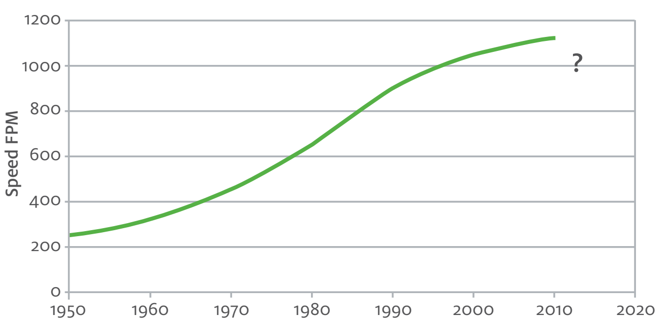
Adhesive strategies for high-speed corrugating machines

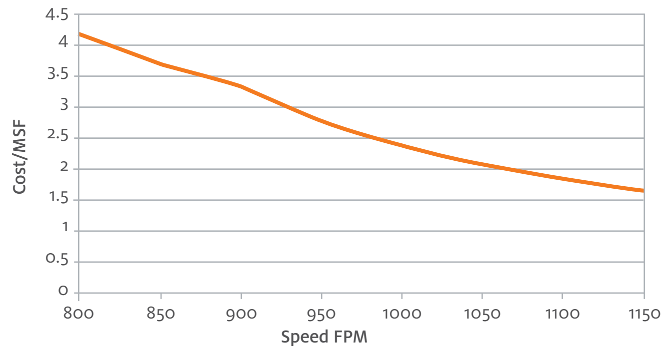
While corrugators continue to be designed to run at higher speeds, there are many variables that impact the ability to reach high or maximum speeds. Over the years, corrugators have continued to increase maximum speeds at a significant rate, however this exponential speed increase is tapering off. Even so, smaller corrugators, which would command efficiencies at 500-600 feet per minute a decade ago, are being pushed out of the market by new, wider machines running at tops speeds approaching 1200 fpm. These highly engineered machines operate under very precise and controlled conditions to meet these speed challenges, and they have changed the way boxes are made and valued.

FIGURE 1: Maximum Corrugator Speed



With each incremental increase in operating speed, additional factors and issues need to be considered. Details like order length or number of paper changes play into the determination of how fast the average running speed is compared to the maximum machine speed. At higher speeds, short orders also can require faster adjustment times and more critical controls of adhesive application and paper conditioning. Even slight errors in adhesive application can impact board performance, which can lead to higher levels of waste. Downtime also begins to play a bigger role on average speed. Proper maintenance, operation, and set up – much like a good pit crew at a race track – are critical to meeting daily performance targets. At stake are significant reductions in overhead (plant, equipment, personnel and utility costs), which impact the box plant's cost of board.

FIGURE 2: Overhead cost/MSF vs Corrugator Speed



When focusing strictly on the mechanics of the corrugator such as temperature, conditioning, adhesive application, contact, drying, the blade section and stacker, there are several rate limiting factors which have been explored and reported in detail that determine how fast a corrugator can actually run. For example, steam roll design was studied to determine the impact of rotation speed on condensate flow. The learnings resulted in new roll and syphon designs that avoid condensate rimming at high speeds. Tension control systems have been fine-tuned to handle the torque and stretch of higher speeds without tearing or unevenly stretching paper. Steam control systems have been improved to provide better control across hot plates and heated rolls. In addition, the design and precision of corrugating rolls have also been improved to the highest levels for these high speeds, reducing vibration, wear and defects. And rate limiting changes such as splices, knife adjustments, and wraps have become more efficient than ever. **One area that still has tremendous impact is adhesive make-down and application, and as machine speeds increase, the formulation and application of the adhesives needs to evolve as well.**

High-speed adhesive strategies

Some of the adhesive factors to consider when corrugating boxes include the bonding and drying time, application (consistency, slinging, surface penetration), water control (bond crystallization), total adhesive consumption, and bond performance. Certain factors can be controlled by typical formulation optimization, but others require additional optimization strategies.

Adhesive viscosity, tack and texture

Viscosity and tack can be controlled by several factors in the formulation. Viscosity can be adjusted to meet optimum machine and paper conditions by adjusting cooked starch solids, borax level, amount of shear or cook temperature, or with the use of performance additives. Likewise, the tack and texture (stringiness, film forming) of the adhesive can be controlled by adjusting the borax to caustic ratio, rheology modifiers or can be combined with viscosity adjustment. Care should be taken with texture adjustments as this could also affect adhesive slinging during application, or can result in poor adhesive pickup or brittle bonds. An important fact to note – higher solids does not necessarily mean higher viscosity – as both high solids and high viscosity can be formulated separately. Higher solids can add additional value on high-speed machines, as it is another means to control moisture added to the board.

Adhesive consumption and storage

Adhesive make-down systems have gotten smaller over time as systems were optimized to make adhesive fresh and on demand, limiting the amount of adhesive needed to be kept in storage. While this has significantly improved the quality of adhesive (fresher is better), it has in some instances affected the adhesive supply to machines that have been upgraded for higher speeds. Specifically, smaller mixers, 100 gallon and sometimes 200 gallon, can have trouble keeping up with sustained production speeds that are 1000 fpm and higher. Batches of adhesive take time to make, and factors like water and starch addition rate, heating time, and transfer to storage are difficult to change. Formulating adhesives to maximize the volume in each batch can make an incremental increase in available adhesive. To optimally improve adhesive availability, reducing adhesive application is a definite advantage. However, reducing adhesive application must be done in concert with maintaining bond quality, and typically will involve optimizing the properties of the adhesive, specifically tack, viscosity and film forming.

A secondary benefit comes from increasing adhesive solids in conjunction with application reduction. By moving the adhesive solids up from 26% to 30%, and simultaneously decreasing application from approximately 10 to 8 mil, total dry adhesive consumption on the machine can be held constant. Properly formulated, the bonded board can meet the same pin adhesion performance, but total volume of adhesive is reduced (meaning less batches per day are needed). As an added bonus, less water is added to the board from the adhesive, reducing dryer load to remove that water.

FIGURE 3: Consumption lb/MSF

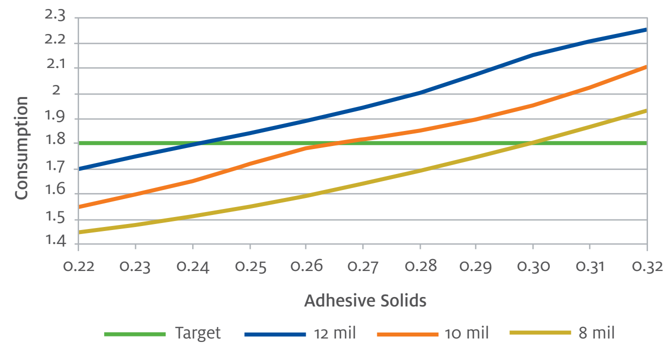
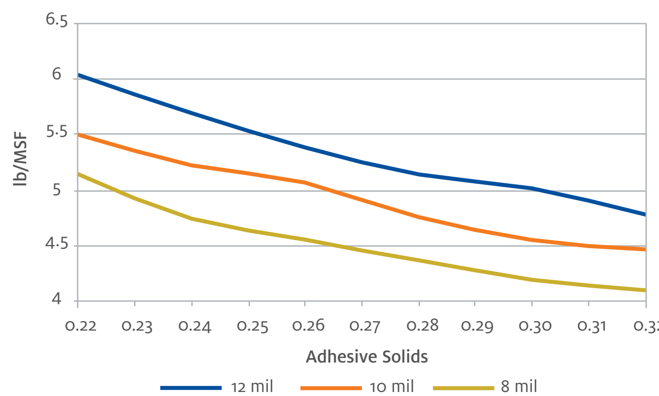


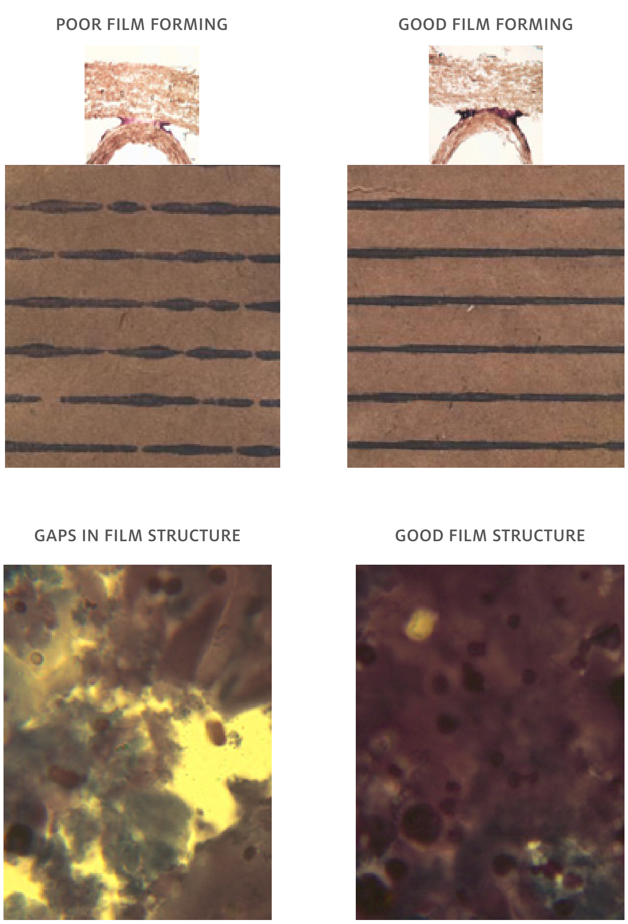
FIGURE 4: Water from Adhesive lb/MSF



Formulating at higher solids also relies heavily on proper conditioning and temperature control, both of the liners and medium, but also the hot plate section. Less water means less heat is needed on the machine, and in fact too much heat can lead to bond crystallization rather than proper gelling. Crystallized adhesive on the board will look good coming off the machine, but after curing will convert to brittle "Zipper bond", cracking and breaking easily as the board is flexed. A good measure for whether too much heat is applied is to examine the board as soon as it cools coming off the machine. Bend and break the board, specifically at the edges, where temperature problems are amplified, and look for over-dried and cracking/brittle medium. If the medium looks dried out, more than likely the glue line is as well, and the board may get rejected after storage.

In addition to proper adhesive formulation and machine temperature control, performance additives can be incorporated to protect and improve the adhesives under these taxing conditions. Higher cooked solids have been shown to improve water holding of adhesives to protect them against borderline high temperatures, which can flash moisture off too quickly. Carrier starches like Ingredion's STABLEBOND® modified starch have been used in high shear adhesives to enhance the water holding, specifically on light weight paper grades which are difficult to condition. On almost all grades, liquid performance additives like CORAGUM® PA-15, or the resin containing CORAGUM® PR-Flex have been used not only to improve the water holding of adhesives, but also to change the rheology and film-forming of the adhesive. Film forming is a crucial element that determines the cohesiveness of the adhesive, and how consistently it can be applied to the flute tips. As adhesive application is reduced, glue lines should be monitored by iodine staining to insure that consistent adhesive application is applied across the board. Otherwise, issues like delamination and blistering can arise, reducing board quality. Performance additives like CORAGUM® PA-15 polymeric resin or PR-Flex performance resin, which synergistically crosslink to starch in the adhesive, provide the improved texture and consistency needed for lighter application on a variety of board grades.

FIGURE 5: Film formation and structure



Machine velocity on adhesive

At higher machine speeds the bonding time of the adhesive significantly decreases. Temperature can also decrease as contact time between paper and heated rolls decreases, even with increased wrap. Fortunately, newer machines and denser paper can accommodate lower temperatures, specifically when adhesive application is reduced. However, contact time in the pressure roll or belts on the singleface, and in the hot plate section go down as speed increases. As a result, the adhesive will need to bond faster to avoid wet, incomplete bonds (white glue lines). Previously the strategy was to lower the gel temp of the adhesive with higher caustic, however a study on "An Investigation of Bonding Mechanisms on the Double-Backer" by Schaepe, Watanabe, and Nanko, demonstrated that adhesive gelling time was complete within seconds regardless of gel temp or hot plate temperature, and that adhesive dehydration played a more important factor on bond strength and thus bond time.[1] This again points to the benefit of increasing adhesive solids to increase bonding speed. Increasing caustic in adhesives, while reducing gel temp, also improves the alkali "bite" into papers, improving bonding and surface penetration. However, because of the impact of low gel temps on starch swelling and viscosity in storage, care must be taken to balance gel temp against maximum adhesive temperature while circulating through the system. This includes any hot spots in piping or glue pans that can begin to swell the adhesive.

Likewise, as adhesive parameters are tightened for high-speed machines, the consistency of the raw starch needs to be controlled. Since the pearl starch used in adhesives is an unmodified starch product, certain attributes such as the natural viscosity, caustic absorption level, and natural gel temp will vary by region and growing season. However, attributes from the corn wet milling process can be controlled, such as insuring viscosity is not damaged in steeping, or that granules are not damaged during drying (alkali sensitivity). These can affect batch-to-batch consistency as well as adhesive stability in storage, specifically with low gel temp and high solids adhesives. While there are various methods for these measurements, it is important that the starch supplier provide consistent material load to load, and consistent control analyses on the COA's with these loads. In addition, the starch supplier should provide a specific specification range for their product which demonstrates the control points used to ensure that customers will get consistent performance in their adhesive. Ingredion's Unmodified (Pearl) Corn Starch meets these high consistency standards, a reason why it is the starch of choice for corrugators world-wide.

An often overlooked issue on high-speed machines is the effect of celled glue roll speed in glue pans. At the top machine speeds, these miniature cells can whip and froth adhesive, leading to foam generation. This foam can impact both the application of films on the flute tips, but more detrimentally interfere with glue level indicators, causing the machine to starve off adhesive flow to the glue pans. This becomes further complicated with water quality or hardness, which can contribute to foam. In these cases, defoamers such as CORAGUM® DF can be added to adhesives to control excess foaming.

Wet strength and specialty grades

Finally there are considerations for both coated or specialty papers, and specialty board grades including water resistant boards. Treated and coated papers can often have higher porosity (denser paper) as well as higher water holdout (Cobb, water drop) and more difficult to bond surfaces. Board grades that are required to have water resistance will utilize wet strength resin to provide wet strength to the adhesive. These resins require time, heat and pressure to perform properly, all of which could be scarce at high machine speeds.

Higher adhesive solids have been demonstrated over the years to improve both bond adhesion and water resistance in adhesives. Formulating higher cooked solids, or the addition of tack building additives such as CORAGUM® PA-15 or HS-30 performance additive have improved performance on difficult paper surfaces. To develop water resistance however, faster acting wet strength resins are needed because of the short dwell time. Here, Ingredion has introduced the latest crosslinking technology in the CORAGUM® SR wet strength resin. The newly developed performance resin bonds more efficiently and at lower reactive solids than traditional wet strength resins. For optimal performance, the blended CORAGUM® PR-Flex performance resin contains both the fast acting resin of CORAGUM® SR wet strength resin with the bonding performance of the CORAGUM® performance additives. In cases where paper density is high enough to impact adhesive surface penetration, a surface acting penetrant like CORAGUM® PT wetting and rewetting agent can be added to reduce surface tension at the glue line and improve penetration. Higher adhesive application will also improve wet strength performance, but comes at a cost to speed (water removal). To fully optimize wet strength and specialty performance, proper balancing of temperature, conditioning, application and formulation is required. This is where the expertise of a full service starch and additive supplier like Ingredion can provide the best benefit and resources to truly meet the maximum speeds of today and the future.

Key takeaway

While the higher speeds of both modern and future corrugating machines will continue to provide challenges to box plants, the ongoing development of optimized equipment, performance grade ingredients, and the best practices of knowledgeable industry suppliers and manufacturing will make it possible to meet those challenges. To best prepare for ongoing developments in technologies, box plants need to partner with their equipment and ingredient suppliers, to best utilize their expertise and experience in meeting the leading edge of speed and efficiency.

REFERENCES:

1. Schaepe, Watanabe, and Nanko. An Investigation of Bonding Mechanisms on the Double-Backer, TAPPI Corrugating International, 3-15, April 2004.

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