Lessons in Feedstock Change

FIGURE 1. Early in development, lab testing is vital to identify the most effective combination of mixing agitators and optimize the process

Many renewable materials offer environmental and financial benefits, but some come with a mixing challenge — higher viscosity

Steve Pung and **Rick Hammers**,
Columbia Forest Products

Ken Langhorn,
Charles Ross & Son Co.

These days, there seem to be more reasons than ever to change feedstocks throughout the chemical process industries (CPI). Whether environmental, or more directly based on financial and market drivers, big benefits usually require big changes. This is especially true in switching to many renewable feedstocks, which either add or compound challenges related to processing solids.

When Columbia Forest Products embarked on a three-year project to change feedstock for its flagship product line, the company took on the special challenge that every market leader faces when it assumes the role of first-mover toward a new technology. The largest manufacturer of hardwood plywood and veneer in North America, Columbia Forest Products chose to switch all seven of its manufacturing plants in North America from an adhesive based on urea formaldehyde (UF) to a new adhesive technology based on soy protein. The transition represented a paradigm shift, both technologically and culturally. It was a high-stakes business decision, since the company was betting its future on the success of the changeover.

Assessing risks

The risk and impact of a feedstock change can vary substantially from one case to another. Key variables include the following:

- The magnitude of change required in production
- Maturity and sophistication of the technology involved
- Awareness and experience among company employees of new technologies needed
- The company's ability to rally key partners to support the company through the changeover and afterward
- The willingness of company employees to embrace new technology and welcome change

Large-scale changes in feedstock do not necessarily present great risk. In some cases, a change in feedstock simply reflects a strategy to create more options for plant inflows and outputs, and become more competitive. In the petroleum industry, for example, a refinery may be adapted to accept new crude-oil feedstocks and allow the operator to respond more nimbly to fluctuations in the price, availability and quality of historic feedstocks.

In such cases, the primary goal is greater flexibility in production, not a metamorphosis. Although the cost of changing feedstock may be high, the task is well-understood, since it has been studied and modeled by legions of researchers, consultants and vendors. The risk is comparatively low.

A switch in feedstock sometimes represents a permanent and inflexible process change, though it may still pose no great challenge or risk in processing. This is often true when modifying the flavor or nutritional profile in a food product, for example — when ingredients change, but key process parameters and in-plant production methods remain essentially the same.

In contrast, Columbia Forest Products' experience with changing feedstock was a process that presented a formidable technical challenge and great risk, with no guarantee of great return. The company was not hedging against market fluctuations or impending regulation. It wasn't implementing a temporary feedstock change to capitalize on a blip in commodity pricing. It had no well-documented model to follow, since it was the first to adopt a radically different adhesive technology.

When the company changed feedstock, it made a permanent, all-in commitment to abandon one feedstock for another, reformulate its flagship product line and overhaul its production method throughout North America — all with no increase in the end-product cost to buyers. There was no turning back.

Seizing opportunities

The opportunity for a strategic feedstock change often results from the convergence of growing market demand and a new development in an enabling technology. In the case of Columbia Forest Products, demand had been apparent for years, but a feedstock change also required a breakthrough in adhesive technology.

UF-based adhesives emerged in the 1950s, and they have been used to manufacture hardwood plywood ever since. Compared to earlier adhesives (which, ironically, included a primitive form of soy-based adhesives), those based on UF were simple to mix, strong and water-resistant, easy to

EQUIPMENT FOR MIXING HIGH-VISCOSITY MATERIALS

Soy solids loading of more than 30% can be challenging with regard to viscosity and thixotropy (the property of certain viscous materials to become less viscous over time when shaken, agitated and so forth). At viscometer spindle speeds of 5 rpm and 10 rpm, the team recorded batch viscosities of 200,500 cps and 180,400 cps respectively.

The high-speed disperser in this dual-agitator mixer (Figure 2) provides plenty of shear to mix the soy flour with water and other minor additions. But at this level of viscosity, the batch material will not flow readily, which inhibits the ability to achieve homogeneity. It also raises the risk of creating localized zones of excessive heat build-up in the vicinity of the disperser.

For supplemental agitation, we rely on a low-speed, low-shear anchor agitator. The two-wing anchor orbits the periphery of the vessel, removes material from the bottom and wall, and feeds the stationary high-shear device. By stimulating vigorous flow throughout the vessel, the anchor allows us to apply intense shear with the disperser and accelerate the batch cycle.

The two agitators in a dual shaft mixer rotate independently, on stationary axes — a robust design suitable for mixing materials of moderate viscosities. (Note: For viscosities up to 8–10-million cP, a transition would be required to equipment in which the agitators themselves orbit the batch in a planetary motion and physically contact all the material in the vessel, even with limited flow.)

FIGURE 2. In production, dual disperser blades apply high shear, while a two-wing anchor scrapes the vessel's sidewall and bottom, promoting flow, then complete discharge

In production, the pairs of mixers and tandem holding tanks that were provided for Columbia Forest Products' plants ranged in capacity from 300 gal and 500 gal to 500 gal and 750 gal. Like the mixers, each supplemental holding tank was also equipped with a slow-speed anchor agitator. The anchor in each holding tank simply keeps the finished batch moving, prevents stratification before use, and helps to ensure consistent performance of the adhesive. ❑

apply, and inexpensive.

UF is a thermosetting resin derived from natural gas through the intermediates of ammonia for urea and methanol for formaldehyde. Raw materials were plentiful and supply easily kept pace with demand, which was driven mainly by the home building and remodeling markets. Hardwood plywood is used widely for interior applications including high-end residential and commercial cabinetry, fine furniture, architectural millwork and commercial fixtures. (Plywood designed for construction sheathing and other exterior applications is typically manufactured with an adhesive based on phenol formaldehyde, which is more weather resistant.)

Starting in the 1980s, UF attracted criticism because it was found to be a source of formaldehyde off-gassing in homes. Especially when exposed to rising levels of moisture and heat, adhesives and other products made with UF resins release free formaldehyde into the atmosphere. Emission rates are highest immediately after product installation and gradually decline, but they continue long afterward.

Evidence of the health risks associated with high concentrations of free formaldehyde in household air mounted steadily. Finally, in 2004, the International Agency for Cancer Research declared that it had reclassified formaldehyde from a suspected carcinogen to a known carcinogen.

Meanwhile, demand was also growing among the architecture and design community for cost-effective alternatives to construction products made with UF-based materials. In a market characterized by unmet demand and a call for change, an opportunity was developing. But the technology had not yet emerged to make a change possible.

In 2003, the enabling adhesive technology finally came to light. Comprised of cost-effective soy proteins and an amino acid that served as a cross-linking agent and wet-strength resin, the new adhesive offered fast curing and high bond strength, even when wet — an ideal combination to enable a switch away from UF adhesives.

The benefit of widescale support. An unequivocal commitment from top management greatly improves the likelihood that a feedstock change will be successful. As the transition team moved forward, it soon recognized the value of this high-level commitment. Approvals came quickly. Resources were made available promptly, whenever they were needed. The priority assigned to the project was never in doubt.

Beginning transition

The team, led by authors Steve Pung and Rick Hammers, devoted most of 2004 and early 2005 to testing and process development.

Recruiting technological partners. The next step after exploratory testing is to recruit the partners necessary to make the venture successful. In this particular case, Dr. Li at the University of Oregon had discovered the adhesive, and the university held the patent. Hercules (now Ashland Chemical), which owned the cross-linking resin technology and licensed Columbia Forest Products to develop its use for wood products, would provide technical support related to process chemistry. Cargill would supply food-grade soy flour and related technical support.

By mid-2004, the team recognized it would need another development partner to provide technical guidance and equipment related to mixing. The soy adhesive was quite different than the UF adhesive that had been used for years, with many more process variables to control. Chief among these was a substantial increase in viscosity.

Testing reveals challenges of handling higher-viscosity materials. The R&D group has since lowered the viscosity of the adhesive dramatically, but the original formulation of the new, soy-based adhesive was more than 200,000 cP during the mix cycle

FIGURE 3. In-plant tests were conducted with a mixer equipped with a high speed disperser and an anchor designed to generate axial and lateral flow

FIGURE 4. With systematic experimentation during in-plant tests, the process is optimized — and later automated

(Figure 1). Since the UF-based adhesive only reached 4,000–6,000 cP, feedstock presented a huge technical shift in this regard.

The team arranged a series of process tests with Ross, the mixing equipment partner. The tests were run on laboratory- and pilot-scale mixing equipment, using actual soy-based adhesive ingredients to replicate conditions on the process line. A successful laboratory test identified a dual-shaft mixer, equipped with a high-speed disperser and a three-wing anchor agitator, as the optimal solution (Figure 3; see box, Equipment for Mixing High-Viscosity Materials). Columbia Forest Products rented a 100-gal mixer for the pilot phase of development.

The team established its development center in the company's plant in Klamath Falls, Oregon. With the mixer operating alongside a dedicated glue spreader, the team systematically explored the influence of key process variables, including pH, soy solids load, cross-linker concentration and various experimental additions designed to modify tack and other properties.

Testing began in earnest in late 2004 using 24 × 24-in. samples of seven-ply hardwood plywood made in the forest products laboratories at Oregon State University. A battery of tests was required to fully assess the performance of each sample, which made this a laborious process. Industry-standard tests for each trial panel included the following: a dry shear test, a cyclic-boil shear test, and a decisive three-cycle boil test.

During this initial phase, viscosity immediately emerged as the most persistent challenge the team would face during testing and rollout. Coaxing the 200,000+ cP material to flow on the glue spreader was difficult, and the adhesive was extremely difficult to pump. On numerous occasions, with pumps bogged down, lines locked up or a hose blown, team members carried glue to the spreader in 5-gal pails to continue tests, while handling equipment was being repaired.

Because of the higher viscosity of the adhesive, breakdowns, repairs and upgrades were routine. But the challenge in handling higher-viscosity material was really only half technical. The team also had to overcome its own expectations about the capabilities of the existing equipment.

The team found that plant staff accustomed to handling much lower viscosities tend to underestimate the challenge of pumping the thicker adhesive. During the rollout, staff in virtually all of Columbia Forest Products' North American plants were determined to move it with existing equipment, but failed. Eventually, the decision was made to upgrade to high-capacity progressive cavity pumps and similarly robust ancillary equipment in every plant.

In-plant trials

In-plant trials are immensely beneficial, because they generate data in conditions that mimic actual production (Figure 4). But in most companies, where floor space is limited for non-production activities, testing occurs near ongoing production lines with employees nearby who are not directly involved in the tests. In such cases, the development team should remain sensitive to the image that testing presents to others. Dramatic "failures" in a test phase are usually not disturbing to members of a development team. After all, a "failure" is simply another data point that helps to define process limits. But when tests are conducted in full view of others in the plant, the sight of seemingly "unsuccessful" tests can be demoralizing.

In the first full-scale mill tests, as process variables were scaled up from test sizes to full-size plywood sheets, negative results were inevitable. The moisture content in the first panel was too high, for example, because the solids content had been lowered in order to lower viscosity — with offsetting adjustments to other additives to prevent a loss in performance. This caused the panel to stick to the press.

In other tests, excessive steam pressure in the hot press essentially blew the panels apart — until the formulation returned to a higher solids content (and consequently, higher viscosity).

After this first round of tests, naysayers predicted failure: "You'll never be able to make plywood with glue this thick. It just won't work!"

In fact, further changes to the adhesive formulation soon produced positive results. But along with the optimal formula for mixing the adhesive, another discovery was made: the importance of anticipating the impact on internal audiences when conducting in-plant testing. The unflagging confidence of plant employees, along

LESSONS LEARNED

For feedstock transitions on any scale, our collective experience left us with these essentials for a successful changeover:

1. Obtain an unequivocal commitment from top management before launching a feedstock change
2. Identify key technical challenges in advance, and assemble the transition team with appropriate expertise and resources to address each one specifically
3. Assess the need for additional equipment and expertise conservatively — especially when transitioning to a process in which you will be handling higher levels of viscosity, it's easy to underestimate the need for robust equipment
4. As engineers, we focus instinctively on technology challenges. Expect human challenges, too. The urge to resist change is part of human nature
5. Never underestimate the importance of making production personnel believers. Make them partners in development, and co-owners of the success that follows
6. Identify believers. Encourage them to speak up and rally others
7. Identify skeptics. With patience, respect and solid information, make them believers
8. Communicate often and explicitly with all staff to reinforce the importance of the mission
9. Cultivate strong, collaborative relationships with key partners — including customers who will benefit from the change, especially if those customers are asking for it
10. Expect to be derailed along the way, and be prepared to respond when it happens
11. Celebrate success at every opportunity ❑

with their enthusiasm for the basic changeover concept, is essential for a successful rollout.

Employee owners: Tough critics, strong supporters. The success of a profound process change in any production environment requires a strong commitment from the production staff. This is especially true in employee-owned companies like Columbia Forest Products. When employees own a stake in the future of the company, they must be convinced the change is positive and likely to succeed. Lingering doubts about the wisdom of the change and the security of their stake in the company will inevitably slow progress. Fortunately, once employee-owners are convinced, they are also likely to maintain a high level of engagement and drive the process forward.

At Columbia Forest Products, enthusiasm generally remained high once the company's CEO and board explained the goal of the program and challenged the staff to roll the process out to all our plants. We had many "high-energy" discussions along the way, but a fairly competitive atmosphere developed and company-wide morale remained high thereafter.

Surmounting rollout hurdles

In most companies operating numerous production facilities, plant-to-plant differences (such as legacy equipment, environmental conditions, and management style) can be quite significant. With many variables in play, the rollout of a major process change should be sequential, flexible and adaptive.

Following this approach, each successive installation provides additional experience and insight and enables the transition team to continuously refine the manufacturing process and improve efficiency.

In planning the three-year rollout, the team anticipated that each plant would represent a unique set of technical challenges, as follows:

1. Variation in other feedstock. Columbia Forest Products plants are dispersed geographically, from Canada to Arkansas, Oregon, North Carolina, Virginia and West Virginia. Wood feedstock, the other major component of plywood besides the adhesive, varies dramatically from region to region. White fir in the Pacific Northwest presents a different set of physical properties (especially density and absorption of moisture) than aspen in Canada or yellow poplar in the Eastern U.S. Each species required adjustments in the formulation and application of the adhesive.

2. Legacy equipment. The new mixing equipment for each plant would vary somewhat in capacity, while the essential designs for the mixer and holding tank would remain consistent. But each plant operated with a unique array of legacy equipment available for handling and applying the adhesive.

3. Process line design differences. The seven plants included a mix of fully automated and semi-automated lines, which required adhesive formulations that differed significantly in curing time and application.

4. Ambient temperature differences. Because of their geographic dispersion, the plants operated in vastly different climates. Regional variations in elevation, relative humidity and ambient temperature — and substantial seasonal temperature variations in some locations — required site-specific testing and adjustment.

With all of these differences to account for, from plant to plant and within certain plants individually, the rollout essentially presented seven separate opportunities (one for each plant) to re-balance all of the technical variables and optimize the process.

On the human side of the equation, each plant also presented a unique combination of personalities, attitudes and experience among managers and equipment operators.

While collaborating with the process development team, the management team in each plant was empowered to manage the rollout locally. This proved an important factor in sustaining a high level of energy throughout the rollout. From the start, each local team owned the rollout and the success they achieved.

Inevitably, the staff at each location included stubborn skeptics and avid supporters. As demonstrated in this particular feedstock switch, quickly addressing both skepticism and support with information, converts skeptics and reinforces the enthusiasm of the program's supporters. Another important strategy is to consistently explain the importance of the program for the company and the vital role that each plant will play.

Increased onsite control

The changeover from UF-based adhesive to the soy-based alternative led to a change that was far more profound than a simple upgrade in equipment. Until the switch, Columbia Forest Products' supplier oversaw most of the mixing of the adhesive. The UF chemistry was entirely in the supplier's hands; the adhesive formulations were monitored and controlled by its staff. The role of the operators at each plant was minor and required only basic expertise in mixing. Local mixing was generally limited to adding

FIGURE 5. Since the transition, Columbia Forest Products has assumed more responsibility for onsite mixology and gained more control over the quality and consistency of its end-products

catalyst and a wheat-flour or pecan-shell filler in a low-viscosity batch.

With the changeover, each plant assumed much greater responsibility for onsite mixology (Figure 5). Tanker trucks still arrive daily from a resin supplier — now, delivering the soy-adhesive cross-linker. But today, instead of simply receiving a readymade adhesive resin, plant production teams make their own adhesive onsite using food-grade soy flour from Cargill, the cross-linker from Ashland, and a variety of other additions.

This shift has brought about three significant changes in the processing culture at each plant.

1. Knowledge base. Columbia Forest Products developed a strong base of company-wide mixing expertise and operational expertise at each plant. The company's adhesive technology team, along with the local expertise developed at each plant, has made Columbia Forest Products stronger, more versatile and more innovative at the process level. Process improvement never stops.

2. Ongoing partnerships. The company strengthened its ongoing partnerships with key suppliers. By leveraging its resources, Columbia Forest Products has greatly increased its collective ability to innovate and continue improving its products.

3. Controlling the company's destiny. By becoming a more active partner in production, Columbia Forest Products acquired greater control over the company's future success.

Bottom-line results

Columbia Forest Products' feedstock changeover concluded late last year. Although the company has now produced nearly 40-million hardwood-plywood panels using the soy-based adhesive, process optimization continues.

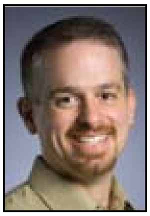
Panels produced with this method are completely free of volatile organic compounds (VOCs) from the adhesive during production and thereafter. They contribute no added VOCs to the atmosphere, whether in the communities that surround production plants, in the workshops where finished cabinets and furniture are made, or in homes, offices and hospitals — anywhere end-products using these panels are installed. Overall plant emissions have been reduced by up to 90%. VOCs detected in the ambient atmosphere inside the plants have declined similarly. ■

Edited by Rebekkah Marshall

Authors

Steve Pung is vice president of technology at Columbia Forest Products. (Email: spung@columbiaforestproducts.com.) He received his B.S. degree in Wood Science from Mississippi State University. At Columbia Forest Products he applies more than 30 years of experience in decorative wood panel manufacturing, with roles in industrial engineering, plant engineering, project management, plant management and product development.

Rick Hammers is a project manager in the Technology Group of Columbia Forest Products. (Email: RHammers@columbiaforestproducts.com.) He has more than 18 years of experience in the production of various types of wood panels. Hammers has held positions of lab technician, technical director, plant manager, and new product development coordinator for leading domestic and international panel manufacturers. He has a B.S. in industrial technology from the University of Nebraska, Omaha.



Ken Langhorn, Technical Director at Charles Ross & Son Company (710 Old Willets Path, Hauppauge, NY 11788; Phone: 800-243-7677; Email: klanghorn@mixers.com; Website: www.mixers.com), has published many articles on mixing and blending technology. Formerly an R&D specialist at Ross, he holds multiple patents for innovations in high shear and high viscosity mixing. As manager of the Ross Test & Development Center, he oversees a large program of testing and process optimization for customers, along with operations in the company's adjacent analytical laboratory.