Modern prepress solvent extraction

The following article is based on a talk by Daniel P. French, president of The French Oil Mill Machinery Co., given at the 37th annual Oilseed Processing Clinic held March 14-15, 1988. The clinic was sponsored by the Mississippi Valley Oilseed Processors Association and USDA's Southern Regional Research Center.

As the pace of technology development quickens and the globe seems to grow smaller with increased international trade, there are many reasons why the vegetable oilseed-crushing industry must constantly change and adapt, to successfully respond to the pressures that squeeze on crushing margins.

Improving the design, and consequently the economic performance and value, of the machinery, equipment and systems used, is one way that a supplier can help the oilseed-crushing industry. Another way is to manufacture a wide spectrum of equipment, and work closely with the oilseed processor, thus offering "tailor-made" solutions to unique application problems.

The principle process steps in prepress solvent extraction have not changed since the process evolved in the 1940s as a method for increasing the capacity of full press plants, mainly processing cottonseed. The process includes the stages of cracking or crushing, seed conditioning, prepressing, extraction, desolventizing and distillation. These stages apply to all high-oil content seeds, for which the prepress-solvent-extraction process is used. There also are the auxiliary processes of delinting, decorticating, cake granulating, meal cooling and grinding, which may apply to different seeds.

One of the most significant process changes has been the elimination of prepressing in the processing of most cottonseed. Cottonseed, after delinting and decorticating, has an oil content of approximately 30%; this level is on the border traditionally determining whether seeds are prepressed or direct-solvent extracted. With the advent of modern high-capacity solvent-extraction systems, it became possible to directly extract cottonseed meats. Direct extraction reduces operating costs; the prepress-solvent-extraction method, however, can produce meal for a more diverse market—for swine and poultry feed, as well as cattle. The difference in capital cost between the two choices actually is not very large, with the cost reduction of not requiring prepresses for direct extraction offset by the necessity for larger solvent-extraction equipment. Most cottonseed in the U.S. is processed by direct extraction. However, in most foreign countries, the prepress-solvent-extraction method is used because it can handle the wide variety of oilseeds available for crushing, as well as the variety of operating conditions and techniques.

For seeds with oil content of 30% or more, such as sunflowerseed, canola, wet-process corn germ or sesame, several manufacturers have designed and perfected high-capacity prepress machines. These have features specifically designed for prepressing, allowing the processor to have greater throughput in fewer machines with corresponding reductions in horsepower, floor space, downtime and maintenance, and an increase in product consistency and quality. We use computer modeling systems to evaluate alternative shaft designs to determine the most efficient worm and collar configurations for all types of seeds.

Our Model B-2100 is designed to handle most prepressing operations, with customized shaft arrangements to process all of the high oil-content seeds. This machine was introduced in 1967, with a capacity in excess of 125 tons per day. Since then, it has been improved to incorporate a force feeder for greater productivity. By adding 10% additional horsepower, its capacity has been increased by 40% or more. There are almost 100 B-model presses in operation around the world, including in the People's Republic of China.

A newer version of this press, the Model B-3100, was developed for the more difficult-to-press wet-milled corn germ and has approximately 50% more drainage area. The B-3100 has been applied to increase capacity and lower the residual oil content for other seeds as well. These machines can process more than 200 tons of seed per day, resulting in a residual oil content of 12-20%.

The Model H2-6600 prepress has a capacity of over 300 tons per day. Due to the water-cooling system on the shaft and cages on all of our prepresses, cake temperatures can be kept low, resulting in a more extractable, porous cake and yielding lower residual oil from the solvent plant. Cooling also produces a better quality vegetable oil.

The greatest strides in equipment design for prepress solvent extraction plants have taken place in the solvent-extraction area.

Another interesting development to meet the demand for higher capacity plants has been mechanical extrusion, a method of increasing capacity at a minimum capital cost. The extrusion machine has not had much use in processing high oil-content seeds, but has wide acceptance in processing soybeans, cottonseed and rice bran. With extrusion, it is possible to increase the capacity of a solvent-extraction plant without increasing the size of the extractor, desolventizer or distillation equipment.

The Enhanser Press, equipped with a 100-horsepower motor, will process over 250 tons of soybeans per day. The unit has an 8- or 8-1/2-inch diameter 12-foot-long barrel. This unit densifies the material, so that a greater mass can be put in the same volume extractor. The material also is very porous and provides greater area for solvent contact, reducing the required extraction-residence time. Users of these machines have experienced capacity increases in the extractor of 50-100% or more.

With cottonseed, 250 tons or more per day of delinted and decorticated meats may be pelletized through this machine. Little, if any, moisture must be added, so that in most circumstances, only cooling of the pellets is required prior to extraction. Solvent-to-feed ratios of less than one have been successfully used, compared with up to 1.8 for normal direct extraction of cottonseed meats. The lower ratio results in full miscella concentrations of 30-35%. This high miscella concentration allows increased capacity of the solvent-extraction system without adding more evaporation and solvent-recovery equipment. The porosity of the pellets allows excellent drainage and results in less than 25% solvent carryover to the desolventizer. Free gossypol in the meal has been in the 0.10-0.20 range.

These are important improvements in the preparation area. However, the greatest strides in equipment design for prepress solvent extraction plants have taken place in the solvent-extraction area. The Arab oil embargo in the early 1970s and the tremendous increase in the cost of energy created significant economic motivation to reduce steam and electrical consumption. This has produced a great number of changes in the extractor and desolventizer and in meal drying and cooling.

The French Stationary Basket Extractor for many years has been the industry standard in solvent-extraction plants. The industry then moved away from deep-bed extraction and concentrated on shallow-bed extraction, due to the concern that deep-bed extractors had greater solvent carryover. Now, the latest improvement to the Stationary Basket Extractor—the patented Rotating Basket Bottom Screen—has eliminated this drawback. In prepress cottonseed plants, the solvent in spent cake has been measured as low as 18% and typically runs under 25%. In soybean plants, carryover is about 29-30%. This is of economic benefit to the processor because it significantly lowers desolventizer-toaster (DT) steam consumption. It now is possible to have advantages such as less sensitivity to exact flake thickness and preparation, simpler operation, lower residual oil and fewer fines in miscella offered by deep-bed extractors, without the problem of higher solvent carryover.

The Rotating Basket Bottom Screen is made from a special profile wire offering consistent drainage and avoiding plugging. It replaces the individually hinged basket bottoms, with their corresponding moving parts, that require periodic maintenance. Rather than remaining in place under the basket during the extraction cycle, the basket bottom now rotates with the miscella collection pan. This has resulted in additional advantages. Because the basket bottom rotates simultaneously with the miscella application nozzles and the miscella collection pan, each section of the Rotating Basket Bottom Screen always will be in the same stage of the extraction cycle. Because of this relationship, it is possible to use screens of different spacing at different points in the extraction cycle to further reduce fines and improve drainage.

The Rotating Basket Bottom Screen can be retrofitted into existing Stationary Basket Extractors easily and inexpensively. Depending on the price of oil and energy, the modification will pay for itself in 10 to 24 months by significantly lowering DT steam consumption, resulting in an increase in extractor capacity and/or lower residual oil, and maintenance savings on the extractor. The modification also can be made to the old "Roto-cell" extractors, with similar improved results.

With these achievements, it would appear that the first requirement for reducing steam consumption in the desolventizer has been achieved—namely, minimizing the amount of solvent carried over to the desolventizer.

The original design of the stacked desolventizer-toaster was a joint development between The French Oil Mill Machinery Co. and Central Soya Co. during the 1950s. French received several equipment patents, and Central Soya obtained a process patent. According to the original equipment patent, desolventizing was performed initially by condensing steam in the solvent-laden flakes in the top kettle of the machine. Subsequent desolventizing took place in lower kettles by the action of jacketed steam condensing, and the heat transferred by conduction to the flakes. A final stage of desolventizing was performed by injecting superheated steam into the bottom of the desolventizer. This auxiliary flow of steam worked its way up through the meal and through the steam-jacketed bottoms by way of auxiliary vents.

This DT was the industry standard for many years. We since have realized that the basic principles behind its design needed only minor modification to provide the steam savings of the modern counterflow desolventizer-toaster. Heinz Schumacher of West Germany did the work necessary to show that much less steam could be used in this process than had been traditionally used.

In the counterflow design, the sparge steam is applied to flakes with the least amount of solvent and the greatest heat. This takes place in the bottom section of the desolventizer. Since these flakes have been heated on the way down, little of the sparge steam condenses at this point; instead, it provides a medium for stripping the final traces of solvent from the flakes. The vapor flows upward through counterflow passages in the intermediate steam-jacketed decks. In so doing, heat from the decks is transmitted to the vapor to inhibit condensation. The rising vapor then contacts flakes with a lower temperature and a higher solvent content. Thus, steam usage is countercurrent to the solvent content and the temperature. A balance is achieved, so that no more sparge steam than is necessary to maintain the minimum dome temperature is added at the bottom of the desolventizer. The vapor temperature from the desolventizer seldom exceeds 160° F. The latest control technology is used to control and minimize sparge steam usage.

We studied the desolventizing-toasting and drying-cooling (DC) processes from a scientific standpoint to understand the actual dynamics of the process. We used several development methods, including making small DT-DC modules with clear sidewalls, so that we could see and videotape the effects of a combination of sparge and counterflow hole patterns and sizes, vapor flow rates, sweep design and other variables. Several people, including those at Kice Industries, assisted us in this development process.

In our modern counterflow desolventizer-toaster, such as the one at Bunge's plant in Marks, Mississippi, we use clusters of countercurrent vapor passages in the decks, so the rising vapors are mixed thoroughly with the meal by the aerodynamically designed sweeps. These cut through the meal like an airplane wing, leaving contrails of vapor behind. Above the counterflow decks are donut-shaped hot plates, known as predesolventizing decks. Placing the vapor passage in the center allows more heating surface area per deck in a given diameter DT. This is vital because ample predesolventizing area is required to heat quickly the incoming flakes, to flash off the surface hexane—which is critical to preventing material coagulation—and to minimize the output moisture of the DT. Recent installations show total steam consumption of less than 250 pounds per ton, output meal moistures of 14-18%, meal discharge with a hexane content of less than 500 parts per million and electrical consumption of less than 0.1 horsepower per ton.

The improved extractors and desolventizers have allowed dramatic reductions in energy consumption, along with a reduction in meal moisture; however, the meal drying step has yet to be eliminated. Traditional meal drying has been performed in rotary steam tube dryers and stacked-type cooker/dryers. These depend on the condensation of high pressure steam in a jacket or in the tubes, and the subsequent conduction of that heat through steel to the meal. This conduction requires that the meal contact the steam jacket for the heat transfer; this means a portion of the steam does not do much good, such as in the top part of the rotary dryer where the meal does not touch the walls or tubes.

On the other hand, modern meal dryers use air as the transfer medium for the heat. This permits intimate contact with the meal, to provide the most efficient heat transfer. The heat is transferred to the air by condensing the steam in heating coils designed to provide efficient convective-heat transfer. The air permeates the bed of meal and discharges through a cyclone collector. Most of the heat required for drying is supplied by the meal itself. The amount of steam supplied to the heater coil is determined by the temperature and relative humidity of the ambient air. With many of our meal dryers, no steam is needed on the heater coil most of the year. This allows an energy-efficient drying system. In many cases, the improved dryer uses only one-fourth as much steam as the rotary steam tube dryer it replaced.

Once the meal is dried, it must be cooled before storage. Air has been used as the cooling medium in meal coolers for many years. With the meal dryer already requiring a foundation, base and drive, it was logical to incorporate the cooling process in the same vessel to minimize cost. The French Meal Dryer/Cooler consists of one or more dryer sections on top of one or more cooler sections, depending on capacity requirements and geographic location.

In the DC, cooling takes place in the same manner as the drying process, except that no heating coil is required. Much of the cooling results from evaporation of another 0.5-1.0% of moisture from the meal. Variations of the DC design now are marketed by the majority of solvent-extraction equipment manufacturers; some are under license, and others are original designs.

Our Meal Dryer/Cooler is equipped with a carefully designed air system and controls to minimize the blow-over of meal into the cyclones, even as throughput varies. It also uses a special design to minimize condensation and "raining" in the cyclones so they do not corrode rapidly or need to be dug out with shovels and sticks.

The countercurrent DT and the DC can be combined in one machine to serve several purposes: to prevent valuable heat loss between the DT and DC, to reduce the capital equipment cost by approximately 15% and to reduce the required plant floor space.

I have summarized major changes that have taken place recently in modern prepress solvent extraction. Now, seed can be processed through fewer than half as many prepresses with half the previous maintenance. It now is possible for the oilseed processor to produce a higher quality product, with as little as half the amount of steam previously required. These changes all have taken place within the last 10 years.

With high energy costs and increasing demand for more edible oils and higher quality oils, it is likely that additional changes will take place even more quickly. I suspect these changes will occur in the process itself. There is much research taking place in the area of alternative solvents and different extraction methods. These, so far, have not shown the necessary economic feasibility, but it probably is only a matter of time before this will be changed by some other factor.

Our company, and other suppliers, will continue to improve our products, for the betterment of the oilseed crushing industry.

Developments in screw pressing

The following article is based on a talk given by Martin A. Stainsby, mechanical development manager for Simon-Rosedowns Ltd., at the 1988 AOCS annual meeting in Phoenix, Arizona, in May.

Screw press problems

In certain applications, screw presses can have fairly high maintenance requirements. The use today of large presses obviously reduces the number of machines in a mill, thereby reducing maintenance to some degree. Even so, larger parts tend to be more expensive and stopping even one large screw press in an oil mill seriously reduces throughput.

Another problem with screw presses is that they are very heavy power consumers. It is important to minimize this problem by having the best possible press configuration and worm assembly design for a given oilseed to make sure no power is wasted. It also is important to have the press run at optimum performance at all times. This often creates a further problem even when screw presses have a worm assembly design and configuration for efficient processing: efficient press operation frequently relies upon the operator's skill, and this often makes automation and consistent performance difficult to achieve.

Also, commissioning, resetting for different seeds and troubleshooting sometimes can be difficult, particularly if operators have little previous experience with screw press mills.

Tackling problems

In most oil mills, the equipment used has evolved gradually and generally is very functional. Unless there is a radically different and improved process introduced, the prospect of further improving the equipment can look quite daunting. A parallel can be drawn to other heavy mechanical equipment such as large machine tools and steel-making and material-handling equipment, where basic methods or processes remain the same and purely cosmetic changes have no place. Yet all these other types of equipment and machinery are undergoing substantial development and improvement. This also will happen to oilseed processing equipment because the rules of the marketplace dictate it is in the manufacturer's interest to continually develop equipment and offer better performance to the mill operator. If a manufacturer does not do this, his competitors soon will put him out of business.

How can equipment be improved? There always has been room for innovation in design, not only for new product designs, but also to enhance existing designs. There also has been the need for designers to be involved with the operation of their product to see how it performs so that they can make improvements.

Today's design engineers have something else to work with—advanced technology. This includes computer-aided design, drafting and manufacture, enabling us to analyze designs more carefully and to produce and develop them more quickly. It also has resulted in new or improved materials and better manufacturing methods to process these materials more efficiently and make more use of them in design. In view of this, it is reasonable to expect the pace of development to speed up.

Assembly design

Worm assemblies have been developed mainly in an empirical manner over the last 60 years. To make further improvements, a more rigorous scientific approach is required to make sure the results of worm assembly design can be predicted more accurately. This becomes important particularly with the larger machines, as a trial-and-error approach can be expensive.

Over the years, many attempts have been made by both manufacturers and academicians to produce useful mathematical models of screw presses and extruders. There has been some degree of success, particularly with the extruders. Unfortunately, the successful screw-press models only really apply to very small presses and many of the assumptions needed when using these models simply do not apply to presses of any useful size. In fact, with empirical methods, the biggest problems have been caused when trying to scale-up designs.

Nevertheless, a great deal of experience has been acquired and different worm assemblies have been used over the years. Some gave excellent results and others gave poor results. Rather than starting from scratch when developing new methods of assembly design, it is useful to analyze these assemblies and their performances, both good and bad, in a scientific manner. In the past, this has been difficult and so time-consuming that it was impracticable. However, recently, computers have been used to analyze this "historic" data to show many important trends and factors that were not previously apparent. The results of this work already are proving useful in assembly design and eventually will be combined with knowledge gained from current research work to produce a better design method. Although this method will be developed from a more scientific and sound basis than previous methods, it still is expected to consist of heuristic rules—that is, rules of thumb or simplifications that limit the search for solutions. For this reason, the method will be incorporated into an "expert system."

Benefits this work will provide to oil millers can be seen from results we already have obtained on a 20-metric-tons (MT)-per-day machine full-pressing palm kernel. Many attempts previously had been made, without much success, to improve the performance of this machine and to reduce oil in cake to levels obtained on smaller 12-MT-per-day presses. A prototype computer control system fitted two years ago took a full 1% off the oil-in-cake level and increased the throughput to 24 MT per day. Last year, we designed an assembly based on our new design methods. This brought capacity to 28 MT per day and took another 0.5% off the oil in cake, to match that of the smaller machine. It also produced a much better quality cake. A new 60-to-65-MT-per-day full-press machine is being built based on the same design rules. Benefits of this work to prepressing can be seen from the performance of our latest large "K Type" prepress.

Materials

It has been standard practice by press manufacturers to hard-face wearing parts in screw presses for the majority of applications. These hard-faced layers tend to be very hard high-chrome or cobalt-based alloys. Manufacturers have been striving to improve the life of these parts by experimenting with different hard-facing alloys, methods of application and thicknesses of hard-facing. However, there has been no significant increase in performance, with respect to wear, for some time. On some screw-pressing duties, the rebuilding and eventual replacement of these parts result in undesirable downtime and obvious expense.

The problems of wear are not unique to the oilseed industry and have been tackled successfully in many other industries. Unfortunately, many of the successful solutions in other applications simply do not work in screw presses or they are prohibitively expensive. For instance, many of the newer methods used with outstanding results on plastic extruders cannot be applied economically to the much larger screw-press parts. Other techniques or materials, although having superb wear properties, do not have adequate physical strength to withstand the forces applied to screw-press worms.

Several years ago, we invested in computerized production systems and discovered that, in addition to producing the standard hard-faced worms, this new production technology opened the way to economically working materials that previously were too difficult and expensive. We already had been working with a university department and material and surface-treatment manufacturers on the application of titanium nitride coatings (TiN) and other treatments to press parts, and decided to invest in a materials-development project. We formulated and tested a wide range of materials and treatments and eventually made a selection for inclusion in a new range of "Goldstar" parts.

These new parts offer a significant improvement to the oilseed processor. During extensive testing on palm kernel full pressing, rendering and other applications involving very abrasive seeds, the parts have lasted two to four times longer than the hard-faced parts they replaced; also, they do not need to be removed for rebuilding or repair of any kind during their useful life. In rapeseed and canola processing, there has been no detectable wear after six months running at 250 MT per day and the parts appear as if they will last several years.

Press control

Today, sophisticated programmable logic control (PLC) systems and industrial computers are used to provide powerful control systems throughout industry. The refinery side of the oilseed business generally has made good use of available control technology, but this has not been true for oil mills. Some newer mills have systems that give good overall control of the mill. However, some of the newer systems do not perform as well as they should.

Usually, screw presses have had only a very basic level of control system fitted or, at best, a semi-automatic control system. Normally, these are used to safeguard the press operation. The control problem is much more obvious when full-pressing, particularly with seeds such as palm kernel. It was for this type of application that we decided to develop a control system providing a high degree of automation and also giving optimum press performance.

Previous attempts to control presses using normal control methods and equipment were without much success. On the face of it, press control looks very simple: one meters the feed into the press to control the press motor load (usually the main shaft motor but sometimes the compressor motor). However, press control responses to disturbances in the feed—either the quality or quantity of feed material—

are severely nonlinear in several ways. These nonlinearities make it impossible for the standard "3 term" controllers to work correctly. These also make the system very difficult to model using classical mathematical control theory.

We tackled this problem by developing special control algorithms that could be implemented by direct digital control using a microprocessor system. We also built in operator "knowledge" that can select the most appropriate control algorithm or course of action at any time, thereby operating as an "expert system."

The resulting system offers performance designed to be better than the very best operator could achieve if he were totally dedicated, took control action every few seconds and worked without respite for 24 hours a day. The system gives smooth and safe startup of the press, automatically selects one of two control regimes depending on whether the press is running full or not, and almost completely eliminates the possibility of the press pulling up under load, due to overfeeding. The system also provides important data on press performance to management and incorporates several important safety features.

The system developed also offers significant advantages over the prepressing of soft seeds, as well as for the more difficult applications for which it originally was intended. All prepressing applications tested showed throughput increases of 10-15% for rapeseed and 20% for sunflowerseed. When full-pressing hard seeds, the system can increase throughput by 20%, while removing 1-1.5% of the oil in cake. In both full and prepressing applications, the high degree of automation provided drastically reduces operator involvement with the presses.

Occasionally in industry, one encounters a process or piece of equipment that is difficult to control and requires a specialized control system that may be very expensive to develop. Contractors designing and installing large plant control systems do not always have the necessary experience with the particular process or equipment, or the time available to successfully tackle these problem areas. Manufacturers may need to supply appropriate specialist systems with such machines; if required, these systems should be capable of communicating with and being integrated into a larger plant control system.

Another important point is that microprocessors enable machine performance to be pushed beyond that expected solely from good mechanical design and the application of new materials. The trend is set for microprocessors to be integrated into press controls and eventually to become low profile, working reliably in the background, transparent to operators and requiring no attention.

Expert systems

Expert systems, otherwise known as Know-How Systems, Knowledge-Based Systems (KBS) or even Intelligent Knowledge-Based Systems (IKBS), are an exciting and fairly recent development in the field of artificial intelligence.

Expert systems have been steadily developing over the last seven or eight years. During the past two years, industry has shown an enormous increase in interest, with many useful applications being developed. Only a short time ago, very expensive computers and a massive programming input were required to produce working systems. Now, there is a good range of software tools to make system development easier and many software packages will run on desktop personal computers.

The reference or association to "intelligence" adds an air of mystique and makes many people very skeptical. This is unfortunate because such systems are becoming powerful tools that we cannot afford to ignore. The name I like best for them is Know-How Systems because they basically contain "know-how." They do not generate this know-how themselves; all the know-how or knowledge has to be obtained painstakingly from a "real-life" expert, then programmed into the system. What they do very well is to access and manipulate this knowledge to give answers to problems requiring a high degree of expertise for their solution. In doing so, they only appear to have intelligence.

As mentioned earlier, they can be used in the design and specification of screw presses. Also, they can be employed by manufacturers to train staff in troubleshooting press, control system and general oil mill problems.

It appears likely that soon, these systems will be supplied with new presses and control systems for use on-site by the operation and maintenance teams. Although these Knowlege-Based Systems are not expected to be the answer to all our problems, the following could be realistic objectives:

- Narrowing down possibilities of problem origin, even if the problem, itself, still is unsolved.
- Outputting or recommending information concerning problems which will be useful to an expert during initial contact when he is remote from the plant.
- Assisting in the tuning of control systems and setting up of presses and pretreatment operations, thereby making optimum performance more easily achievable.
- Helping plant personnel remove the causes of problems rather than just helping to cure the symptoms.
- Training maintenance staff and plant operators.

Most people would agree that new technology is set to make a significant impact on mechanical extraction in one way or another. This should have benefits for both manufacturers and processors. Although the screw press has been around a long time, it still is capable of much improvement. This task likely will keep all manufacturers' development staffs busy for some time to come.