Scanner data ■ Extrusion control: Art to science

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EXTRUSION ADVANCES

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Extrusion automation:

Art to SCIENCE

BY WILL HENRY

Extrusion uses shear, steam and pressure to cook a variety of shaped foods. Extrusion has long been a manual process with the best results only coming from those operators with a depth of experience and the knack for producing high-quality, consistent product.

For years, it was believed that automating the cooking extrusion process was an overly expensive solution that—in the end—would not even improve the process and/or product. Nowadays, however, the best extrusion control systems can achieve dry feed accuracies with a moisture variance of less than ± 1%. Companies with automated extrusion systems are seeing as much as a 40% improvement in throughput, a decrease in changeover times by more than 65%, and enhancements in product quality in terms of size, shape and consistency.

Quality and moisture control

Improper extrusion control costs manufacturers thousands of dollars in wasted product. Even with an experienced, attentive, and accomplished operator, consistent results can still mean a moisture variation that exceeds ± 5%. Such high moisture variation requires drying the product beyond the optimum target moisture to produce acceptable storage characteristics. The over-drying results in extra utility usage and reduces the optimum yield of the product because of the extra moisture extraction.

Managing the delivery of the dry feed to the extruder is at the heart of tight ingredient control and moisture control. In order to achieve an acceptable degree of dry feed accuracy (± 1% of maximum delivery rate), a delivery system that is metering on a weight basis is a must. It is not unusual to see a typical volumetric dry feed system into the extruder vary by as much as ± 6%. The characteristics of the dry feed mix—grind and fat content, for example—have a significant effect on the metering characteristics of the mix.

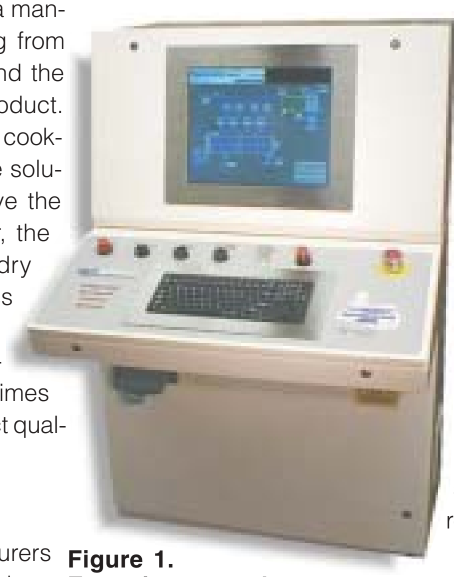

Figure 1. Extrusion control system console. Once thought to be too expensive and unreliable, cooking extrusion automation is now one of the most effective means for improving process efficiency.

We prefer loss-in-weight (LIW) systems, as we have found them to be more accurate over time. Our experience shows that the dry feed mix delivery systems used in the petfood industry require some intelligence in the control software to achieve consistently high accuracies. Neural nets, fuzzy logic and adaptive modeling are the more popular "intelligent" control schemes. The adaptive modeling technique works very well for extruder applications, as it is quick to adjust to system process changes. It is also relatively independent of the system hardware configuration, which means that software modification is not necessary whenever any hardware is changed.

With any system, the delivery error should be less than ± 1% in order to manage the moisture and other ingredient streams precisely. It has been our experience that traditional LIW techniques will not consistently produce acceptable accuracies.

Learning delivery characteristics

The best method we have found for achieving dry feed accuracies with a variance of less than ± 1% is to use a computerized model that learns the delivery characteristics of the particular dry feed mix being processed. We have developed

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a proprietary algorithm that accounts for the specific dry feed being processed and further determines how to manage the feed delivery system during the live-bin refill. This mathematical model continues to be refined during every cycle of active LIW mode to improve the mass flow management during the refill cycle. Once a predictable dry feed delivery system is employed, then the other ingredient streams can be accurately managed by slaving them to the dry feed rate on a ratio basis. The other feed parameters (such as moisture addition and alternate liquid addition) become ratios of the dry mix feed rate and are integrally controlled by the extrusion control system. Any change in dry feed rate automatically adjusts the other additive streams to maintain the formula ratio that produces the final product.

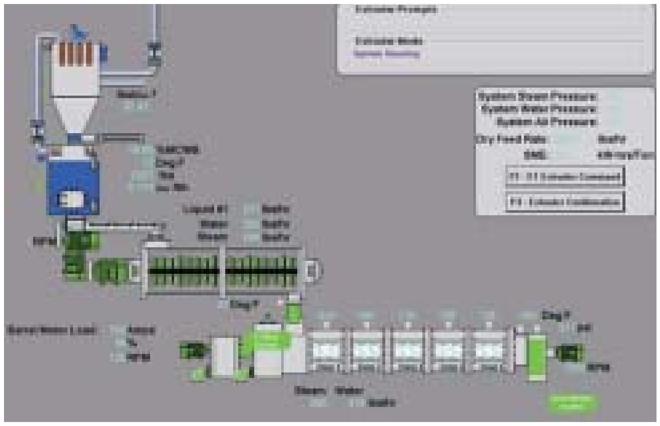

Figure 2. A properly automated extruder can run right up to the budgeted rate and keep it there, around the clock.

Maximizing yield

Simply put, good yields are a product of wasting as little as possible and then maximizing output per unit of input. Product changeovers, startups and unscheduled extruder outages can all add up to significant waste.

Typically, an extruder begins with a higher moisture percentage at startup than the runtime setting for the on-spec product. The rate at which the extruder transitions through the start-up mode and into the runtime mode—delivering on-spec product—is key in minimizing startup waste material. Each product changeover is a startup, triggered by a new formulation and/or new die configuration. The ability to minimize the startup-to-runtime transition—despite the introduction of a new set of extruder performance settings—is crucial to waste reduction and yield increases.

Unscheduled extruder outages—trips, faults, downtime—not only require another startup after correcting the problem, but the extruder may have been making some out-of-spec product before it actually tripped offline. This raises the challenge of determining how much out-of-spec product has been introduced to the dryer and where it currently resides in the product stream headed for packaging. If the solution is to divert a portion of the dryer discharge to waste (to avoid sending the off-spec product to packaging), then that will likely be a significant penalty to yield since the off-spec material was being generated at full production rates.

A well-designed control system can identify problems before they happen and make necessary adjustments to avoid as many unscheduled outages as possible. For instance, load monitoring and trending enable the system to detect conditions that might indicate a die that is beginning to plug and cause downtime. The system can attempt a moisture correction and observe the results. If the results still indicate a plugging die, then the extruder can automatically go into a controlled shutdown where the parameters reach the shutdown values entered in the formula screens for that particular product, minimizing waste and reducing downtime as much as possible.

Reducing waste example

Current process: Average cost per metric ton of recipe = $300. Average number of startups per week = 12.

Assumptions: Average amount of waste per manual startup = 150 kg. Average amount of waste per automatic startup = 20 kg.

Calculations: Manual—12 startups x 150 kg = 1,800 kg waste. Automatic—12 startups x 20 kg = 240 kg waste. Waste reduction = 1,560 kg or 1.56 metric ton.

Net savings: 1.56 metric ton x $300 = $468 per week or $23,000 per year.

Some systems further reduce waste by incorporating an expanded set of formula pages that allow the user to describe the characteristics and parameters of each product for both startup and runtime with a built-in startup/runtime transition. The formula selection screen makes it easy to recall and load your formulas from your own library of products.

Managing the moisture content of the extrudate can also have a significant impact on yield. As dry feed varies, the moisture contribution will vary at least by that amount, even if the moisture component—slurry, digest, steam, water—is being delivered by a perfectly tuned controller. If the moisture component(s) is being controlled manually or with poorly tuned control devices, the moisture variance only gets worse. With such a moisture variance in the extrudate delivered to the dryer, the dryer settings have to be at a level to ensure that all product delivered to packaging is less than a certain percentage to avoid on-the-shelf spoilage. Not only do you sacrifice overall product density by over-drying a high percentage of your total production, but you also spend the energy costs to extract otherwise usable water from the product.

The ability to deliver a consistent moisture level as close to the maximum allowable level for packaging will significantly increase throughput. The impact of simply not removing an additional 1% of moisture in the dryer can result in dramatic savings.

Controlling moisture example

Current process: Production rate = 20,000 lb/hr. Operation 16 hrs/day, 264 days/year. Value of packaged product = $0.40 per pound. Currently drying to a targeted 7% to allow for 2% moisture deviation (maximum allowed for packaging is assumed to be 9%).

Assumption: Tighten moisture control at extruder to achieve ± 1% deviation. Change dryer targeted moisture from 7% to 8%.

Calculations: 20,000 lb/hr at 7% moisture = 18,600 lb/hr dry basis. 20,000 lb/hr at 8% moisture = 20,217 lb/hr dry basis. Net change in feed rate = 217 lb/hr.

Net savings: 217 lb/hr x 16 hr x 264 days/year = 916,608 lb/year. 916,608 lb/yr x $0.40/lb = $366,643/year in savings.

Moisture control alone accounts for the above theoretical gain. This example does not take into account any reduction in waste, improved uptime, or reduction in changeover times. The example also does not add back any of the energy costs required to remove the additional 1% moisture in the dryer.

Managing efficiency

As obvious as it seems, keeping the extruder at full production rate while producing on-spec product maximizes throughput. A properly automated extruder can run the extruder right up to the budgeted rate and keep it there, around the clock.

Beyond extrusion automation

A well-designed plant network architecture integrates the mix system, extrusion system, dryers, coolers, etc. together into one automated system. By interlocking the upstream and downstream equipment, process-related data pass easily from one system to the next.

Figure 3. Product changeovers, startups and unscheduled extruder outages can all add up to significant waste. Photo courtesy Extru-Tech, Inc.

Data logging at the various cells within the production process allows yield tracking and online analysis of critical ingredient and product properties, such as bulk density, moisture and protein, resulting in better product and better information from which to make adjustments to the process. Tracking activities across multiple production cells (receiving, batching, extrusion, packaging) within the plant is most practically accomplished when applied to a well-designed plant network architecture.

To maximize extrusion automation's benefit to the entire organization, the extrusion and plant floor operations need to interface to the financial and business operations of the company. Tying information such as production schedules, recipes, production results, raw material usage, lot tracking, and downtime into the business systems gives management the near real-time data it needs to make critical business decisions.

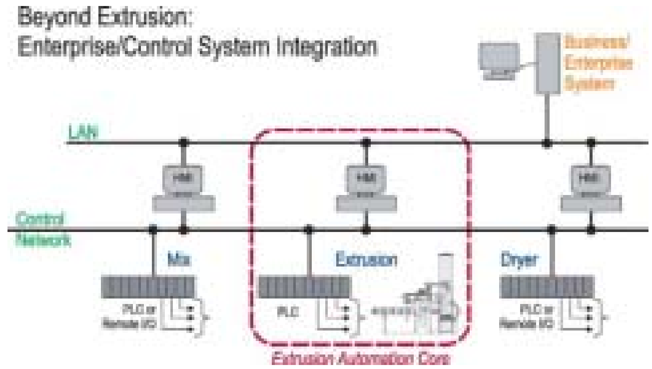

Figure 4. To maximize extrusion automation's benefit to the entire organization, the extrusion and plant floor operations need to interface to the financial and business operations of the company.

Preventative maintenance

Unscheduled extruder downtime must also be minimized to enjoy high throughput. One solution is to employ a preventative maintenance package within your extrusion system. Some features of a preventative maintenance package may include:

- Ability to pull parts out of service and return to inventory with accumulated usage history;
- System check before starting a campaign run against estimated remaining life of installed, monitored components; and
- Automatically issue maintenance order for a component when it has reached a predetermined usage point.

Choosing a control system

When choosing an extrusion control system, petfood producers must determine the objectives for product performance, data tracking and business results. Any extrusion control system should include the following features at a minimum:

- Monitoring system conditions and announcing to the operator when something is not in accordance with process parameters.
- Advanced status messaging to inform the operator of the extruder's current state and any conditions that may be causing delays in reaching the next step (status messages are not alarms; waiting for a temperature to reach a setpoint is not an alarm – it is a permissive to continue with the sequence).
- Full integration of all ingredient streams into the extruder, including automated temperature control for the barrel heads.

Once thought to be too expensive and unreliable, cooking extrusion automation is now one of the most effective means for improving process efficiency, increasing production throughput, and consistently producing quality product. These immediate savings can allow for payback in a matter of weeks. In effect, it is like having the company's best extrusion operator available for each and every production run.