Using a Making / Packing Simulator to Aid in Process Reengineering

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I. Overview

Manufacturing plants which process and package bulk materials face continuing challenges and problems. These operations produce bulk materials, pastes, or liquids by mixing and processing ingredients in steps, which are characterized as continuous, or batch. The material is then conveyed or delivered as a batch to a packaging operation which fills containers of the outgoing material.

In designing a new making / packing operation or managing an existing one, a myriad of issues must be considered. The following are initiatives that might be undertaken to improve such operations:

- reduce failure rates
- reduce processing cycle time
- increase or decrease inter-process storage
- introduce an alternate scheduling method
- change run sizes
- add higher capacity equipment

Managing the design or improvement effort is a challenge. It is difficult to predict the effect of proposed specifications or changes, and therefore to know how to prioritize. One reason for the difficulty is that so many factors within the operation interact, often in a dynamic fashion occurring through time. An example of dynamic interaction is the balance in some operations between reliability and inter-process storage. Designers of an operation may opt to add inter-process storage to cover up the effect of poor equipment reliability. From the reverse standpoint, inter-process storage may be reduced, but to achieve a required downstream utilization, the reliability of upstream machines must be improved. The question of "How much storage does an improvement of 1% in reliability buy me?" is difficult to evaluate, even using a sophisticated spreadsheet.

When scheduling is brought under consideration, the interacting nature of a whole host of factors is encountered. It is difficult to evaluate the factors important to scheduling in isolation from each other. Principal concerns are the control of sequences of operations, the volume and mix of products to be produced, and the characteristics of products, which might affect rate, failures or changeovers. Adding to the complexity of addressing scheduling is that making and packing often march to different drummers, since they are typically separated by location, scheduling methods, and even corporate cultures.

The way in which important factors interact with each other through time in a making / packing operation makes simulation the tool of choice for evaluating problems and predicting the effect of design or improvement decisions. A making / packing simulator provides a tool for testing design specifications or improvement efforts. In the same way that a flight simulator can be used to help pilots learn the best way to fly an airplane, a making / packing simulator can be used to experiment with a making / packing operation.

II. Case Study of a Making/Packing Simulator

A case study of a typical simulator illustrates the kinds of issues that can be addressed by simulation. Each simulator is different, depending on the goal of the simulator as it relates to the problem addressed. Following this discussion, we will look at some details of how simulators work, and then review some classes of simulators.

This case study involves a plant which is partially built and running, and in which new making and packing systems are to be added. The envisioned newly designed operation has two making lines, each capable of producing any of about 20 basic formulations. Three packaging lines package these formulations in a variety of container sizes and shapes, each with a different label. Multiple sets of surge tanks are in place, which can accept product from any making system, and then supply to any packaging line. Making lines and surge tanks must be cleaned prior to accepting a formulation which is different than a previous one.

New and rebuilt making and packaging lines are planned for the plant. There is uncertainty as to their ability to handle anticipated production schedules, which involve new products and different product mixes. A simulator was developed to address the following questions:

1) Will the new equipment be able to handle the new produce mixes and schedules?
2) What kinds of scheduling policies work best for running the new equipment?
3) How many surge tanks and what sizes of tanks are needed?
4) What is the effect of improving making or packing reliability?
5) What is the effect of different cycle times in the process?
6) Is there a need for more Making resources, which are shared by the 3 lines?

The model was implemented in **SDI Industry Pro**, a simulation platform developed and marketed by Simulation Dynamics. **SDI Industry Pro** is a set of simulators and templates which model the flow of product as items or continuous streams. The continuous streams can represent either bulk or high-speed flow. The product includes components for modeling process control and scheduling, as well as hierarchical templates used to represent higher level constructs.

Figure 1 is the overview model worksheet. It shows the two making lines, the surge tanks and the individual pack lines. The actual components of the model are contained within a hierarchy of blocks, which are successively opened by double clicking on their images. The model schedules, equipment performance and failure characteristics, changeover times and other data are contained within the tables of a database housed within the model, and accessed by a logical scheduler construct.

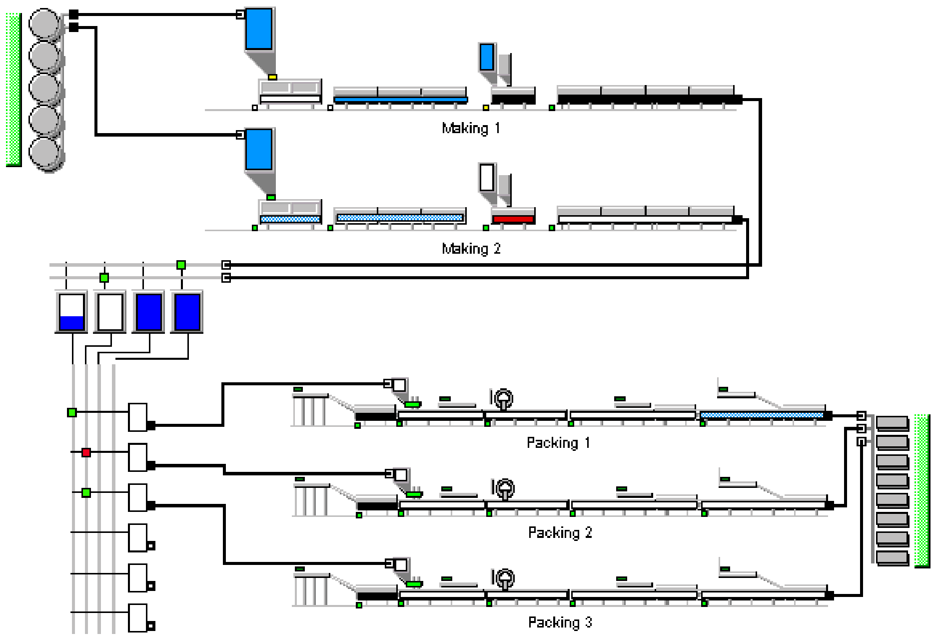

Figure 1. Making / Packing Simulator

This model runs products through making and packing equipment under the control of a logical scheduler, which accesses a sequence listing the products and quantities to run. The scheduler sets up the machines' rates and directs machines to perform changeovers when necessary. The model produces reports, which are similar to what the real operation reports; e.g., production and utilization reports. The model experimenter is able to view these reports to address the questions posed.

This simulator was used extensively to assist the project team at the plant to determine the number and configuration of new making lines, packing lines, and surge bins to install. Several test schedules were developed to represent typical and extreme production requirements. These were run on the model of the existing plant and on a variety of proposed packing line designs. The sensitivity of proposed designs to vendor efficiency claims was also tested.

III. Simulation of Time, Flow, and Schedules

When a simulator is run, a simulation clock keeps track of elapsed time, which is incremented in steps. Steps of time are not predefined, but rather caused by events. In addition, the flow of material in the simulation is represented as rates. A simple example is the filling and emptying of a bin. An upstream machines fills the bin by supplying material downstream into the opening of the bin at a certain rate, say 9 ppm (pounds per minute). Another machine downstream from the bin pulls material from its exit valve at a rate of 2 ppm. The bin starts the simulation empty, and has a high setpoint of 70 pounds. Since the contents of the bin rises at a relative rate of 7 ppm (9 minus 2), the high setpoint will be reached in 10 minutes. If these were the only dynamics involved in the simulation, the first step would be this first event, which occurs 10 minutes after the simulation is started. Once the bin reaches its high setpoint, the model can take different courses of action, simulated by using controls, which respond to events. Figure 2 illustrates a certain kind of bin which only feeds forward when it is full.

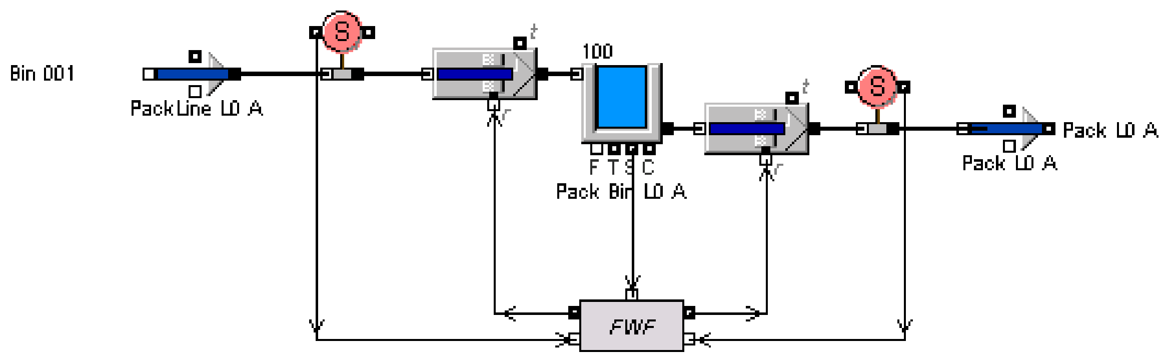

Figure 2. Submodel of a Feed When Full (FWF) Bin.

A machine can be configured to be realistic with respect to changes that can occur over time. For example, a simple machine could be set to always have a certain rate, such as 9 ppm, but to also have downtime. Downtime can be represented by intermittently scheduling events in which the rate is changed to 0, and having it persist at 0 for a certain duration. Both the times between these events, and the duration during which the rate persists at 0 can be generated randomly, to realistically represent random time between failure and time to repair.

A machine's rate can also be changed by way of a schedule, which either adjusts the rate at certain points in time, or after certain quantities of product have been produced. In the latter case, the cumulative product is accounted for by knowing the rates and times that the machine persisted at those rates. In the FWF bin example, the cumulative production of the downstream machine at 10 minutes into the simulation is found by multiplying 10 by the rate of 2 ppm, which equals 20 pounds of cumulative production. A machine can be configured to estimate when a specified quantity goal for a given production run in the schedule will be attained, and to trigger a model event when that occurs. This event can in turn trigger other events to be scheduled, such as changeover processes, which are dependent on both the previous and next product.

IV. Kinds of Simulators and their Uses

The kind of simulator used to analyze a manufacturing system depends on the problem to be addressed. Some simulations involve only processing operations or only packaging operations, while others involve both. Simulators can involve simple dynamics of starting up and shutting down, or they can be driven by a complex schedule. Models can also describe the transformation of material properties and constituents in unit operations such as reactor, aggregators or sifters, grinders, agglomerators, dryers, and pelletizers.

Startup / Shutdown Simulators

An example of a packaging simulation alone is shown below.

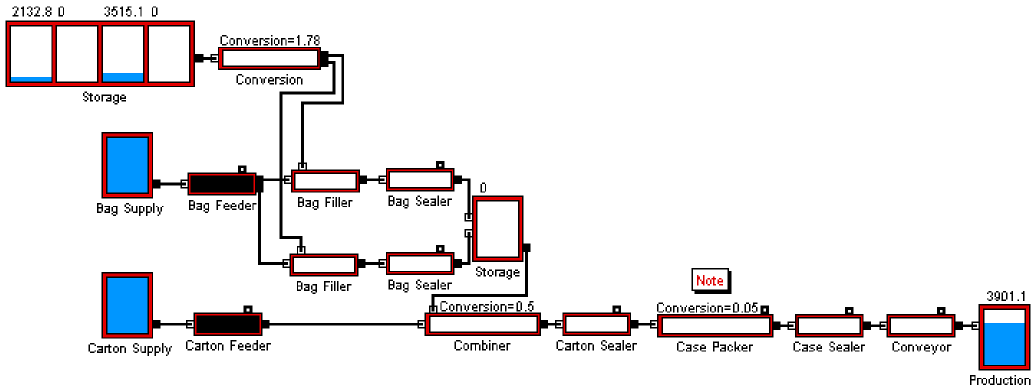

Figure 3. Packaging Line Simulator

In this example the material from making in "Storage" is represented as an unlimited supply. Such a model is useful for designing a packaging line's buffer sizes, and for investigating the balance between reliability, rates and buffer sizes. By modeling the supply from making as unlimited, the model assumes that upstream operations never break down. If we wanted to characterize interruptions or flow rate changes from upstream, we could simply vary flow over time to get closer to reality. At some point our desire for more realism in the characterization of flow from upstream would drive us to model the making operation in the same model. Another aspect of this model is that there is no schedule driving the production. Instead, material is produced at a constant rate, and each machine undergoes periodic breakdowns, characterized by distributions for Time Between Failure (TBF) and Time to Repair (TTR). This kind of model is appropriate if the issue of scheduling is not so important in the problems addressed.

Schedule Driven Simulators

Scheduling and the issue of schedules often play a crucial role in the study of operations. A simulation model which addresses the scheduling issue will be a schedule, or sequence of specific kinds of work activities, to drive a dramatization of the operational actions and interactions that occur as that schedule is played out over time. Such a model enables you to test scenarios using any proposed sequence within any operational configuration. The model can be used to evaluate the real-world potential of a specific schedule, or it can be used to compare one scheduling policy against another, on the basis of how well schedules of each policy perform in the model. By experimenting with the different schedules, you can discover which schedule or even schedule-generating rules are best, because for each schedule the model will show real-world results such as production, utilization, and downtime, which can all be affected.

A simulator, which uses a schedule, should be able to import a sequence of runs, which has been created inside a spreadsheet or database. Scheduling personnel typically employ spreadsheets or macros to manipulate schedules, so the model must be able to capture the sequence prepared in the scheduler's spreadsheet. Beyond this import capability, it is extremely beneficial to have a way of generating schedules quickly so that various schedules can be tested.

Some simulators have a built-in module, which describes your scheduling practices. The simulator then quickly and flexibly generates both typical and experimental schedules, which are based on demand requirements or actual demand schedules. While such a scheduler module can calculate some deterministic measures of evaluation, the real test is performed by turning the schedule over to be run by the simulator, which yields complete results captured in the context of real world dynamics played out by the simulator. The scheduler can generate either firm schedules used across a whole simulated horizon, or it can be invoked throughout the run to generate inter-horizon schedules as dictated by the conditions through simulated timed. The model can show how well demand is met, and the status of all inventories throughout the simulated time horizon.

A simulator, which is driven by a schedule, can be extremely realistic in its representation of the dynamics involved in running an operation. For example, characteristics of the product can be used to set flow rates, drive changeovers from product to product, and to configure machine failure patterns related to the kind of product run. An example of this kind of configuration can be seen within the lower level detail of the case study model:

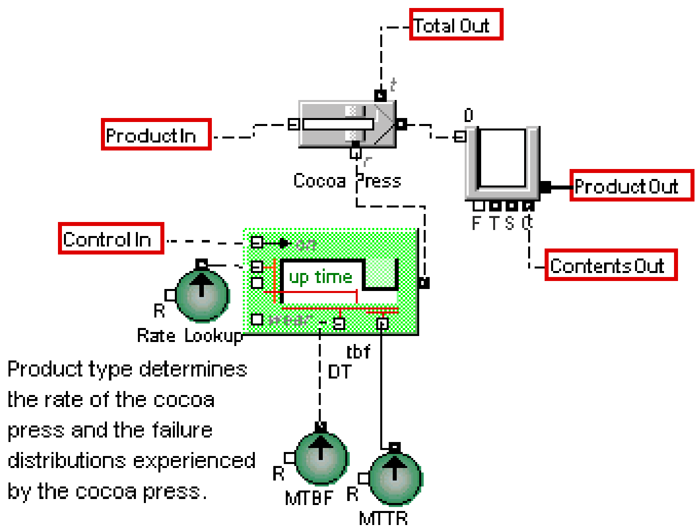

Figure 4. Submodel of Making Line Ingredient Supply

This section of model is used to describe the process of supplying ingredients to a making line. It shows how the feed rate and the downtime parameters are both set by the type of product. The Rate Lookup and MTTF blocks find tables, which contain process values as a function of product type.

V. Conclusions

Simulation is the tool of choice for studying problems in making and packing operations. Since so many of the factors interact in important ways through time, a simulator can provide a much more realistic vehicle for understanding the effect of design or improvement decisions. In effect, s simulator can be used like a pilot plant to test new concepts, or to evaluate proposed projects.

Simulators can be designed in a variety of ways to address the problems within industry. The simulators discussed here are provided in **SDI Industry Pro**, which is only one part of a family of simulators for studying industrial problems. A related product in this family of solutions is **SDI Supply Chain**, which is used to study the dynamics of the supply of materials to an operation through a chain of supplies. These two products can be integrated to create simulators, which focus on problems both within an operation and also upstream to suppliers and downstream to customers.