

Apply Model Predictive Control to Reduce Batch Cycle Time and Increase Consistency

Keywords

APC (Advanced Process Control), Batch, MPC (Model Predictive Control)

Summary

Model Predictive Control (MPC), once applied almost exclusively to continuous processes, is now being applied successfully to batch process control. Although MPC requires a higher initial investment in terms of dollars

Apply MPC to gain significant benefits through reduced batch cycle time and improved batch-to-batch consistency, effectively increasing plant capacity without increasing capital outlays.

and implementation time, for suitable applications the advantages over PID control are worthy of the additional effort and expense. Batch manufacturers who use MPC are experiencing significant benefits in the form of reduced batch cycle time, which effectively increases plant capacity without increasing capital outlays. Other

noteworthy benefits include improved product quality and consistency between batches. Typical applications that can benefit by adopting MPC technology include batch reaction and distillation to name a few.

Analysis

Batch processes are widely applied in many sectors of the chemical, pharmaceutical, food & beverage, polymer, consumer products, and biotechnology industries, among others. Batch processes are frequently utilized because of the inherent flexibility they possess in meeting market demand under short notice through product mix adjustments. However, batch processes are typically more difficult to optimize than continuous processes since they rarely reach a steady state. This has resulted in the adoption of inadequate control strategies and inefficient utilization of assets.

With globalization of markets, increased competition, and a greater demand for custom products, batch manufacturers have an increasing need to achieve greater flexibility and just-in-time manufacturing. Leading economic indicators suggest that the economic recovery will continue, resulting in capacity-constrained production that further exacerbates the

need to tightly control and optimize batch processes. Most improvement efforts are now focusing on either scheduling optimization or process optimization. Advanced process control is a technology that has important implications for process improvements in batch operations.

Model Predictive Control for Batch Processes

MPC is an optimization-based multivariable control strategy that uses a mathematical model, incorporated into a control system, to predict in real-time the control action to be taken on the process. The predictive model represents the relationship between the process inputs and the process outputs. The MPC has the ability to predict process behavior and proactively take measures to optimize control.

MPC has been the most popular advanced control strategy since its inception a few decades ago. It has found broad application and widespread use on continuous processes with well-documented benefits. Until recently, MPC has found limited use in batch applications. Without a doubt, if properly applied, advanced process control has the potential to improve performance significantly. The benefits of MPC applied to batch processes

can be just as significant as those achieved with continuous processes.

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Independent loop controllers perform poorly when attempting to control processes with interacting control variables. MPC is capable of providing improved control

for this situation by anticipating and compensating for interactions between variables and control loops. In other words, the predictive nature of the process model allows control loops to minimize the detrimental influence of a disturbance even before the actual affect of the disturbance is felt on the loop. In addition, MPC allows the optimization of variables within the constraint imposed.

MPC is equally applicable to single loops where PI or PID control performs inadequately because of long dead times or large time constants. This situation occurs quite frequently in manufacturing operations that utilize, among others, batch reaction and distillation. Operations that are prime candidates for applying MPC include those that are widely used in manufacturing processes and those that account for a significant amount of added value.

MPC Migrates to Batch Applications

Several examples of MPC batch applications are available that demonstrate that the benefits for batch operations are just as compelling as they are for continuous processes. For example, BASF is using MPC on several batch reactors at its ethyleneoxide-glycol surfactant plant. Prior to MPC implementation, the reactors used PI temperature control. The dynamic behavior of the exothermic chemical reactions caused the PI control to oscillate between heating and cooling. About 5 to 10 percent of the time, the oscillations were large enough to initiate a safety shutdown before the completion of the two-hour batch run.

BASF decided to use MPC on the reactors. The main reactor uses approximately 20 different recipes. It took about 4 months to perform the model identification process for all 20 recipes using data collected from open loop

By applying MPC, Baxter was able to reduce batch distillation cycle time by about 20 percent. Essentially, a reduction in cycle time translates into increase plant capacity.

experiments. Since implementing MPC, BASF has nearly eliminated all process stops.

Kaneka Delaware Corporation is a producer of chemicals and plastics. They operate a batch polyvinyl chloride (PVC) reactor where it is difficult to apply effective PID temperature control because the response is characterized by an open loop integrator with long delay and time constant. However, for this application, temperature control is critical because the amount and speed of product formation is highly dependent on maintaining a specific temperature profile.

Before applying MPC, Kaneka resorted to sophisticated ad hoc PID control strategies that used conservative temperature set point ramp rates to deal with the poor PID controller performance. By applying MPC, Kaneka was able to reduce the temperature variability by more than 60 percent. The improved temperature control allowed the reactor to be operated at higher temperatures, thus increasing reaction rates. This reduced the batch cycle time by 35 percent and effectively increased overall plant capacity. Subsequent to the successful implementation, however, the plant stopped production because of the decline in demand for PVC.

Baxter Healthcare is using MPC for its pharmaceutical facility that produces inhalant anesthetics. The MPC is being successfully applied to a batch distillation operation. The inhalant is produced in batch reactors along with other intermediates and byproducts. The inhalant products are separated by a batch distillation process. This distillation has been con-

trolled with various combinations of traditional PID control for the past ten years. The distillation process has been acceptable in terms of product yield and quality, but had unacceptably long cycle times. Using MPC, Baxter was able to shorten the cycle from about 18 hours to about 14 hours.

MPC Advantages and Disadvantages

Reduced batch cycle time is MPC's biggest value proposition for batch manufacturers. For production-constrained manufacturing, MPC can provide additional throughput or capacity without additional capital expenditures. In addition, MPC reduces process variability for improved safety, higher quality, and better batch-to-batch consistency. These benefits must be weighed against the fact that MPC is more expensive to implement due to the need to build a process model and may be more difficult to maintain.

Recommendations

- Consider adopting MPC on major process units where significant value is added to your product. Perform a cost/benefit analysis to determine if the incremental cost of MPC implementation is justified relative to the potential benefits.
- Identify critical processes or bottlenecks where throughput or quality is paramount. If the processes are characterized by long dead times or time constants, consider replacing PID control with MPC.
- Operator training is key to sustaining the benefits of an MPC project. Operators must be knowledgeable and comfortable using MPC otherwise they will turn it off. This requires dedication and a commitment by management.
- Many major control system suppliers and independent software suppliers offer MPC packages for continuous control applications. Look for a supplier with expertise or experience in applying MPC in batch control applications.

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