Applications and Benefits

Applications and benefits of Simulation in SME Process Industries

This analysis is based on a survey of simulation cases reported in literature and in various internet sites including Sim-Serv web site. The emphasis has been on finding “best-in-class” cases where the benefits have been clearly presented and if possible quantified. The resulting collection of cases has been published in Sim-Serv project database. This document links to the relevant entities in project database. The references have been underlined.

Small and medium size process industry is often characterized by batch processes due to the better flexibility and smaller capacity. The importance of these types of processes has also increased because of the trend to more differentiated products, such as specialty and techno chemicals, which are more tailored to customer needs. This is as opposite to bulk products, which are manufactured in large quantities by major companies.

There is certainly a need in small and medium size enterprises (SMEs) to improve their production, products and processes. The methods and approaches are somewhat different to large scale process industry. A difference is the type of production as discussed. There are also differences in the way of managing the improvements. It is typical for SMEs to use more external consults to manage the improvements, because the own resources are smaller.

In this paper the trends of applying simulation in small and medium size process enterprises for improving production, processes and products are discussed in more detail.

1.1 Production improvement

Many of the improvements in processes are available without changes in process equipment by using only improvements in the ways of process operation. Methods available include: Production planning to make the production to correspond the demand. A shorter time production planning called scheduling. In scheduling equipment is allocated for different products and a detailed production time schedule is done. Receipts can be optimised to use less expensive raw materials or varying product sources and to produce more even quality. Process conditions can be optimised for better product yield and quality. Operating conditions for new raw materials and products can be found more easily. All this is aided by implementing process simulation and optimisation as discussed in this paper.

1.1.1 Production scheduling

Batch production plants often include a relatively large number of equipment and products manufactured. Short-term production planning (scheduling) is needed to arrange the production time schedules of products for different machines or operations for a short period such as a week or two.

In multipurpose batch plants it is typical that the utilization rate of equipment is quite low, as one piece of equipment is waiting for the next batch. Therefore a large potential of capacity increase exists without investment costs. Better scheduling can increase capacity usually with tens of percentages compared to manual scheduling. Operating costs are reduced and product yield is improved. Also the time to produce a product is reduced. The man hours needed for scheduling can be reduced up to 50 %. (**case Leiras**)

In scheduling the problem is how to optimise the production operations in schedules. This involves discrete optimisation of a large number of variables. Methods available are based on mixed integer nonlinear programming (MINLP) or genetic algorithms.

may suffer e.g. fouling which reduces capacity during time. This is typical to filters, heat exchangers and membrane units. In some scheduling applications it is possible to plan the production in an adaptive way by considering the effect of the equipment capacity changes and to optimise the washing / purification times in relation to production schedules. (**case Genencor Intl**)

1.1.2 Production planning

In batch plants the products are often manufactured in campaigns, which are planned based on the orders received or expected. This is called production planning. In a campaign a product is manufactured for a time and then another campaign is started to produce another product. It may also be possible to manufacture several products at a time.

By using simulation on expected demands, available raw materials and other resources, production equipment, storage capacities and transport systems the production is planned for a longer period such as months. The aim is optimise the plant utilization and minimize costs. Often it is possible by planning to make longer campaigns and in this way to reduce the product changeover time. This results to an increased net production time in a year. (**case Lahden lasitehdas**)

1.1.3 Receipt management

Receipt management can help operation by keeping track of the production sequences going on and on the other hand by scaling and modifying receipts for different production arrangements. This may be needed if production scheduling allocates for example different equipment for production or another product quality is needed. This can be done by receipt simulation models. Savings in labour costs and better product quality can be achieved. In a dye manufacturing company a day was needed to rewrite recipes to use different equipment. Now an operator can reassign the equipment in seconds by using recipe management software. As a result the plant capacity has increased from 700 000 lb/month to 1 million lb/month (**case dye manufacturer**).

1.1.4 Receipt optimization

In many processes the product design problem is to manufacture a product with specified properties from several available raw materials. The aim is to maximize the use of inexpensive and easily available raw materials and to use expensive ones only for trimming the final quality. It may be possible to use different qualities of raw materials to manufacture a specified product (**case Rhone-Poulenc2**). Usually the quality changes of product are unacceptable, so the main aim is to minimize the product quality changes even the raw material quality is varying by natural variation. An example of this is the manufacture of mixture type of products such as metals or oils. The usage of cheaper raw material components is maximized.

A company recycling scrap metal to metal products (**case Kuusakoski**) used stochastic simulation and optimisation to increase the utilization of recycled raw material usage. The problem was stochastic variation of scrap metal quality, which was used as a raw material for melting in the manufacture of products of specified metal composition. For tuning the product composition expensive higher purity metal components we used. The percentage of recycled raw material could be increased from 35 to 50 %. This resulted to savings in raw material costs.

1.1.5 Optimisation of process conditions for better yield & product quality

Process operations are often not run in optimal operating conditions (temperature, composition, residence time). Finding the optimum is time consuming and risky by using the existing process as a test bench. By simulation more exact conditions are found more easily for maximum product yield in reactors and maximum recovery in separation processes. Rhone-Poulenc was able to increase the production capacity of a batch plant by 8% without any capital investment by only identifying better operating parameters by simulation. This corresponds for an addition of $300000 in profits. (**case Rhone-Poulenc)**
Merck (**case Merck**) estimates that an overall performance enhancement of 20-30% can be achieved by systematic improvement of space-time yields.

If also scheduling is used in process operation the optimised residence times can be implemented in production. Otherwise it may be impossible to run the process in a new way due to schedule limitations. The simulation and scheduling usually lead also to a better and more even product quality. (**case Billerud**)

1.1.6 Optimising the process operation for new products, raw materials or ways of operation
A common problem encountered in production is to estimate new production parameters or process changes needed for a new raw material or a new product. This can be done usually quite quickly by process or equipment simulation. If key reaction parameters are known from experience or experiments, the new optimal residence times in reactors can be simulated. The capacity of separation equipment can be checked as well as the other equipment involved such as the utility systems. In addition to simulation it is also useful to check, if there are changes in scheduling, which may lay constraints on production due to lack of common resources such as steam, labour etc. In this way the feasibility of changing e.g. to a less expensive raw material can be checked by simulation and the new operating parameters determined. (**case Rhone-Poulenc2**)

1.2 Process design and improvement

In process design and retrofitting process simulation can be used in many ways. These tasks differ from the previously mentioned, because they include usually changes in process equipment and therefore capital investments are involved. By using batch process simulation 5% reduction in capital costs and 20-40% reduction in operating costs in the design of new plant was noticed (**case Merck**).

1.2.1 Process efficiency improvement by rigorous simulation of equipment
By using rigorous unit operation simulation a more exact prediction of operating values and equipment capacities can be calculated. Earlier much ideality assumptions were made in simulation, since models were not very rigorous. For instance separation units were assumed to work in equilibrium stages and reactors to exhibit either ideal mixing or plug flow patters. Because of these assumptions empirical correction factors (efficiencies) introducing accuracies in design were employed. Since many new rigorous simulation methods such as rate-based models, new phase-equilibrium models and computational fluid dynamics are available for more reliable results. Therefore possibilities to optimise have improved resulting to cost savings in design and operation.

Better models can also aid process development by reducing the number of experiments and test scales needed to develop and a new or improved process. Therefore by using simulation also SMEs can improve their processes and even develop a new process with a more reasonable cost, since the man hours and capital investment needed for experimentation are much less than by using the traditional approach, which included many experiments and test equipment building in various scales. (**see white paper on simulation trends in computer aided process engineering in Sim-Serv web site**)

1.2.2 Process system simulation and debottlenecking
Often non-simulation based approaches lack the consideration of the system point of view of the process. It is not enough to study only a single piece of equipment for improving a process or increasing its capacity but also the whole system including utilities and auxiliary systems should be simulated in the new situation. In a known case (**case Eli Lilly**) the investment plan has been totally changed after a total system simulation check, when it has turned out that making a 'capacity increase' in a system would in fact reduce the total system capacity in a batch plant because of limitations in utility systems. By simulation much less capital intensive way of increasing capacity was found.

Other simulation benefits are savings in capital investments as noticed in a case, where a simulation study gave as a result, that it was not necessary to replace several equipment items with larger units as proposed by designers prior to making a simulation study. (**case Rhone-Poulenc**).

1.2.3 Safety improvement
Also in SMEs many accidents have taken place due to runaways and explosions in reactors, batch columns etc. The safety checks can utilize simulation after the reaction chemistry has been checked experimentally in a reaction calorimeter. The capacity of the cooling system can be simulated either in steady state or more realistically in a dynamic way together with the relief and blow-down systems. In this way a realistic understanding of the capacity of the system is received. Rechecks

can be done more easily by simulation when new products are being manufactured in future.

1.3 Conclusions

In the last years new methods has been introduced, which serve especially small and medium scale process enterprises. Process production planning and scheduling by simulation and optimisation based methods has lead to large capacity increases often without capital investments by increasing the equipment utilization and reducing product changeovers.

More rigorous process equipment simulation has lead to the possibility of optimise the production parameters in a reliable way for many operations such as reactors and separation equipment. This has lead to larger product yield, better productivity and less waste. Also process improvement and even new process development has become attractive to SMEs since previously the time consuming and expensive development projects can be fastened by simulation, since part of the experimentation and piloting can be substituted by simulation.

The reliability of process improvements and de-bottlenecking projects has been increased, when the total process systems can be simulated more easily. The capacity of the total process can now be checked in the new situation even together with the utility systems. In this way fewer surprises arise as the capability of the total process has been checked in the new situation.

In future more realistic and rigorous simulation and optimisation methods are available: More complicated batch process scheduling and product trim problems (minimization of cutting waste) can be solved by optimisation, when the models even allow more variables.

Equipment calculation will in future include consideration of non-ideal fluid flow patterns as standard. For example reactors can be simulated with more realism, when the real concentrations fields in a vessel are known instead of ideal mixing assumption.