PROCESS PLANT KNOWLEDGE BASED SIMULATION FOR DESIGN AND MANUFACTURING

Mihailo Peruničić[1], Snežana Krstić[2], Milan Milivojević[2],

[1]University of Novi Sad, Faculty of Technology,
21000 Novi Sad, Cara Lazara 1, Serbia
[2]University of Belgrade, Faculty of Technology and Metallurgy
11000 Belgrade, Karnegijeva 4, Serbia

snezana@tmf.bg.ac.yu(Snežana Krstić)

Abstract

This paper presents an integrative framework describing concept techniques to particular knowledge engineering problems to be ivolved for process simulaton. Modelling the production of many products can be used as a valuable design and manufacturing tools. One of the most interesting and ecouraging trends in process simulation is its use in many more of the total range of activities concerned with process plant design and operation. This paper describes multipe model purposes to simulate reality. It many years since process simulation become a standard tool for design work in most companies. They need technology which at the design stage allows them to evaluate operating strategies, perform optimization, evaluate control system performance and subsequently gain full benefit in manufacturing. The best feed for for the plant considerring issues such as feed cost, product quality and current product value in the market were analyzed to design of the plant. As a case study a plant of sweet slurry for aromatiziring drinks, from starch was used. The obtained results of the sequential modular approach simulation from unit operation to unit operation were illustrated of the best quality for slurry using for different products.

Keywords: Designer, Optimizer, Multipurpose simulation, Knowledge based technology.

Snezana Krstić. Assistant. University of Belgrade, Department, Faculty of Technology and Metallurgy; Education: B.Sc., M.Sc. and Ph.D. degrees at the University of Belgrade, Faculty of Technology and Metallurgy; Research Interest: Process Operation and Optimization, Process Design, Safety and Risk analysis, Computer Aided Process Operation, Information System, Data Bases, Expert Systems; Informatics; Management. Other Professional activities: Over 40 papers in the field, Member of many professional organizations.

ISBN 978-3-901608-32-2

1 Introduction

Being a key to survival in global markets including the previous needs and challenges, process engineering necessitates the today evaluation in research and teaching. It involes the whole of scientific technical knowledge necessary for physicochemical and biological transormations of raw material and energy into targeted products necessitaed by the customer.

Thus chemical and process engineering is now concerned with the understanding and development of systematic procedures for the design and optimal operation of chemical and process systems, ranging from microsystems to industrial scale continuous and batch processes [1-3].

It many years since process modeling become a advanced tool for design work in most companies. Yet the major impact of this technology may still be in the future as more companies appreciate its values as strategic support for business operations especially in manufacturing. The means that process engineers and plant managers need even more sophisticated tools to study the behavior of the plant.

The outstanding advantage of the knowledge based simultor is its flexibility. These techniques are much more demanding in terms of numercal techniques it is only in recent year that such systems have matured sufficiently for use as a day to day production tool.

2 Knowledge based simulation

The general framework presented above generally is valid in the development of any complex computer based applications in process engineering, such as plant simulation models, or model based training systems. The life cycle concept may lead to a reliable and maintainable software tool.

One of the most widely used forms of simulation is that for operator training. So far operator training simulators have tended to use greatly simplified models in order to ensure real time performance and most effort has been invested in the development of user interface. With the availability of much increased computing power the way is now open for the same simulation model to be used for operator training purposes. A further aspect of the extended application of simulation for operator assistance could well be achieved in conjunction with expert systems [4] .

2.1 Design

The use of flowsheeting in design, however, differs from its use in operations and this should be reflected in the development of the simulation procedure. In design, attention focuses on the main elements of material and heat balances, on equipment investment, and more generally, on process economics. The systems approach permits the evaluation of feasibility and global plant integration, always for a predicted behavior of the reaction systems. While a deeper systems analysis of the plant would be worthwhile, considering that the basic design could be responsible for more than 80% of the cost of investment and operation, a detailed simulation and constrained, however, by the project schedule and lack of data.

2.2 Operation

In operation, in contrast, attention centers mainly on product flow rate and specifications, but also plant troubleshooting, controllability, and maintenance. The performance of reactors and separation systems impose the rules of the game. They are independent and time variable to some extent. Only a detailed plant simulation enables an understanding of these interdependencies and their quantitative evaluation. Thus, the exact knowledge of a detailed material and energy balance is by far more important in operations than in design. Even the flow rates of trace impurities are relevant, because they may impact equipment maintenance and environment protection. The material and energy balance as well as the operational characteristics of a plant are highly interconnected, and well suited for a system analysis.

3 Knowledge based process plant model development

Using commercial flowsheeting software, it is possible to produce a computerized tool that will permit us to learn or even “mirror” the plant behavior under different operating conditions or with different raw materials and product specifications. Such as tool is called the steady state plant simulation model. Process simulation and modeling techniques are very useful for optimizing design and operation.

Developing such as model is a preliminary and necessary stage in achieving real time plant optimization which involves treating data reconciliation and rigorous simulation simultaneously by means of optimization techniques, whose objective is to maximize process profitability. The steady state model, which is simpler to build, and has a wide variety of applications in its own right, it can be used directly in revamping and a wide variety of other engineering projects.

3.1 The plant simulation model objectives

The plant simulation model should mirror the behavior of a complex plant subject to constraints in feedstock, products, equipment capacities, operational parameters, and utilities consumption.

It's objectives include to:

Provide comprehensive report of material and energy streams,

Determine the correlation between the chemical reactors and separation systems;

Study the formation and separation of byproducts and impurities;

Support preventive maintenance by tracking performance of key equipment over time, and its relation to the buildup of impurities;

Improve to robustness to plant operation;

Asses how to eliminate wastes and prevent environment pollution;

Evaluate plant flexibility to changes in feedstock or products;

Validate process instrumentation and enhance process control,

Update process documentation and prepare future investments, and

Optimize the economic performance of the plant.

The achieve these goals, the rigorous simulation model must be tuned. This demands reliable plant data stream compositions, temperatures, pressures, and so on. These are obtained from test runs during steady state operation.

3.2 Flowsheeting recycle structure

To develop a plant simulation model, should be first developed a Simulation Flow Diagram-SFD. It is close to but not identical with the process flow diagram-PFD, because of modeling limitations or flowsheeting convergence constraints. This means that the simulator should be provided with capabilities assuring flexibility both in modeling as well as in flowsheeting procedures, for instance.

Transfer of information between units, such as heat exchanger duty and mechanical work or between streams,

Full access to stream and unit variables, both in retrieving as well as in modifying mode,

Powerful user programming capabilities, and

Flowsheet split/ merge features.

Unfortunately, the technical literature provides little information about structural analysis of a large plant for simulation purposes. First, the recycle structure of a large flowsheet may be analyzed by means of some simple structures. These typically are structured loops, crossed loops, and interconnected loops.

Flowsheet decomposition involves selection appropriate tear streams. The basic concept in tearing has bean review in references [5].Most commercial simulators provide automatic procedures tear stream identification and for generation of the calculation sequences (ASPEN PLUS, SPEEDUP CHEMSHARE, CHEMCAD etc.).

3.3 Dynamic simulation

Dynamic simulation is a process engineering tool that predicts how process and its controls respond to various upsets as a function of time. Dynamic simulation model leads benefits during plant startup. Control system design is validated using dynamic simulation. Dynamic simulation also provides controller tuning parameters for use during startup.

Dynamic simulation model can be used to evaluate equipment configurations and control schemes.

4 The starch plant model

Summer wheat mills and starch converts into sugars after liquefaction, fermentation and conversion using corresponding enzymes. Partial starch hydrolysis is performed with α-amylase. The second phase deep hydrolysis is occurs at the present sweeting enzymes.

4.1 Biochemical reaction models

General kinetic model have involved Monod's

model. $E + S \underset{k-1}{\overset{k1}{\rightleftarrows}} ES \xrightarrow{k2} P + E$

$$\frac{dc_{ES}}{dt} = k_1 \cdot c_E \cdot c_S - k_{-1} \cdot c_{ES} - k_2 \cdot c_{ES} \quad (2)$$

and product rate

$$\upsilon = \frac{dc_P}{dt} = k_2 \cdot c_{ES} \qquad (3)$$

where *E* is enzyme, *S* is substrate, *P* is product,

c is concentration and *k* is specific rate constant.

4.2 Model for sweet syrup production

The starch plant for continuous sweet syrup production consists of a container for spring bean, mill, fermentor, exchangers, bioreactors, and filter as individual process stages, or equipment items.(Fig.1).

The overall mass balance

$$\sum_{i=1}^{NM} s_i \partial_i F_i = 0 \qquad (4)$$

Substream mass balance

$$\sum_{j=1}^{NSS} \sum_{i=1}^{NM} s_i F_i f_{ij} = 0 \qquad (5)$$

Component mass balance

$$\sum_{k=1}^{NC} \sum_{j \neq 1}^{NSS} \sum_{i \neq 1}^{NM} s_i F_i f_{ij} z_{i,j,k} = 0 \qquad (6)$$

and overall energy balance

$$\sum_{i=1}^{NM} s_i \partial_i F_i h_i + \sum_{i=1}^{NH} s_j \partial_j H_j + \sum_{i=1}^{NW} s_k \partial_{ki} w_k = RHS \qquad (7)$$

equation i, where s_i = ,+1 for inlet streams and -1 for outlet streams, ∂_i is stream scale factor, F_i mass flow stream *i*, f_{ij} is mass fraction of substream *j* in stream *i*, z $_{ijk}$ is mass transfer of component *k* in sustream *j* of stream *i*, NM is number of inlet and outlet material streams, NH is number of inlet and outlet heat streams, NW is number of inlet and outlet work streams, NSS is number of substreams within material streams, NC-number of components specified on the components main or components group forms, h_{ij} is enthalpy of stream *i*, H_j is flow of heat stream *j*, w_k is work of work stream k, RHS is right hand side of the energy balance equation.

Additional material relationships can be specified which is very useful for reactive systems,

$$\sum_{j=1}^{NT_i} C_{ij} F_{ij} = RHS_i \qquad (8)$$

where C_{ij} coefficient term j in equation *i*, as determined by stream, substream and term, RGS_i right hand side of mole/mass equation i, NT_i is number of terms in mole/mass equation i.

Having defined the relevant compounds, the elementary and enthalpy balance can now be defined. There are three relevant elements and three elementary balance for C,H,O and enthalpy balance need to be formulated.

Carbon balance: $6x_g + 6x_{st} + x_c + x_s = 0$

Hydrogen balance:

$$12x_g + 10x_{st} + 2x_w + 2x_{sacid} = 0$$

Oxygen balance:

$$6x_g + 5x_{st} + 2x_o + 2x_c + x_w + 4x_{sacid} = 0$$

Enthalpy balance:

$$-303x_g - 235x_{st} - 94x_c - 68x_w - 194x_{sacid} - 536x_s + rH = 0$$

5 The plant design and operation

The input component data base and data base of kinetic parameters have developed as a relational data base system which linked with operation simulation by process models.

A reactor simulation with detailed kinetics and a realistic flow model may be executed better with specialized software[4]. In fact, in flowsheeting only need an accurate description of the transformation linking the input the output of the reaction system. This again highlights the differences between design and operations, in the design mode, the modeling of chemical reactors focuses on the main products rates,

Fact, the time behavior, like catalyst activity, or impurities generation , is difficult to estimate. In contrast, in operations, a detailed knowledge of the reaction systems is available, but its interaction with other equipment items is still unknown.

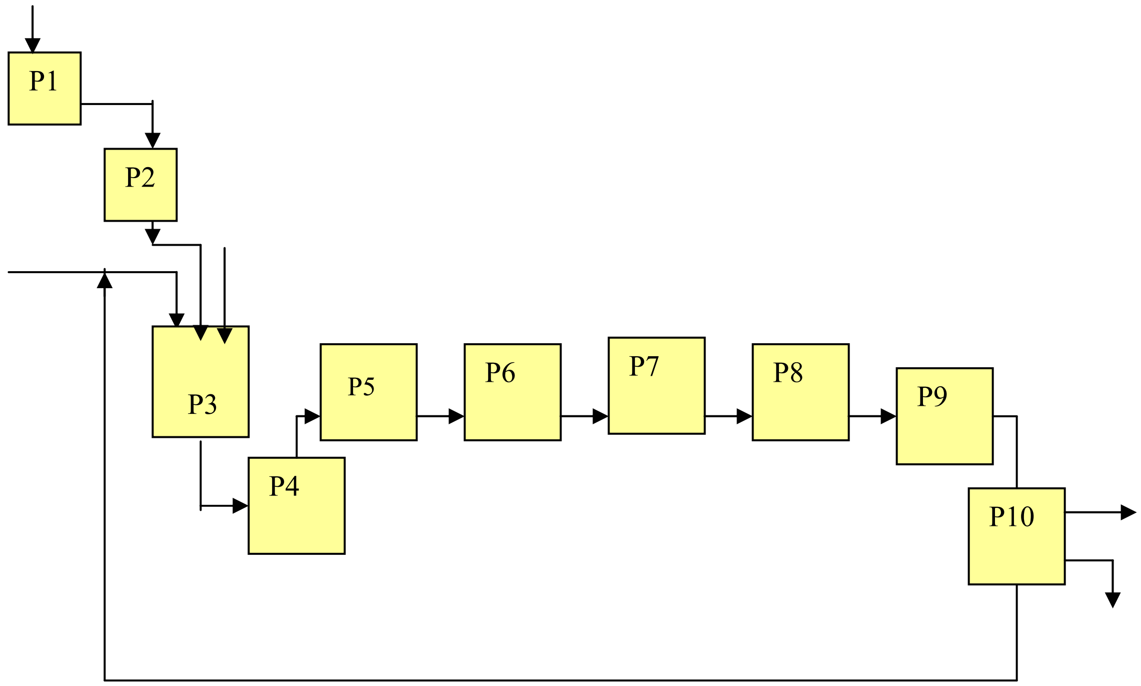
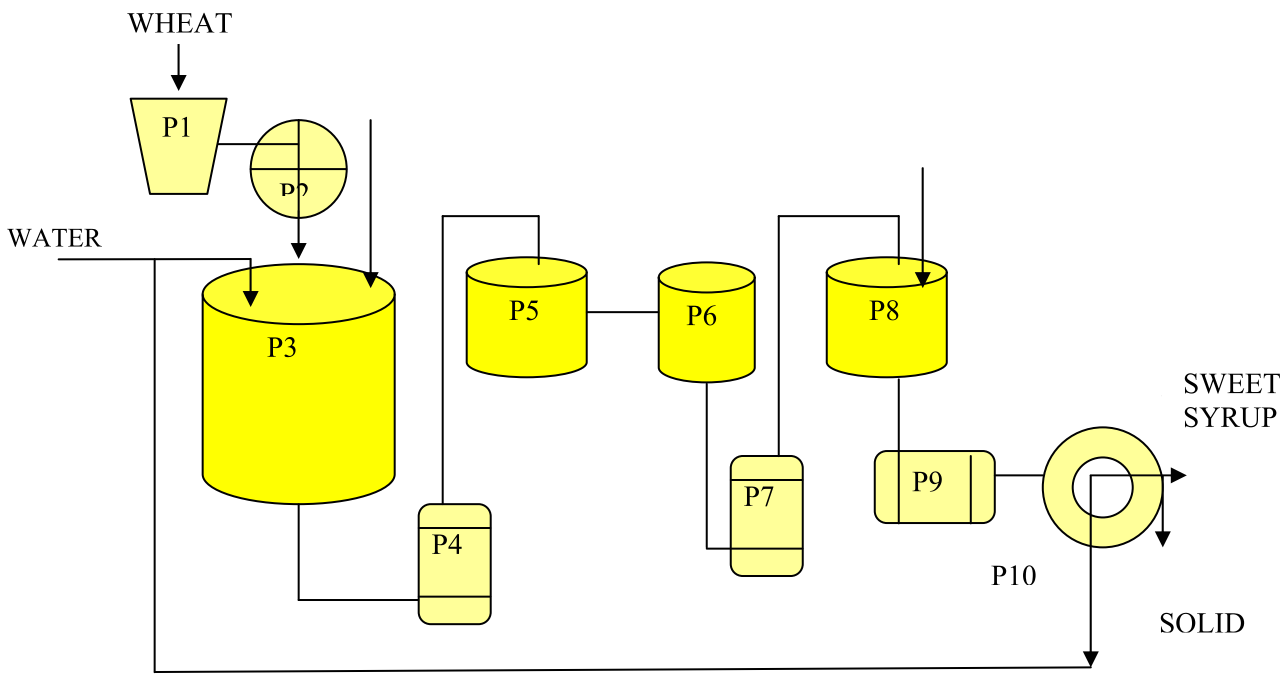


Fig. 1 The starch plant process simulation diagram



P1- container for summer wheat, P2- mill, P3 –fermenter, P4 –heat exchanger, P5- first bioreactor , P6- reactor for starch decomposition,P7-cooler, P8-reactor,P9-heatexcahanger and P10-filter.

Fig.2 The starch plant process flow diagram

ISBN 978-3-901608-32-2

The ability to describe the output composition of a complex reaction system for given reactor operating conditions as function of variable input stream is the key feature that need in modeling the chemical reactor in flowsheeting. A set of stoichiometric, independent chemical reactions has been formulated and molar extent of reaction used as the reaction coordinate (Eq.1)and (2).

For the examined starch plant in which starch converts into sugars after liquefaction, fermentation and conversion flowsheeting is shown in Fig.1. Fig.2 shows the process plant flow diagram with main process units.

The use of advanced modeling technique for an actual automated equipped involved the continuous steady state nature of the processing units starting from the crude tanks and ending in the component tanks.

5.1 Glucose reactor dynamic simulation

Starch converts into sugar in reactor (P6). In attending caustic soda and calcium chloride mass of sugar increases and mass of starch decreases with time. A various conditions and operation region during starch conversion was simulated.

Acknowledgment. The authors wish to express their gratitude to the Fund of Serbia for Financial Support.

6 Conclusions

In this paper knowledge based process design of the starch plant was studied. The simulation flow diagram and the process flow diagram were developed.

Process plant simulation models were constructed and collected for starch plant design and operation. The knowledge based system which automated the process, enabling engineers to perform modeling and simulation was built.

A relational data bases which including component data base and data base of kinetic parameters have developed. This relational data base system has linking with operation simulation by process models.

Advantages of the employed technology to the acid hydrolysis are higher yield of dextrin, less contents salt in the products, and no protein decomposition.

References

[1] Mah,R.S.H., *Chemical Process Structures and Informatuion Flow*, Butterworths, Sevenoaks, U.K.,1990.

[2] J.Savković-Stevanović, *Process Modeling and Simulation*, FTM, Belgrade,1995.

[3] B.Thome ED., *System Engineering-Principles and Practice of Computer Based Systems Engineering*, John Wiley, New York,1993.

[4] J.Savković-Stevanović, Process plant knowledge based Simulation, Proceedings of the *12th Symposium and Seminar on Information and Expert Systems in the, Oil, Pharmaceutical and Food Process Industries*, p.8-71,Oct.26-27,2001.

[5] J.Savkovic-Stevanovic, T. Mosorinac, S.Krstic,R.Beric, Computer aided operation and design of the cationic surfactants production, Chapter 195-200, *Computer Aided Chemical Engineering -24*, Eds. V.Plesu and P.S Agachi, 195-200,2007..

[6] J.Savković-Stevanović, An interactive software package for fermentation processes,*CIPE89-Computer Integrated Process Engineering,* P/Ad.,England, September 25-28,1989.

[7] J.Savkovič-Stevanović, *BIOPRO- Simulator for bioprocesses*, Manual broshure, Faculty ofTechnology and Metallurgy Belgrade, 2000.

