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by Iwan Soenandi

A Real Time Simulation Model of Production System of Glycerol Esterification With Self Optimization

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Abstract— **This paper presents a new approach of a Real Time Simulation (RTS) to model the Glycerol Esterification (GE) production system with Self Optimization(SO). The quality and capacity of production GE are the factor that need to monitor and control. In this model, we deployed BPMN to analyze and design the requirement and used data acquisition system with real time sensor. Real-time data acquisition by optical sensors acquired several quality parameters such as viscosity, pH, purity and density which was interfaced to a SQL database. The model of self-optimization for quality surveillance was based on previous Wagels (2012) work. The experiments showed that the evaluation of the system performance was operatable to optimize a range of parameter esterification with Oleic Acid in producing Glycerol Mono Oleate (GMO) such as temperature between at range of 240-260 °C, baffle rotation speed between at range 300-400 RPM and volume at range 25-30 L for each batch .The previous works only set in a fixed value at 250 °C,350 RPM and 24L. In future work, it is recommended to accelerate the whole process including to re-structure the real time data acquisition system.**

Keywords: real time simulation; Glycerol Esterification (GE); self-optimization.

I. Introduction

The integration of advanced data acquisition for optimization and real time simulation offers considerable potential for innovations in the field of conventional production system. To increasing performance of system affected by many internal or external factors. An increase in the quality of the production system, which will secure sustained production for manufacturing companies, can thus be achieved [1]. Using SO on process level, for example can be used to calculate machine and process parameters online according to changing outer conditions [2]. In process production GE there exist many possible scenarios how to solve these problems, but which of these scenarios is the best (optimal)? Is it possible to imagine how a change in the subsystem affects the entire system? , As one a product of agriindustrial sector, Glycerol as by product of biodiesel. The production of Biodiesel is still increase, as the result from the government policy that use it for mixed material for solar. Glycerol is an oil soluble food additive It is also used as an ingredient in the production of chewing gum and ice cream [3].To produce Glycerol Esterification (GE) process that using raw material Crude Glycerol, there is small medium manufacturing that used conventional production system and has many customer requirements to make Glycerol Mono Oleate (GMO).

One of motivational example in optimization in GE production is such as follows : In conventional GE production system, the quality of product may vary from the customer requirement. It would affect to the unstable volume of production as this requirement observed and controlled manually. Our proposal for the optimization and simulation in a real time mode would enable for monitoring the flow of production and find the best parameter with SO. The mechanism of SO within the framework of RTS assumed each monitored parameters to a right adjustment.

The objective of these paper is to construct the model that applied the RTS method with SO. This method can be explained with BPMN diagrams, using sensors and data acquisition system and find the parameter of production that closely related to the quality of product and the volume target of production Glycerol Ester. In these paper for Section II we briefly explain description of problem. In Section III we briefly review the concept of SO in production system of GE. In Section IV we present analysis and design production system of GE. For Section V we make an experiment to compare the performance of system of the proposed method with the existing method and the conclusion are discussed in Section VI.

II. Description Of Problem

System is an integrated set of interoperable elements that working synergistically to perform value-added processing and to satisfy the user with a specified outcome [4]. Every system consists of its inputs, entities, outputs, stakeholders, roles, constrains, etc that need to be identified. The quality and capacity of production are the problem that involve in production system in GE because of their variously characteristic for quality in end product that sometimes in a part of the product that not satisfy the customer . In this research we focused on production and quality control that dynamically changes by the factors like: material condition and capacity flow process for the process reaction. To optimize all that division we are using computer simulation in real time ,and to find the best configuration of production system with SO . In these paper we explained how to collect data set by system acquisition with sensors and flow measurement of the process to monitor and control the volume by using BPMN diagrams and using discrete and continuous (hybrid) modelling simulation computer software ARENA (Rockwell Automation Software Inc 2011) and interfaced with a SQL database.

III. SELF OPTIMIZATION CONCEPTS IN PRODUCTION SYSTEM

A. Production System of GE

The complexity of production system on production GE, we analyzed it by using Business Processing Modelling Diagram as in Fig 1, With this analysis, we can explain clearly the low level tasking in the production system that can improve the efficiency and effectiveness in the system [5] especially in order to produce the GE.. The purity of glycerol obtained is low due to the presence of impurities such as remaining catalyst, water, soaps, salts and esters formed during the reaction [6]. The process of production GMO by reaction of Esterification that involving many parameter affected quality.

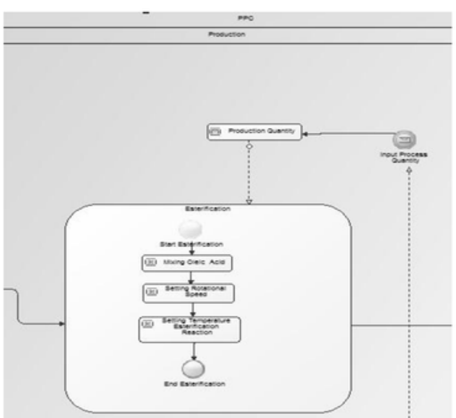


Fig 1.BPMN Esterification Process

B. Quality Control

In testing with FTIR, the method provides separation of acylglycerides, methyl and ethyl esters peaks. It was used C23:0 as internal standard. The method developed is faster and allows the elution of long-chain triacylglycerides [7]. But in this research we are setup QC system using Mid IR optical source and detector for identification ethyl ester peaks to meet the quality needed for the customer in GMO production as in Fig.2.

Fig 2 .MID IR LED Optical Source

C. Self Optimization

In order to design production system with using the optimum parameter we are using SO and simulation with real time data acquisition method .The behavior of optimization algorithms is random, so we had to perform many optimization experiments to identify the pure nature of the optimization algorithms doing it by automatically as diagram in Fig. 3. By considering the number of simulation experiments we can divide the number of simulation experiments as follows:Simulation experiment –simulation run of simulation model.

- Optimization experiment –performed with concrete optimization method setting to find optimum of objective function.
- Series –replication of optimization experiments with concrete optimization method setting.

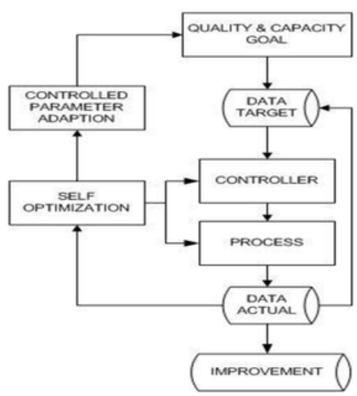


Fig.3. Self Optimization Process

We specified the same conditions to satisfies for each optimization method, e.g. the same termination criteria, the same search space where the optimization method can search for the global optimum. optimization method has the same parameters as another optimization method, we set up both parameters with the same boundaries (same step, low and high boundaries). Self-optimizing systems are defined by the interaction of contained elements and the recurring execution of the actions: [8]

1.continuous analysis of the current situation, in this case is parameter selected of pure gliserol

2.determination of quality targets of GE , production capacity , and

3.adaptation of the system's behavior to achieve these targets like temperature setting and rotational speed of reactor.In this paper we concerned to compare data from each sampling. We assumed:

$$f_{min}=f_t-f_{(t-1)} \quad (1)$$

and for the object optimizing is O_i, the self optimizing object , can be formulated as:

$$O_{i\ avg}\ opt(P)\leftrightarrow(A) \quad (2)$$

Where **P** is process, and **A** is attribute. In this case we can analysis **P** as $\{p_1,p_2,\ldots,p_k\}$ and attribute as $\{a_1,a_2,\ldots,a_m\}$.For Mathematical model of RELIEF(feature selection) The weight of the i th feature is then updated, the mathematical model is:

$$w_i = w_i + \left|x^i - NM^i(x)\right| - \left|x^i - NH^i(x)\right| \quad (3)$$

As we used in this research to find the parameter closely related to determined quality of GMO.

The development of a simulation of an actual system involves the creation of a conceptual model of the actual system to be simulated), which may be based on a set of rules, or a set of mathematical equations, or some other method of defining the state of the simulation and and the way in which it changes with time. A simulation based on a discrete model establishes an initial state of the system and a future event queue with event timings. Event-based simulation in which time advances from event to event in a single software thread has been the basis of many popular discrete simulation languages, but, as parallel computing options increase, process based simulation using parallel processors and multiple software threads has become the more popular approach.

D.Real Time Simulation

Real-time systems differ from traditional data processing systems in that they are constrained by certain nonfunctional requirements (e.g. dependability and timing constraints or requirements). An efficient simulation of real-time system requires a model that satisfies both simulation objectives and timing constraints [9]. There is one research developed a structure and architecture for automatic simulation model generation for very detailed simulation models intended to be used for real-time simulation based shop floor control [10]. They identified two essential stages to be automated for automatic simulation model generation: System specification and the associated model construction. In this work, a proposed methodology for building an Arena simulation model from a resource model as seen in Figure 4. This was made possible because the Arena simulation software supports Visual Basic Application (VBA), which enables application integration and automation. undertook the development of a modeling methodology to efficiently model real-time systems to satisfy given simulation objectives and to achieve arbitrary timing requirements.

In this paper we built the simulation of Manufacturing Systems is performed using RTS concept with Discrete and Continuous Event (Hybrid) Computer Simulation Program [11]. The Software for simulation we using ARENA Version 12 (Rockwell Ltd,2011)[12] with the schema in Fig.4 and real time data acquisition system with using flow sensor. The data was collected to SQL after the system of process has steady state condition.

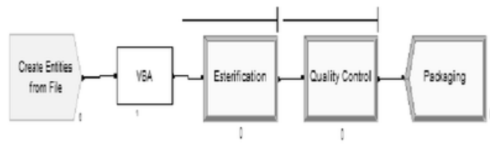


Fig.4 . Real Time Simulation Diagram of Production GE with ARENA

In this research we use field and data type for SQL as in Table 1, and designed the system block for processing signal from sensors to interface with a SQL connection in this work we deployed MySQL (Oracle 2014)[13] by using Microcontroller as diagram in Fig 5.

Table 1. Data Type For SQL Database

Field	Data Type
Time	Time
Sensor 1.2 µm	Numeric
Sensor 3.4 µm	Numeric
Sensor 5.4 µm	Numeric
pH Sensor	Numeric
Viscosity Sensor	Numeric
Temperature	Numeric
Rotational speed	Numeric

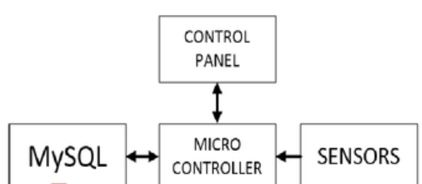


Fig.5. System Block Diagram for Real Time Data Acquisition

E. Quality Control Factor Analysis

In this work, o analysis the factor that are related to quality control and for select the parameter we used RELIEF algorithm which are generalisable to polynomial classification by decomposition into a number of binary problems proposed by [14]. We used RELIEF to reduce unimportant features that result for a more efficient computation and sensor task. In order to propose some updates to the algorithm (RELIEF) to improve the reliability of the probability approximation and make it robust to incomplete data, and generalising it to two-class quality problems which is passed and not passed as in Fig. 6 and the selection attribute weighted as in Fig.7. In RELIEF classification we have collected 30 dataset being tested by the customer of GMO.

%Water	Viscosity (poise)	%FFA	pH	Purity	Rel.Density	Quality Pass
50	0.0514	30	7	70	0.95	NO
40	0.0500	50	7	80	0.98	YES
70	0.0456	20	6	50	0.96	NO
30	0.0514	60	7	90	1	YES
50	0.0534	70	8	70	1.020	YES
40	0.0512	40	7	80	1.005	YES
80	0.0511	50	8	40	1.045	NO

Fig. 6. Sample Data Parameter for Quality Control

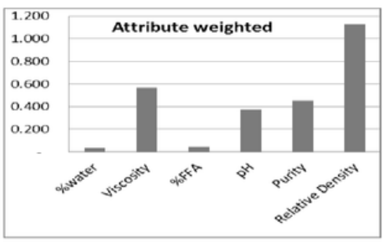


Fig. 7. Attribute Weighted Quality of Esterification

With RELIEF method we found the parameter that close related to quality is Relative Density, Purity, pH and Viscosity as the algorithm properties to explain this method as in Fig. 8. we identified quality parameter we are using optical sensors with real time data acquisition that connected to several quality parameter. And for the sequence of flow mixing as a process of production Glycerol Ester and Task properties for setting temperature was in Fig. 9 and Fig. 10.

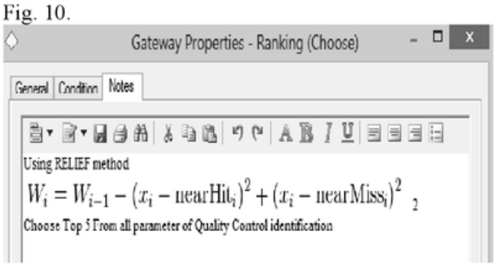


Fig. 8. Properties for RELIEF Method

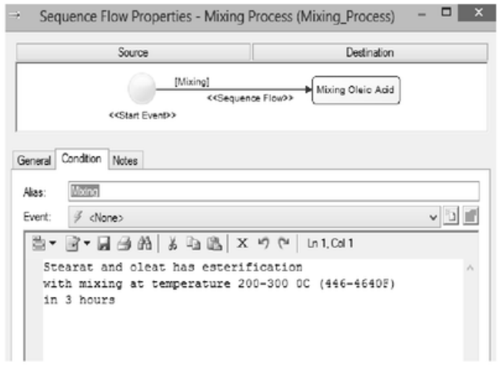


Fig. 9. Sequence Flow Mixing Oleic Acid

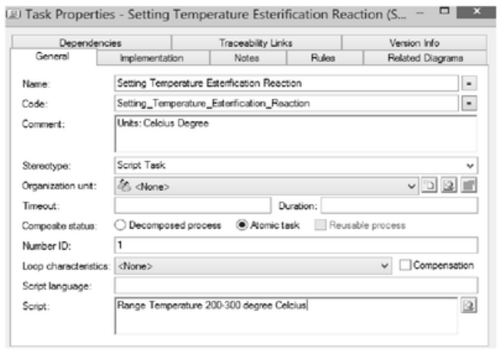


Fig. 10. Task Properties Setting Temperature

IV. Analysis and Design Production System of Glycerol Ester

A. BPM and Process Modelling

We refer to a Business Process (BP) as "a collection of related and structured activities undertaken by one or more organizations in order to pursue some particular goal. Within an organization a BP results in the provisioning of services or in the production of goods for internal or external stakeholders. Moreover BPs are often interrelated since the execution of a BP often results in the activation of related BPs within the same or other organizations [15]. BPM supports BP experts that providing methods, techniques, and software to model, implement, execute and optimize BPs which involve humans, software applications, documents and other sources of information.

This work had clearly shown that BP modeling has been identified as a fundamental phase in BP techniques which can help organizations to implement high-quality BPs,and to increase process modeling efficiency, has become an highly attractive topic both for industries and for the academy, to the best of our knowledge none of them introduces and supports formal verification techniques., such as the BPMN 2.0 [16].The primary goal of BPMN is to provide a standard notation readily understandable by all business stakeholders [17]. In this research we deployed BPMN regarded to the usefulness to model and represent for the complexity of the system. It means a clear description of the lower level process of the system analysis and design . Widespread adoption of the BPMN also helps unify the expression of basic business process concepts [18], as well as advanced process concepts (e.g., exception handling, transaction compensation). In this paper we found the reaction of esterification to get final product in this case is GMO as BPMN diagram in Fig.9. For the simulation we can explain the process with Event Generator as BPMN diagram in Fig 11.

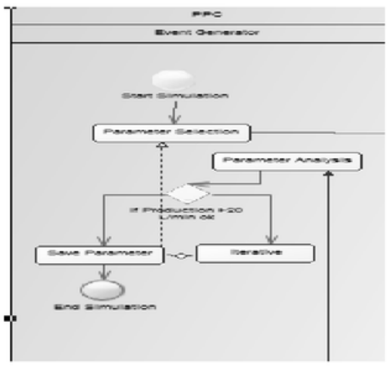
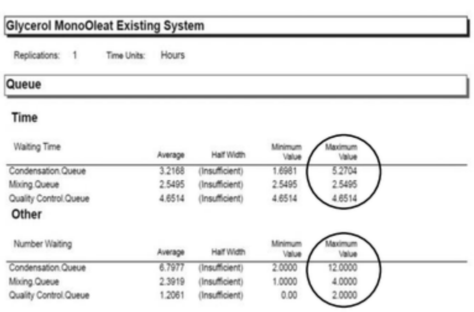


Fig. 11. BPMN Event Generator for Simulation

V. COMPUTATIONAL EXPERIMENT

A. Result and Discussion

For data acquisition we are using online data measurement interfaced with SQL database and inputs by optical sensors. From the RTS that collected after steady state condition in process production. We compared the performance of the system between existing process and using SO, we get lower average waiting time in process condensation and quality control as in Fig. 12 and Fig. 13.



Glycerol MonoOleat Existing System

Replications: 1 Time Units: Hours

Queue

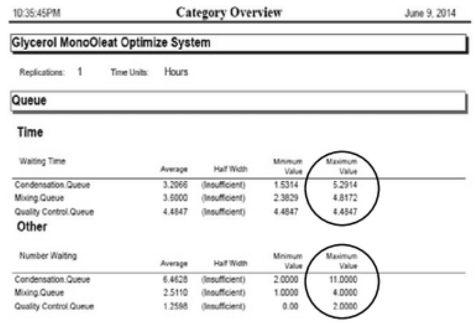
Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Condensation.Queue	3.2168	(Insufficient)	1.6981	5.2704
Mixing.Queue	2.5495	(Insufficient)	2.5495	2.5495
Quality Control.Queue	4.6514	(Insufficient)	4.6514	4.6514

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Condensation.Queue	6.7977	(Insufficient)	2.0000	12.0000
Mixing.Queue	2.3919	(Insufficient)	1.0000	4.0000
Quality Control.Queue	1.2061	(Insufficient)	0.00	2.0000

Fig. 12.Output Existing Process



10:35:45PM **Category Overview** June 9, 2014

Glycerol MonoOleat Optimize System

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Condensation.Queue	3.2066	(Insufficient)	1.5314	5.2914
Mixing.Queue	3.6000	(Insufficient)	2.3829	4.8172
Quality Control.Queue	4.4847	(Insufficient)	4.4847	4.4847

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Condensation.Queue	6.4628	(Insufficient)	2.0000	11.0000
Mixing.Queue	2.5110	(Insufficient)	1.0000	4.0000
Quality Control.Queue	1.2598	(Insufficient)	0.00	2.0000

Fig. 13. Output Optimized Process

In this research we identify the effect of controlled parameter, consist of: temperature, baffle rotation speed and volume production for this research we have collected 100 data from production process as the sample of data in Table. 2 to find the range of SO for best parameter in production system.

Table 2. Sample of Production Data

Temperature (C)	Rotation Speed (RPM)	Volume Production(L)	Quality
240	300	28	Good
260	300	27	Good
260	350	29	Good
250	400	30	Good

B. Verification Model

Computerized model verification ensures that the computer programming and implementation of the conceptual like modelling the production system GE using Power Designer. When a simulation language is used, verification is primarily concerned with ensuring that an error free simulation language has been used, that the simulation language has been properly implemented on the computer that a tested (for correctness) pseudo random number event generator has been properly implemented and building diagram of BPMN , and the model has been programmed correctly in the simulation language [19]. In this case verification is primarily concerned with determining that the simulation real time functions (e.g., the time-flow mechanism, pseudo random number generator, and random variate generators) and the computer model have been programmed and implemented correctly [20]. With Power Designer we verify the model with error checking as captured in Fig. 14. If the result has shown 0 error and 0 warning, it means the flow of the sequence and interaction of data flow between all swimlane is correct.

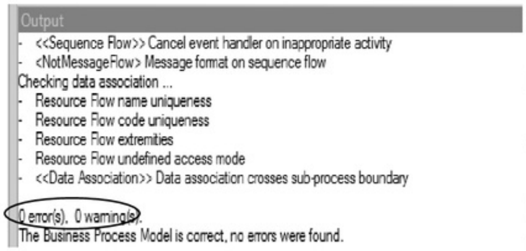


Fig. 14. Error Checking Report in Power Designer

VI. CONCLUSION

The modelling of a real time simulation model of production system of glycerol esterification with self optimization contribute to support the production system of GMO. The analysis of the model was described for lower level process detailed in BPMN 2.0 diagram. With those diagram we found the relationship and interaction between stakeholders and clearly used for the simulation to improve the performance system. Verification of the model ensured implementation of the conceptual model. As a result of zero error checking and the RTS run as well. The experiments showed that the evaluation of the proposed system such as temperature between at range of 240-260 ^{0}C, baffle rotation speed between at range 300-400 RPM and volume at range 25-30 L for each batch .Compared with the previous works only set in a fixed value at 250 ^{0}C, 350 RPM and 24L. In future work, it is recommended to accelerate the whole process including to re-structure the real time data acquisition system.

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