CHAPTER I

INTRODUCTION

1.1 Introduction

A batch scheduling process has been attracted wide attention of the scheduling research and industry community over the past two decades (Liu and Cheng, 2006). The processing time of batch is equaled to the longest processing time of the job in the batch. It is studied and implemented in manufactures such as automotive and petrochemical industries. The proposed of batch scheduling is to optimize the batch processing in order to increase production capacity, decrease defective material and avoid manual intervention.

In this study, it is to scope in the optimal and batch scheduling of suspension polyvinyl chloride production which has been founded and serviced in one of local petrochemical company in Map ta phut industrial estate, Rayong province, Thailand. The company holds production technology from one European licenser.

Polyvinyl chloride, (IUPAC, Poly-chloroethanediyl) commonly abbreviated PVC, is the third most widely used thermoplastic polymer after polyethylene and polypropylene (Wikipedia, 2008). In terms of revenue generated, it is one of the most valuable products of the chemical industry. Around the world, over 50% of PVC manufactured is used in construction. As a building material, PVC is cheap, durable, and easy to assemble. In recent years, PVC has been replacing traditional building material such as wood, concrete and clay in many areas. The use of non-PVC materials has been on the rise due to concerns about the environmental and toxicity characteristics of PVC. Nevertheless, the PVC world market grows with an average rate of approximately 5% in the last years and will probably reach a volume of 40 million tons by the year 2016.

Polyvinyl chloride is produced by polymerization of the monomer named vinyl chloride (VCM). Since about 57% of its mass is chlorine, creating a given mass of PVC requires less petroleum than many other polymers.

The most widely used production process is suspension polymerization. Unlike other plastic resin production, PVC production can be separated in 2 phases which are batch and continuous process. The first part is polymerization reaction part. In this process, VCM and water are introduced into the polymerization reactor calls autoclave and polymerization initiator, along with other chemical additives, are added to initiate the polymerization reaction. The contents of the reaction vessel are continually mixed to maintain the suspension and ensure a uniform particle size of the PVC resin. The reaction is exothermic, and thus requires a cooling mechanism to maintain the reactor contents at the appropriate temperature. As the volumes also contract during the reaction (PVC is denser than VCM), water is continually added to the mixture to maintain the suspension.

The second part of suspension polyvinyl chloride production is continuous process. Once the reaction has run its course, the resulting PVC slurry is degassed and stripped to remove excess VCM (which will be recycled into the next batch for polymerization) then passed though a centrifugal decanter to remove most of the excess water. The slurry is then dried further in a hot air fluidized bed and the resulting powder sieved before stored or palletization. In normal operations, the resulting PVC has VCM content of less than 1 part per million.

Other production processes, such as micro-suspension polymerization and emulsion polymerization, produce PVC with smaller particle sizes (10 μm until 120-150 μm for suspension PVC) with slightly different properties and with somewhat different sets of applications.

In the last few years, one local PVC producer had revamped their production line manufacturing by double annual rate production capacity (box diagram of the former revamping is in Fig 1.1). To reach this objective, one new batch autoclave reactor had been installed with the existing line. Down stream process had been modified to mach with the capacity from couple reactors. Stripping process which was needed to eliminate the residual vinyl chloride remained in pore of PVC resin had been developed from batch stripping to continuous stripping process. Decantation by centrifugal decanters, Fluidized bed dryer, Pneumatic transport for sending PVC to silos and PVC resin storage silos had been replaced by the new equipments. Block diagram of modification is here below in Fig 1.2.

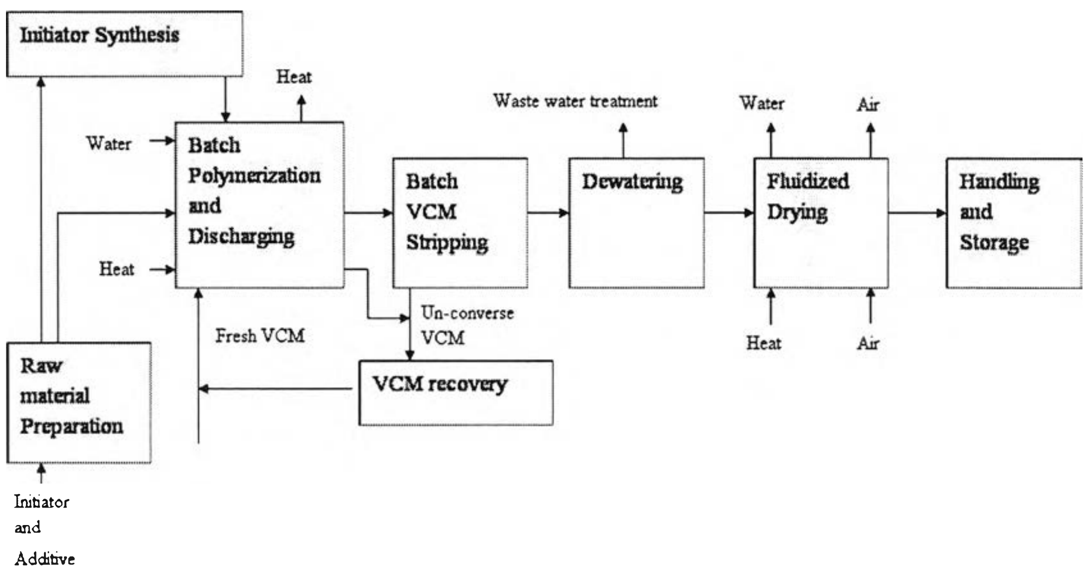

Figure 1.1 Box diagram of suspension polyvinyl chloride production line before revamping (Document submitted to BOI, Usaha, 2006).

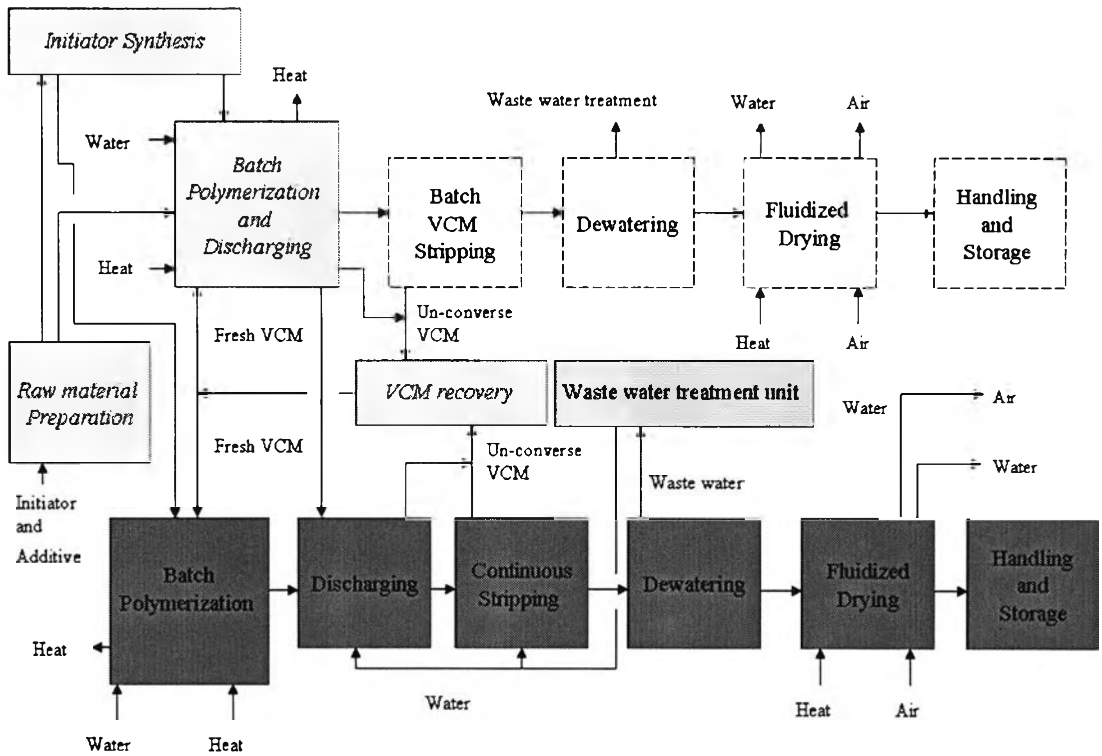

Figure 1.2 Box diagram of suspension polyvinyl chloride production line after revamping. Yellow boxes are existing unit, Blue boxes are unit and dot boxes are cancelled unit (Document submitted to BOI, Usaha, 2006).

Process flow diagram of the suspension polyvinyl chloride production after revamping, and duties of main equipment can be described following here bellows with the flow diagram in Fig 1.3.

1. Polymerization in 2 autoclaves (VCM → PVC): batch process.
2. Inventory in degasser: Batch to continuous frontier and main VCM degassing to gas-holder and recovery unit.
3. Cleaning slurry from PVC crusts in the filter.
4. Inventory in buffer tank: Used for smooth stripping column feed transitions.
5. Stripping in the stripping column: Eliminated residual VCM in pore of PVC resin.
6. Inventory in dryer feed tank: Used for smooth dryer feed transitions.
7. Centrifugal decanter: For mechanical drying PVC resin.
8. Actual drying in the fluidized bed dryer: Continuous process for final drying PVC resin.
9. Storing in 2 silos and hoppers for truck charging or to bag packaging hopper.

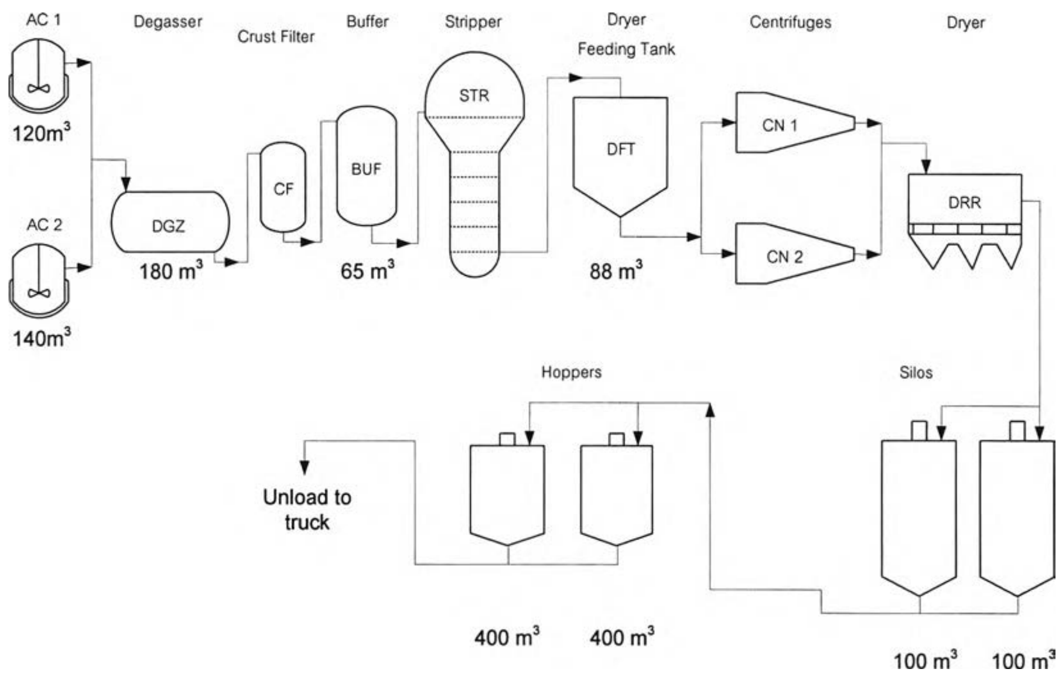

Figure 1.3 Process flow diagram of the Suspension polyvinyl chloride after revamping

In the rest of the document, it is considered all the magnitudes with the following these units.

1. Volumes in m^3
2. Volumetric Flows in m^3/h
3. Mass Flows in kg/min
4. Times in minute

1.2 Research problem

Because of its importance, it is briefly described the key equipment in this hybrid system, discharge and degasser tank, DGZ following process and instrument diagram in Fig 1.4.

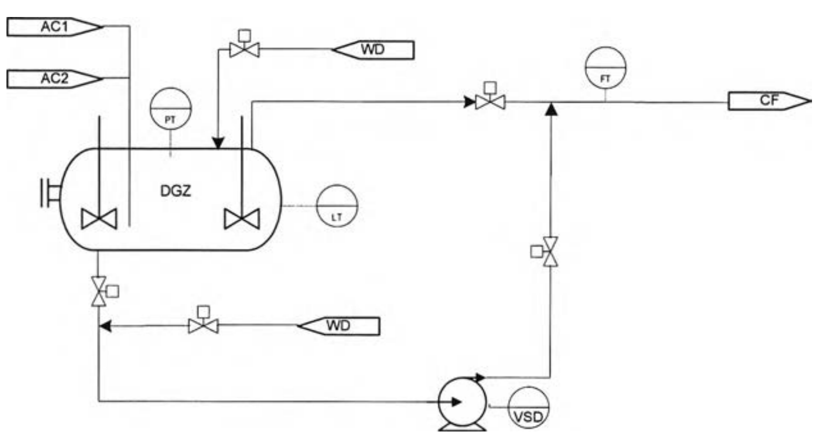

Figure 1.4 Control schematic of discharging and degasser

Two batch polymerization reactors call AC1 and AC2 discharges slurry (PVC resin suspends in water) in to degasser, DGZ. This 180 m^3 horizontal vessel represents the batch to continuous frontier in production line. This vessel is equipped with 2 agitators that maintain homogeneous of slurry, and has two possible outputs by drained at top or pumped by bottom of vessel. The bottom output pipe from the vessel goes to centrifugal pump that aligns with stripping column feeding tank (BUF) through crust filter (CF). Flow is measured by magnetic volumetric flow-meter and can be controlled by vary speed drive of feeding pump. This tank can be isolated from production line closing the 2 on-off valves. Pipe can be cleaned by opening the on-off valve. The level in the tank is indicated by the level transmitter.

The volume of DGZ (m^3) must be maintained between 10 m^3 and 150 m^3 because of both quality and technical reasons. An autoclave discharges is 125 m^3 (from AC2 which is larger volume than AC1). Total of slurry (nearly 115 m^3 slurry plus nearly 10-15m^3 of water to clean AC) means a variation of 125/(150-10) = 89% in the DGZ volume for each discharge (Principle of calculation from Biegler, 1999).

This is a very tight margin. To avoid autoclave waits for high level in DGZ of discharge or fault if the volume during the discharge exceeds 150 m^3 is necessary to have a very accurate control of the output flow out off the DGZ (m^3/h). The quality of this control strongly depends on the time estimations accuracy. For this reason, the time duration of each phase are automatically updated for each autoclave.

1.3 Objectives

Develop mathematical model to find the optimal schedule in order to.

1. Maximize the production rate to the most constrained bottle neck.
2. Start the batch at right moment to maintain constant time between batches discharge in degasser tank and compatibility with the current line maximal production rate avoiding waiting time.
3. Smooth the line production rate by predictive action by integration of the line limitation in the optimization problem.

1.4 Scope of research and assumptions

1.4.1 Scope of research

This study is scoped about the process operation and process control philosophy of suspension polyvinyl chloride production in order to understand clearly the existing operation prior considered simulation and optimization. The manufacturer produces suspension polyvinyl chloride polymerization in batch process and the down stream in continuous process. This study will be considered in both processes.

Main equipment which is installed and in serviced in the same line will be considered. The list and the capacity are in the table 1.1.

Table 1.1 Capacity and limitation of equipment in train

Equipment	Number	Capacity	Operation
Autoclave	2	140 m^3	Batch
Degasser	1	180 m^3	Continuous
Waste water drum	1	3.8 m^3	Batch
Degasser transfer pump	1	50 m^3/h, 30m	Continuous
Crust filter	1	3.08 m^3	Continuous
Stripping column feed tank	1	65 m^3	Continuous
Column feed pump	1	60 m^3/h, 60m	Continuous
Stripping column	1	23 ton/hr	Continuous
Column charge pump	1	60 m^3/h, 30m	Continuous
Slurry tank	1	88 m^3	Continuous
Centrifuge	2	15 x 2 ton/h	Continuous
Fluidized dryer	1	22 ton/h	Continuous
Pneumatic transport	1	25 ton/h	Continuous
Silo	2	100 x 2 ton	Batch

This study is performed for a suspension PVC resin grades 266RC which is around 70% of overall production and always kept production in this line production. Raw material and utilities here below in table 1.2 are limited to supply. The study is considered in the time horizon and the process is in the normal condition.

Table 1.2 Raw material and utilities for suspension polyvinyl chloride production

Raw material and utilities	Variable name
Initial water charging (WD)	WD
Anti-oxidant agent(s) loading	RMB
Dispersing agent(s) loading	RMX
VCM charging	VCM
Initiator loading	INI
Hot water charging (Hot WD)	WH
WD Polymerization	WDS
NH4OH loading	INH
Mass flow AC discharge	SYO
AC cleaning	HP
AC antifouling pulverization	NOX

1.5 Material and methods

Computer programming Matlab R2009b for simulation, optimization and a calculation mathematical model is used in the study.

1.6 Objective function

The objective function of studying is finding the scheduling in order to get maximum production rate in the assigned time horizon. In this study, the maximum production rate is the optimal period for starting up polymerization batch from both reactors.

Therefore the upper limit of the production is physical constrained of equipment and bottle necking of plant and the limitation of utilities supply. The lower limit of the production is constrained of minimum flow rate feed through equipment with out any equipment shut down. It can be selected from the maximum value of all limitation flow rate through equipment. If flow rate below the minimum value, process control need to let equipment shut down because of quality problem.

1.7 Assumption

- Utilities supply to the process is limited.
- Process which is used for created the model and optimization is in normal operation and situation. All assumption is all equipment will be operated until it's the physical constraints and plant bottle necking.
- Conversion rate of polymerization in both autoclaves are assumed to be constant.
- It is not considered the process in abnormal operation such as run away reaction of polymerization, equipment failure and the reduction production rate from marketing situation.

1.8 Benefit

Get mathematical model for optimal batch scheduling of suspension polyvinyl chloride production. It will be the proposed guide line to insure operation at nominal production rate and to maintain production line at top of its productive capacity, with out adding new equipment to the existing plant.

1.9 Research procedures and the sources of data

1.9.1 Research procedure

- Literature review for the concerned topics in journal, books, etc.
- Study about the process control philosophy of suspension polyvinyl chloride production for understanding clearly in existing operation. This manufacturer process produces suspension polyvinyl chloride polymerization in batch and down stream in continuous process. This study will be considered in both processes.
- Develop process model in Matlab R2009b to represent the real process which is studied in prior step.
- Verify process model and correct it if required.
- Formulate optimization problem in order to maximize the production rate in the time horizon. This stage will be considered base on physical constrained of equipment, the bottle necking of the plant and the limitation of utilities supply. It will be performed base on objective function.

- Solve optimization problem.
- Compare with the real production.
- Analyze the result of model. It is possible that the model will be revised and simulated again.
- The study will be performed for 1 suspension PVC resin grade. In this study 266RC is selected.

The work flow diagram can be written following here below in Fig 1.5.

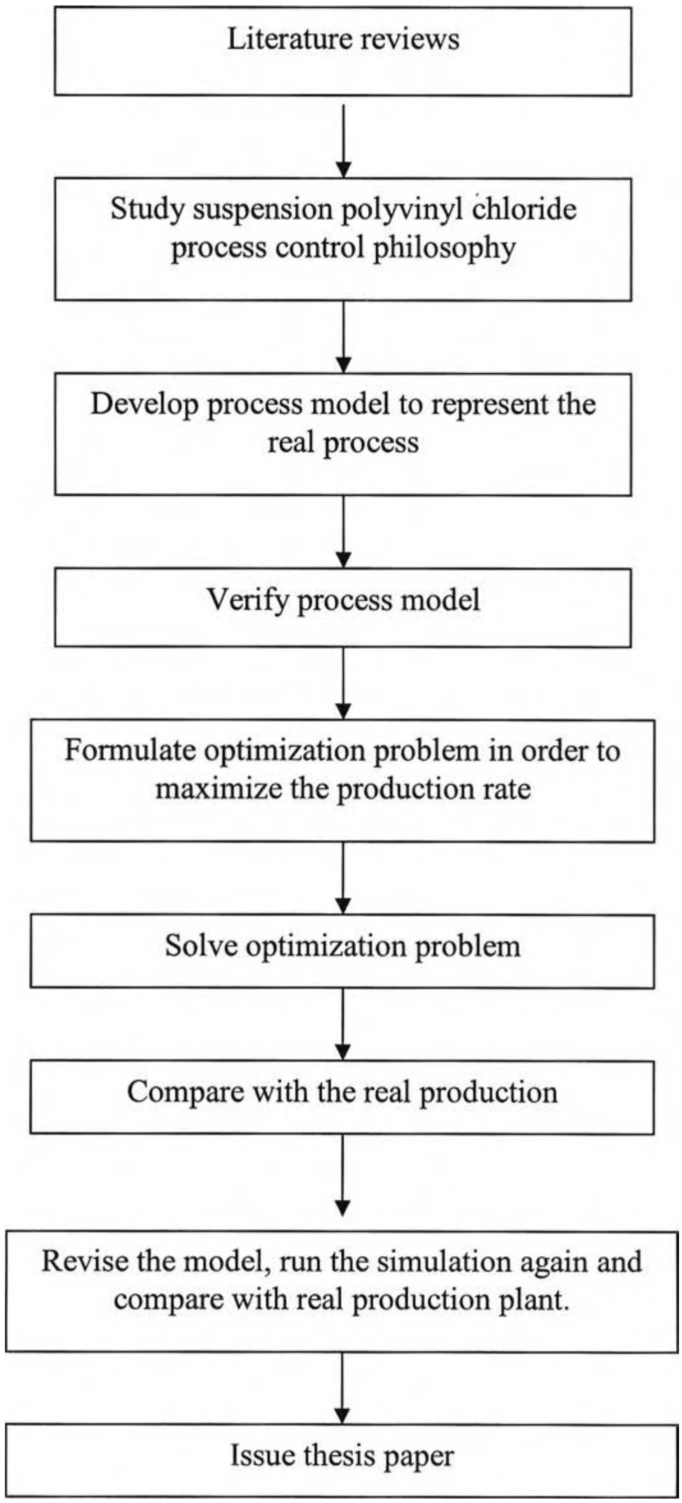

Figure 1.5 Research procedure

1.9.2 Sources of data

Raw data for model calculation and verified model with real process is come from suspension polyvinyl chloride production which has been founded and serviced in one of local petrochemical public company in Map ta phut industrial estate, Rayong province Thailand. The company holds the production technology from one European licenser.