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Plant Structure Based Equipment Assignment in Control Recipe Generation Considering Conflicts with Other Batches

T. Fuchino∗ and H. Watanabe
*Department of Chemical Engineering, Tokyo Institute of Technology
2-12-1, Ookayama, Meguro-ku, Tokyo, 152-8552, Japan

Abstract

This paper describes the equipment assignment in a control recipe design. To produce a batch in a batch plant, equipment assignments to each task of a batch are carried out on the basis of the equipment requirement information of the master recipe. However, the equipment units satisfying the equipment requirement are not necessarily connected topologically with each other, especially in the multiple-path and/or the network structural batch plants. Furthermore, there is no guarantee that the assigned equipment unit does not compete with other batches on a production schedule. In this study, plant structure based equipment assignment system considering conflicts with other batches is developed.

Keywords: Control Recipe Generation, Equipment Assignment, Plant Structure, Conflict between Batches

1. Introduction

The process industries are confronted with competitive situation in these days that requires production of high value added products with higher productivity and quality. Batch processes are suitable for producing such products, and their operation should be designed to realize the property of batch processes. In batch processes, the necessary information to produce a product is specified in the recipe, which is hierarchically categorized into four types; general, site, master and control recipe.

To produce a batch in a batch plant, the control recipe corresponding to the batch is generated by assigning equipment to the batch and sizing the master recipe to meet the quality requirement, and it is imputed to the operating system for execution. The assignment is carried out on the basis of the equipment requirement information of the master recipe. However, even though the equipment units satisfying the equipment requirement are assigned, it does not ensure that they are topologically connected with each other. Especially, in the multiple-path and/or the network structural batch plants, there exist plural production paths and alternative equipment units for flexible operation, but certain equipment units may not be connected with pipe each other originally or temporally. If such equipment units were assigned for a batch in the control recipe,

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∗ Authors to whom correspondence should be addressed: fuchino@chemeng.titech.ac.jp

production interruption, abortion of unfinished product and/or unexpected release of hazardous material would occur. It is necessary to consider the plant structural connect-ability on real-time in generating the control recipe to maintain productivity and safety.
Furthermore, in general, multiple products and/or multiple batches are produces in a batch plant, and the equipment units are assigned to these batches simultaneously or time is shifted. When a new batch is planed to be produced in a batch plant, assignment of equipment units to the new batch can not be decided independently, because it is restricted by the other batches, to which equipment units have already assigned, and their occupancy time. Therefore, it is necessary to consider such conflicts with other batches in generating the control recipe.
There are several previous studies about recipe design support environment based on ANSI/ISA-S88.01 which is an international standard (Aoyama et. al. (2002), Hoshi et. al. (2002), Kaneko et. al. (2003), and so on). These studies paid attention to the relation between plant structural properties and the operation (recipe), but not to the conflicts with other batches. On the other hand, although batch scheduling systems based on ANSI/ISA-S88.01 have been developed (such as Nortcliffe (2001)), they are not taken into consideration about the plant structural connect-ability. In this study, the control recipe generation is considered based on ANSI/ISA-S88.01 (S88.01), and plant structure based equipment assignment system considering conflicts with other batches is developed.

2. Control Recipe Generation

The control recipe is generated based on the master recipe by assigning equipment to tasks and sizing the batch. In the master recipe, equipment requirements to carry out recipe procedures are specified, and the equipments satisfying these requirements should be assigned. However, in order to consider the plant structural connect-ability, not only the main equipments, but also piping and a valve should be considered as an object to be assigned. Therefore, to enumerate alternative equipment assignment, the master recipe representation and the plant structure (P&ID) representation are necessary.
On the other hand, the conflicts with other batches can be detected by comparing the plant schedule and the individual batch schedule. The occupancy time of assigned equipment is calculated by their sizing, and the batch schedule can be obtained by ordering of the occupancy time of the assigned equipment. In order to avoid conflicts with other batches, dispatching rule becomes effective. Based on the above consideration, this study aims at developing the control recipe generation environment shown in Figure 1 as IDEF0 activity model.
The plant structure, master recipe and scheduling information are put into the system as control of this IDEF0 model and their XML representations are provided at A5 sub-activity in this study. In the plant structure representation, equipment, piping and valves are defined as objects, and the structural connections are represented by their associations. The property and specification of the objects are defined as their attributes. The master recipe representation is based on ANSI/ISA-S88.02, and the entities to describe occupancy time for respective equipment unit are defined in the recipe representation in this study. Furthermore, the schedule information is represented by the production order and time of starting the respective batches, so that the plant schedule is

obtained by correlation of the schedule information and occupancy time here. On the basis of these XML representations, the control recipe is generated.
In the A2 sub-activity, the alternative equipment units are enumerated by mapping the equipment requirement in the master recipe representation and properties of equipment units in the plant structure representation, and the available paths are searched to check the connect-ability by tracing the associating piping and valves, and mapping the equipment requirements and properties of piping and valves, in the A3 sub-activity. The candidate of connect-able equipment assignment is informed to A4 sub-activity, and the occupancy time is calculated. The conflict with other batches is checked and a very simple dispatching rule; time of starting is delayed if the task conflicts, otherwise reassign equipment, is applied here. Although not only conflicts with other batches but evaluation to quality, safety, etc. should be performed in this activity, only the conflict is considered here.

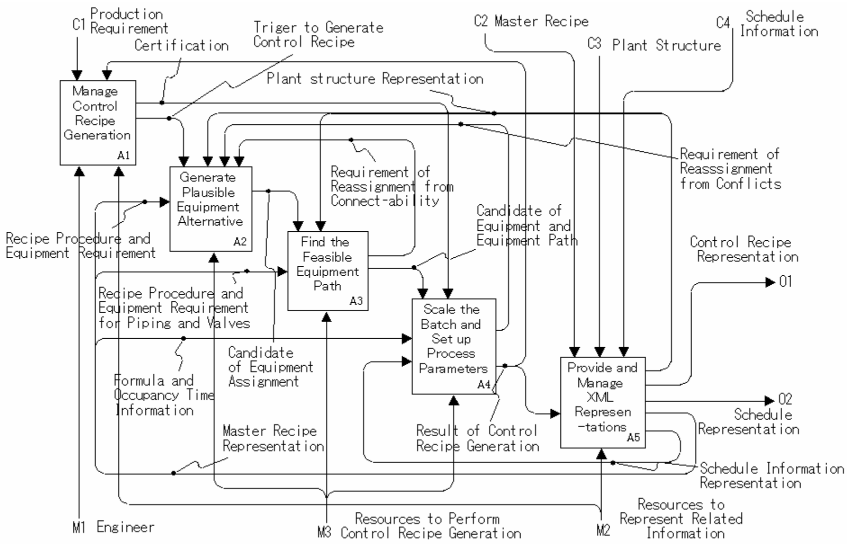

Figure 1. The ESCAPE styles used in this document

In case that the equipment, which is connect-able and satisfying the equipment requirement without conflict with other batches is found, the result is informed to A1 sub-activity, and certified. Information of the assigned equipment, scaled formula and the batch schedule information are added to the XML master recipe representation, then the control recipe is generated. The time of starting and associated control recipe ID and so on are revised on the XML schedule information representation.
In the next section, the XML representation (plant structure, master recipe and schedule information) and implementation environment are explained, and an application to an example test case is described in the further section.

3. Implementation and XML Representation.

In this study, MS Visio is used "Resources to Represent Related Information" shown in Figure 1 of mechanism for A5. The plant structure, master recipe and schedule information are described by using its GUI interface, and their XML representations are converted by using VBA. The each sub-activities; A2 to A4, shown in Figure 1 are implemented as external XML parser, and Ruby; the interpreted scripting language for object-oriented programming, is adopted.

3.1 Plant Structure

In this study, the two stage polymerization plant, which is provided by The Japan Society for the Promotion of Science, Process Systems Engineering 143 (JSPS PSE-143) committee, is considered. I&PD for the plant is shown in Figure 2, and is converted into XML code. The property data for each object are defined by using Custom Property function of Visio, and XML code only for the plant structure is extracted as shown a part bellow.

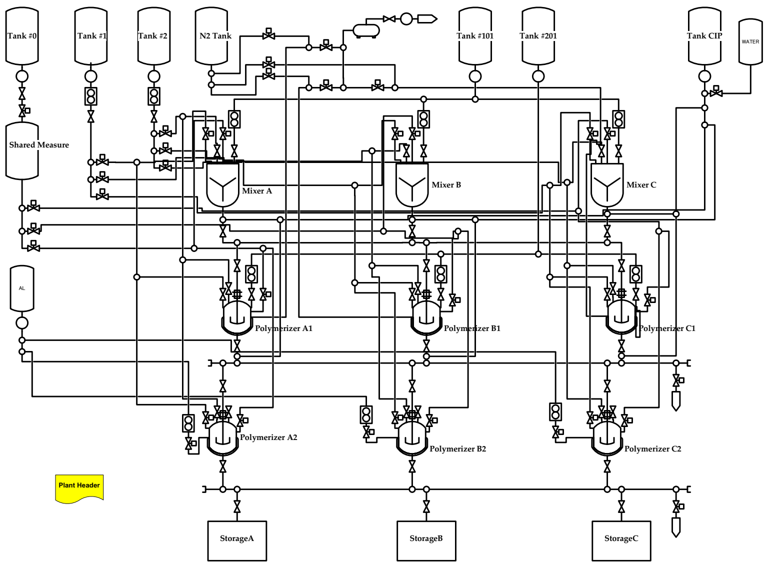

Figure 2. Plant(Process)Structure of Two Stage Polymerization Plant

In assigning the equipment, it is necessary to ensure not only the consistency with the equipment requirement in the master recipe, but also the connect-ability with other equipment units which constitute the process. To ensure the consistency with the equipment requirement, the attribute of the equipment should be described within the "UnitAttributes" tag using the same manner with that describing the equipment requirement in the master recipe. In this study, the property of equipment is specified by using predefined property class as shown following underlined XML tag.

<UnitAttributes>
<UnitAttribute UnitName="Reactor" />
<UnitAttribute Service="Mixing-2, Heating-1, Cooling-2, CIP" />
</UnitAttributes>

Furthermore, to ensure the connect-ability, the precise connection information, which is not the connection of equipment to equipment basis, but that of equipment phase to equipment phase basis. In this study, not only the main equipment but also valves, tee, pipe and so on, appeared in the P&ID are defined as objects, and their connections are defined using equipment ID, connection port ID and connecting object ID. For example, when the connection port “1” of the equipment “E-01” is connected with the connection port “1” of the valve “MV-01” via the pipe “Pipe-001”, then the relation between “E-01” and “MV-01” is described as follow.

```
<Connections>
<Connection>E-01.1, MV-01.1, Pipe-001</Connection>
</Connections>
```

3.2 Master Recipe

The master recipe is described hierarchically on the basis of procedure. The formula, equipment requirement and so on are defined as property of the procedure, in this study. In order to assign the equipment which satisfies the equipment requirement, the specifications on equipment are described by using predefined property class as same as the equipment properties in the plant structure representation. On the other hand, in assigning equipment, not only the consistency with equipment requirement, but also the conflict between other batches should be checked. To detect the conflict, the occupancy time of the assigning equipment for the scheduled batches and the necessary time for the task should be compared. However, the necessary time for the task is depending to the assignment. Therefore, in this study, the necessary time is modelled as a function of equipment capacity, in this example as shown a part at “ProcedureAttribute” tag, below.

```
<ProcedureAttributes>
<ProcedureAttribute Name="#1Charge" />
<ProcedureAttribute NecessaryTimeF="!input_1_Q!*0.1" />
<ProcedureAttribute EquipmentRequirement="#1" />
<ProcedureAttribute Formula="Charge_Rate = bulk, Charge_Temp = -25+-5 [C]" />
</ProcedureAttributes>
```

3.3 Schedule Information

There are two types of scheduling information are used in this study; the plant schedule information and the batch schedule information. The former specifies sequence of batches and their preferable time of starting and finishing. The assignment of equipment is to be performed according to this order. According to the plant schedule information, the provided external XML parser generates the batch schedule information, i.e. enumerate candidates of equipment for assignment, assign feasible equipment, calculate necessary time for each task, and decide the time of starting the batch not to conflict with other scheduled batches. In the batch schedule information, finally the time of starting and finishing the batch is generated, as shown as follow.

```
<Batch Name="Batch6" />
<BeginTime BeginTime="Wed Dec 24 02:45:30 JST 2003" />
<EndTime EndTime="Wed Dec 24 09:12:00 JST 2003" />
```

Based on the batch schedules, the Gantt chart for the batches appeared in the plant schedule information is provided.

4. Illustrative Example

To illustrate performance of developed method to assign equipment in control recipe generation, an example problem is solved. Six batches (No1 to No. 6), which are specified by the same master recipe, are scheduled for the forgoing two stages polymerization plant as shown in Figure 1. The production priority is in that order, and equipment assignment is decided one by one according to the priority specified in the schedule information. The result shown in Figure 3 as a Gantt chart of main equipment is obtained successfully.

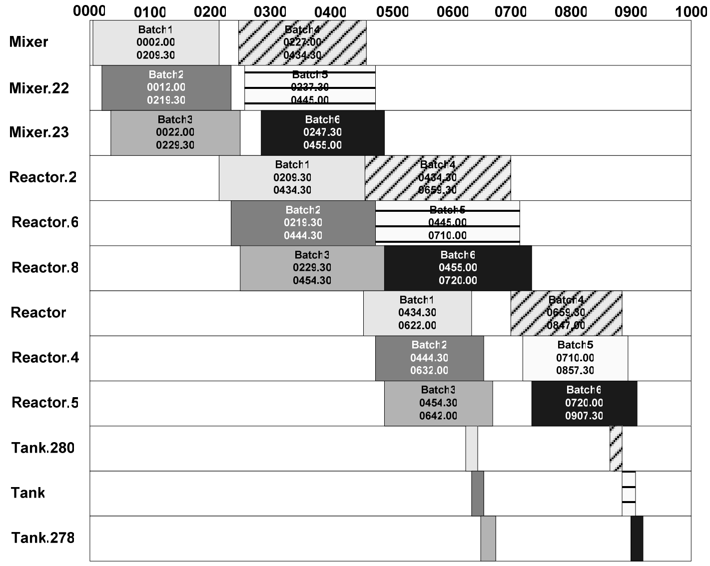

Figure 3 Result of Assignment for six batches

5 Conclusions

In order to assign equipment to tasks in generating control recipe, plant structural connect-ability of equipment units and conflict with other batches should be considered. In this study, plant structure based equipment assignment system considering conflicts with other batches is developed.

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