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The Hybrid Scheduling System for the Store Block

by

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Abstract

In general, it is difficult to schedule operation for whole large chemical plant. In the case of polymerization plant, the plant operation is usually scheduled to divide to some blocks, which are production block, store block, and so on. The production block is scheduled to minimize production cost. On the other hand, the store block is scheduled to operate the production block using feasible scheduling. The following features make the store block scheduling difficult. (1) The product must be treated as a continuum. (2) The product is handled by two or more machines concurrently. (3) The capacities of queues for intermediates have upper bound. (4) The operations are not necessarily started when the operations can be started. (5) The store block is very large system.

This paper proposed the hybrid scheduling system to achieve Just-In-Time (JIT). The proposed system determines the schedule of store block using push type algorithm by the production block demand, and determines that using pull type algorithm by the delivery demand. The effectiveness of the proposed system is assessed via numerical studies.

Keywords: Just in time, Hybrid scheduling, Scheduling system,
Silo system, Systems engineering

Introduction

In general, it is difficult to schedule operation for whole large chemical plant. In the case of polymerization plant, the plant operation is usually scheduled to divide to some blocks, which are production block, store block, and so on. The operations for each block are scheduled by scheduling expert operator. The production block is scheduled to minimize production cost. On the other hand, the store block is scheduled to operate the production

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block using feasible scheduling. The following features make the store block scheduling difficult.

(1) The product must be treated as a continuum, because the minimum unit of a lot handled in the store block is a polymer pellet.
(2) The product is handled by two or more machines concurrently.
(3) The capacities of queues for intermediates have upper bound, because the intermediates should be stored in silos.
(4) For the store block, the operations are not necessarily started when the operations can be started. As a result of the operations, the scheduling may be deadlocked by the upper bound of the queues capacities. As a function of the store block, the intermediates should be stored until due dates. Therefore, the start time of operation should be determined properly.
(5) The store block is very large system, which consists of scores of machines.

The scheduling problem, which has features (1), (2) and (3), is usually formulated as a mixed integer problem. However, it is difficult to solve the large scale scheduling problem using a mixed integer programming.

Besides, Just-In-Time (JIT) scheduling is desirable for delivery to customers. To achieve JIT, the pull type scheduling systems, which are Kanban system[1)2)] and virtual kanban system[3)], has been proposed. However, these systems cannot deal with continuous products.

This paper proposed the hybrid scheduling system to achieve JIT. The proposed system determines the schedule of store block using push type algorithm by the production block demand, and determines that using pull type algorithm by the delivery demand. The effectiveness of the proposed system is assessed via numerical studies.

1. Outline of store block

The production block is scheduled to minimize production cost. On the other hand, the due dates are determined by customers. The store block plays a role of buffer between the production block and delivery. The store block consists of machines, which are silos, kneaders and fillers, and pipes connecting the machines. Furthermore, the silos are classified into buffers, measuring hoppers, blenders, stock silos and filling silos with their functions and positions. In addition, products are classified into homogeneous and non-homogeneous. The former passes through the kneader and the latter doesn't pass through the kneader. The flow of these products is illustrated in **Fig. 1**.

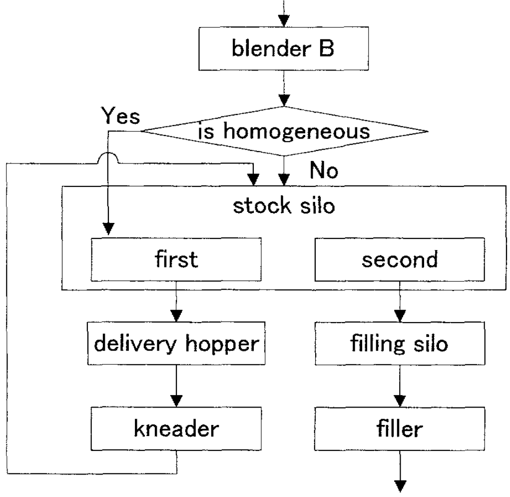

Fig. 1 The flow of the products.

2. Hybrid scheduling algorithm

The proposed system handles upper stream from blender B and lower stream from stock silos, respectively. The push type scheduling is used for upper stream, and the hybrid scheduling is used for lower stream.

2.1 Push type scheduling algorithm

The upper stream is easy to schedule, since it has few degrees of freedom of scheduling. As to features (1) and (3), the capacity of receiving side is adopted as the dividing unit of a lot. As to feature (2), the available machine is used in order. As to (4), the operations are started as soon as the operations can be started.

2.2 Hybrid scheduling algorithm

The lower stream has large degrees of freedom for selecting machines and start time of operation, since it contains stock silos to store intermediates. The large degrees of freedom of the lower stream make the scheduling hard. Against the problem, the hybrid scheduling algorithm has proposed in this paper. The proposed algorithm is explained using an example. Silos information and orders information of the example is presented in **Tables 1** and **2**, respectively. **Table 1** represents silos information which defines names, capacities and sending rates. **Table 2** shows orders information which defines number, amount, start time of receiving from polymerization block and due dates.

Table 1 Silos information for example.

Name	Capacity [ton]	Sending Rate [ton/h]
stock silos (#1, #2, #3)	50.0	10.0
filling silo	35.0	5.0

Table 2 Orders information for example.

number	amount [ton]	start time of receiving [h]	due date[h]	latest finish time of receiving [h]
#1	20.0	0.0	35.0	31.0
#2	18.0	3.0	28.0	24.4
#3	22.0	10.0	57.0	52.6
#4	18.0	16.0	34.0	30.4
#5	20.0	22.0	50.0	46.0
#6	24.0	33.0	56.0	51.2

Step 1. Calculate latest finish times of receiving in stock silos.

For each orders, (latest finish time of receiving) ← (due date) − (amount of order) / (sending rate of filling silo). The delivery won't meet its due date, if the sending from stock silo to filling silo isn't finished at the latest time, even though intervention among orders is ignored. The last column of **Table 2** shows the latest finish times of receiving of each order.

Step 2. Assign orders to stock silos.

Each orders is assigned to the stock silo which is available to send and has the earliest time among latest finish time of receiving (0 if the silo has no order) of last order belonging to the stock silo. If two or more stock silos the earliest time, the order is assigned in order of the number of stock silo.

For example, the orders of #1, #2 and #3 are assigned to the stock silos of #1, #2 and #

3, respectively. #4 order is assigned to #2 stock silo, because latest finish time of receiving of #2 order assigned to #2 stock silo is earlier than that of #1 order assigned to #1 stock silo, even if #4 order can be assigned to the stock silo of #1 or #2. In the same way, the orders of #5 and #6 are respectively assigned to the stock silos of #1 and #2 as shown in **Fig. 2(a)**.

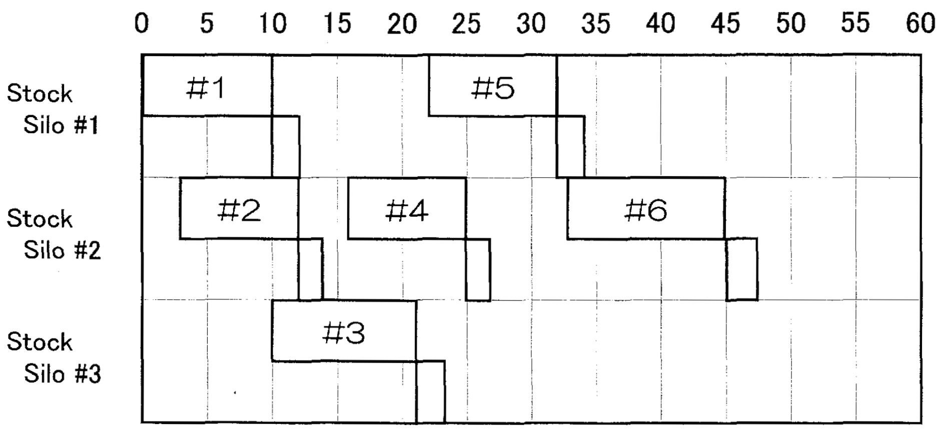

Fig. 2(a) Step 2

Step 3. Calculate start time of sending and finish time of sending of the order in the stock silos.

If the order is the last order in the stock silo, or (start time of receiving of the following order) ≧ (latest finish time of receiving of the order), (finish time of sending) ← (latest finish time of receiving).

Else, (Finish time of sending) ← (receiving start time of the following order). (Start time of sending) ← (finish time of sending) − (amount of order) / (sending rate of the stock silo).

These times are demonstrated in **Fig. 2(b)**.

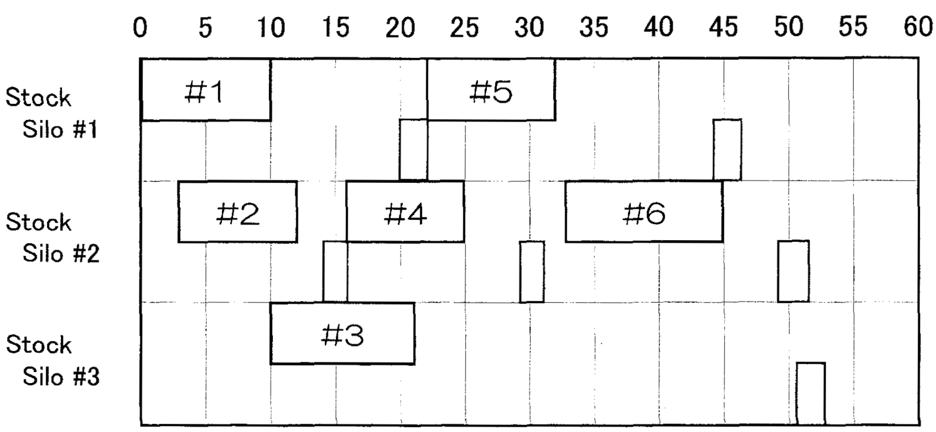

Fig. 2(b) Step 3
Fig. 2 Example's Gant Chart.

Step 4. Assume scheduling of filling silos.

The operation times of each order in the filling silo are assumed in following manner.
(Start time of receiving) ← (start time of sending in stock silo).
(Finish time of receiving) ← (finish time of sending in stock silo).
(Start time of sending) ← (finish time of receiving in filling silo).

(Finish time of sending) ← (start time of sending in filling silo) + (amount of order) / (sending rate of filling silo).

These times are assumed in **Fig. 2(c)**.

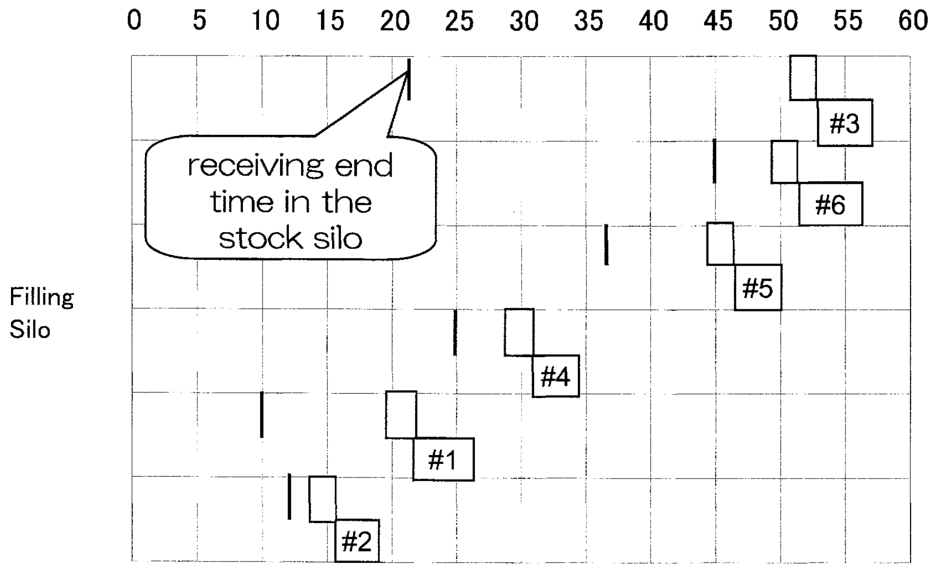

Fig. 2(c) Step 4

Step 5. Recalculate scheduling of filling silos.

The operations of each order in the same filling silo are rescheduled in order of later start time of receiving. For the orders, the schedules cannot be duplicated, and start time of receiving in the filling silo should be later than finish time of receiving in the stock silo.

For example, because #3 order and #6 order are duplicated, finish time of sending of #6 order should be the same with start time of receiving of #3 order in the stock silo. But, start time of receiving of #6 order in the filling silo should not be earlier than finish time of receiving in the stock silo. Then, finish time of sending of #3 order is made the same with

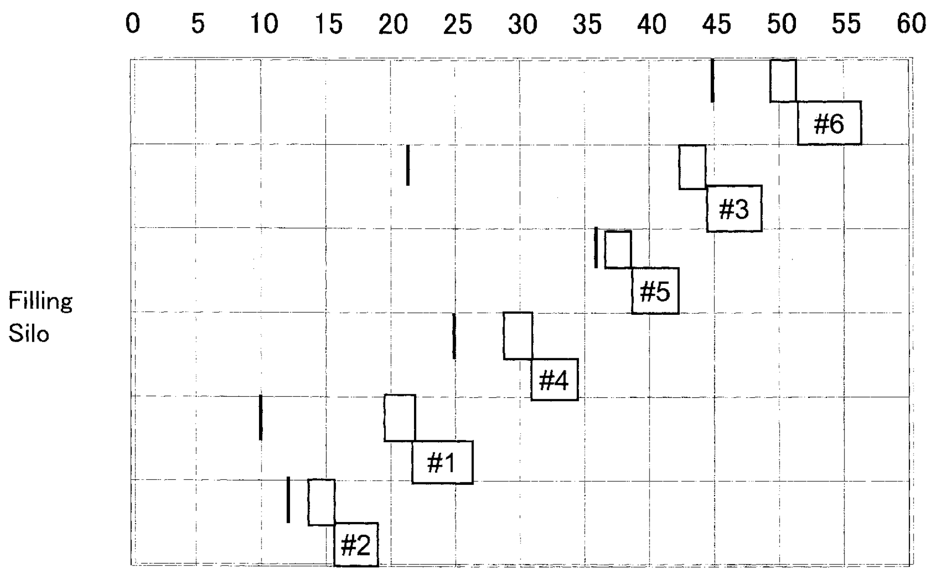

Fig. 2(d) Step 5

Fig. 2 Example's Gant Chart.

start time of receiving of #6 order in the stock silo. In the same way, the schedules are recalculated in order of later start time of receiving of each order as shown in **Fig. 2(d)**.

Step 6. Recalculate start time and finish time of sending in the stock silos.

To meet the schedule in the filling silos, (start time of sending in the stock silo) ← (start time of receiving in the filling silo), (finish time of sending in the stock silo) ← (finish time of receiving in the filling silo) for each order.

Final gant chart scheduled in this way is shown in **Fig. 2(e)**.

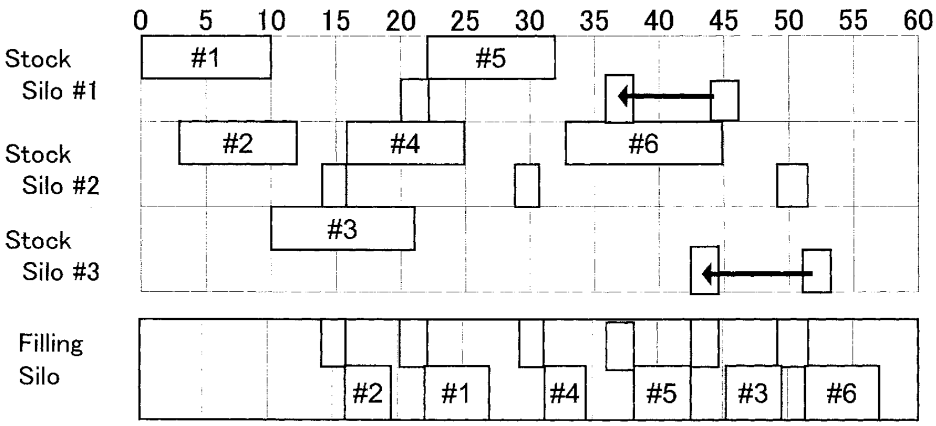

Fig. 2(e) Step 6
Fig. 2 Example's Gant Chart.

3. Numerical studies

3.1 Specifications of objective

In this paper, a large scale store block based on an existed plant is used as numerical studies. The specifications of objective are shown in **Tables 3–5**. **Table 3** represents silos information which defines names, numbers, capacities and sending rates. **Table 4** explains products information which defines brand, type, polymerization series, kneading series and delivery series. **Table 5** shows orders information which defines brand, amount, start times of receiving from polymerization block and due dates. Cases 1–3 respectively demonstrate the case that due dates are in the same order with start times of receiving from polymerization block, the case that due dates aren't always in the same order with that time, and the case that due dates are concentrated between 70 [h] to 90 [h].

Table 3 Silos information.

Name	The number	Capacity [ton]	Sending Rate [ton/h]
buffer	2 series		3.0 or 4.0
measure hopper	8	5.0	15.0
blender A	2	21.0	20.0
blender B	2	21.0	20.0
stock silo	13	50.0 or 60.0	10.0 or 15.0
delivery hopper	3	5.0	4.0
filling silo	4	35.0	5.0
filler	4		

Table 4 Products information.

brand	type	polymarization series	kneading series	delivery series
1	homogeneous	1	1	2
2	homogeneous	2	2	1
3	non-homogeneous	1	-	4
4	homogeneous	2	3	2
5	non-homogeneous	1	-	4
6	non-homogeneous	2	-	3

Table 5 Orders information.

brand	amount [ton]	start time of receiving [h]	due date[h]		
			case 1	case 2	case 3
2	24.0	0.0	28.0	42.0	80.0
1	24.0	0.0	30.0	60.0	78.0
3	34.0	6.0	45.0	30.0	75.0
6	33.0	8.0	42.0	31.0	78.0
1	20.0	14.5	60.0	65.0	80.0
2	27.0	19.0	50.0	50.0	73.0
5	30.0	19.5	65.0	45.0	75.0
1	24.0	27.0	78.0	90.0	88.0
4	30.0	28.0	65.0	78.0	75.0
3	28.0	33.0	83.0	78.0	70.0
2	21.0	38.0	78.0	98.0	78.0
1	26.0	40.0	88.0	88.0	82.0
6	24.0	45.0	90.0	70.0	85.0
5	34.0	46.5	92.0	83.0	77.0
2	33.0	53.0	98.0	100.0	87.0
1	20.0	55.0	104.0	108.0	84.0
5	32.0	60.0	108.0	104.0	90.0
6	27.0	64.0	100.0	90.0	92.0
2	21.0	73.0	108.0	108.0	112.0
4	30.0	80.0	118.0	118.0	118.0

3.2 Results

Simulation results are shown in **Table 6**. The table indicates the average surplus of due date, the maximum surplus of due date and the number of orders finished JIT of each cases. Here, the surplus of due date means a difference between finish time and due date for each orders. To decrease the surplus of due date reduces the cost from finish the product to be

Table 6 Simulation results.

	the average surplus of due date [h]	the maximum surplus of due date [h]	the number of orders finished JIT
case 1	0.0035	0.07	19
case 2	0.84	4.4	16
case 3	7.45	29.62	6

received by customer.

In all cases, all of the orders are finished in the due dates. In case 1, almost orders are finished JIT, and the schedule need little cost, since the system determines the start time of operation. In case 2, about 80 % orders are finished JIT, and the schedule also need little cost, because the system rearranges the orders in proper sequence. In case 3, the proposed system can make feasible schedule for excessive loads, and 6 orders are finished JIT.

Conclusion

The hybrid type scheduling system is proposed. The proposed system determines the schedule of store block using push type algorithm by the production block demand, and determines that using pull type algorithm by the delivery demand. For normal orders, almost orders will be finished JIT. For excessive loads, the proposed system can make feasible schedule. To manage a real plant, continuous operation of the kneaders and deadlock of the filling silos should be considered.

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