

Scheduling Method for MTS/MTO Production System

Tadeuz and A Maruf*

Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung 40132,
Indonesia

Email: tedtadeuz@gmail.com and anas@lspitb.org

Abstract. In order to fulfil the demand from customers, company can carry out its production activities using several policies. There are two policies which are commonly used, Make-to-Stock (MTS) and Make-to-Order (MTO). Both of these policies not only can be implemented separately, but also can be combined on a production floor, for example in foundry which the production activities have a flowshop characteristic. This paper proposes a Base-Stock Control System (BSCS) model to classify each incoming orders into the category of MTS and MTO. Each incoming orders will be first classified into the category of High Volume (HV) and Low Volume (LV). All products in these two categories will be and scheduled using two alternative methods, the First-In-First-Out (FIFO) and Priority Rule (PR). The production activities are scheduled by considering the capacity of each work station and performed in batch using overlapping operations. Several scenarios conducted on the proposed method reveals production delay reduction from 36% to 5.3 % and also the total amount of finished products in ten months horizon planning by approxi mately 66.6%.

Keywords : Make-to-Order (MTO), Make-to-Stock (MTS), First-In-First-Out (FIFO), Priority Rule (PR), Overlapping

1. Introduction

Companies that implement a combination of policies MTS and MTO should be able to determine the correct production policies for each product ordered. Companies must be able to know the characteristics of each incoming orders. Products manufactured with MTS tend to have large order quantity and not a customized product. MTS policy implementation is to anticipate any change in demand from customers. Meanwhile, the products manufactured with MTO have a unpredictable pattern of arrival and ordered in a small amount. MTO policy is suitable to use if the company wants to reduce inventory because the production activities start when there is an incoming order. [1].

The decision of MTS and MTO affect the scheduling mechanism conducted in the company. Scheduling for MTS products tend to have a longer time than the MTO product. Mistake of choosing the right policy can be fatal to the production floor because the possibility of delay of the product completion.

*Corresponding author. Tel.: +62 22 2506449; fax.: +62 22 2506449



To determine the policy to be used, the company can make the consideration of the characteristics of each product. Incoming product can be ordered periodically or only at certain times. Ordered products can be derived from old customers or new customers. The products can be ordered in high or low quantities. Basically, all of the products that go into the company can be classified into two broad categories, namely high volume (HV) which has the characteristics of high demand rate and Low Volume (LV) which has a low demand rate.

In this study, the production scheduling method will be proposed based on Base-Stock Control System using two alternative scheduling method, namely the First-In-First-Out (FIFO) and Priority Rule (PR). Scheduling is done for each product category and will be seen whether both feasible alternative methods used in this study or not. Results of the implementation of the proposed scheduling method will be compared with scheduling as-is applied in the research object.

2. Problem Description

The company in this research is a educational institution which provide both academic service and manufacturing goods for customer. The company has two main department, foundry and machining. Production activities in the foundry department is flow shop consisting of 6 workstations, namely:

1. Pattern forming
2. Molding, consist of mold and core making process. This process is carried out using two production lines, using machinery and manpower
3. Melting, the process of heating the metal until it reaches its melting point. This process is carried out using 4 furnaces, each 2 of them have capacity of 250 kg and 350 kg. However, due to the limitations of electric power supplied to the company, there is only one furnace that can be operated in one production cycle. Once the metal has been melted, it will be poured into a mold and going through cooling process until it is hardened
4. Finishing, a process that is done after the molten metal was harden. Finishing process consists of three activities, namely shake out, shot blast, and fettling
5. Heat treatment, a process that is specifically made for materials that have a higher level of toughness than others
6. Quality control

All incoming orders are done sequentially through six workstations, but only a few types of orders that have to go through the process of heat treatment.

Foundry department is still working on orders by using MTO as the production policy. There are three types of incoming orders :

1. Type A : Order comes in the beginning of the year (around January to February) but the due date given by the company in the same month the order must be completed
2. Type B : Order comes in a given month and the products will be delivered in each quartal
3. Type C : Order comes about 2-3 weeks before the specified due date

The order execution is still done using the scheduling method that is not well structured. The workers are still doing scheduling activities with conjecture and based on experience in previous years so it has a high possibility of failure. Production activities for each order has not been scheduled well so there are frequent delays in production which result in workers having to work overtime.

The as-is scheduling characteristics of the foundry is as follows:

1. Scheduling of production tends to be done backward.
2. Department has two lines of foundry mold-making, namely manual and machine that can be used simultaneously

3. Department of foundry has not been doing production in a make-to-stock for some products that come periodically in large quantities. During this time, production is done in a make-to-order for all incoming orders
4. There are batch forming in production activities, but the batch size is too small. Thus, the capacity of the furnace is not used optimally
5. Scheduling begins with the production planning based on the capacity of existing machines in a master schedule. Production planning is done for a period of a week

3. Proposed Algorithm

In this paper, the proposed scheduling method uses the concept of Base-Stock Control System (BSCS) [3] which can be seen in Figure 1 :

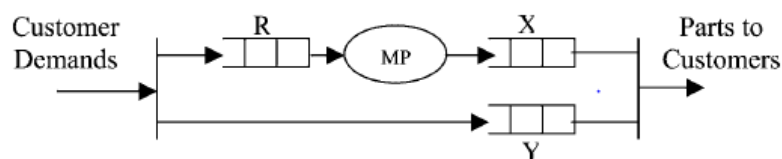


Figure 1 Illustration of BSCS

source : Youssef et.al.(2004)

BSCS Model has four major components :

1. MP : production floor that covers the whole range of manufacturing processes
2. R : queue of raw material waiting to be processed in MP
3. X : queue of finished products waiting to be delivered to the customer
4. Y : queue of the demand comes from customers who have not been completed

The mechanism of proposed MTS/MTO scheduling method is divided into four stages : classification of HV-LV product, classification MTS-MTO policy, designing the scheduling method, and gantt chart construction.

3.1 Determine the Classification of Low Volume and High Volume

The first stage of the design of the scheduling method in this study is to determine the classification of incoming orders to the foundry department into the category of high volume or low volume. This classification is related to demand conditions in the foundry department itself. Foundry department received an order with different characteristics in terms of quantity, the arrival pattern, and the production process of the products ordered. By grouping orders into the category of high volume and low volume, the company has consideration in production activities whether to produce with MTS or MTO. If the company make the wrong decision, it can cause the delay of production activities

Products with high-volume category have the characteristics of high demand rate, while low volume products have lower demand rate. In addition, the number of orders for high-volume products is less than low volume. High volume products tend to come with a large quantity and has a fairly long due date, while the low volume products are otherwise [3]. BSCS model has the same characteristics with conditions of foundry department so that it can be used as a basis for designing the method of scheduling in the foundry department.

On this model, there will be various types of product with the index from 1 to k. Products that enter are divided into two categories, namely high volume (HV) and low volume (LV). Products with high-volume category have a high level of demand with an index from 1 to k_{HV} , while the low volume

productst have a low level of demand with an index from $k_{HV}+1$ to k . The total number of HV and LV products meet the following criteria:

$$k_{LV} \gg k_{HV} \quad (1)$$

Arrival demand Poisson distribution with average demand rate meets the following rules:

$$\lambda_j \ll \lambda_i \quad (2)$$

The i index represents HV products while j represents LV products, thus $i \in \{1, \dots, k_{HV}\}$ dan $j \in \{k_{HV}+1, \dots, k\}$

The notations used in this model are as follows:

k : total number of products

k_{HV} : the number of high volume products

k_{LV} : the number of low volume products (note: $k_{HV} + k_{LV} = k$)

λ_i : the average demand per unit time

The classification steps of high volume and low product volumes can be seen in figure 2

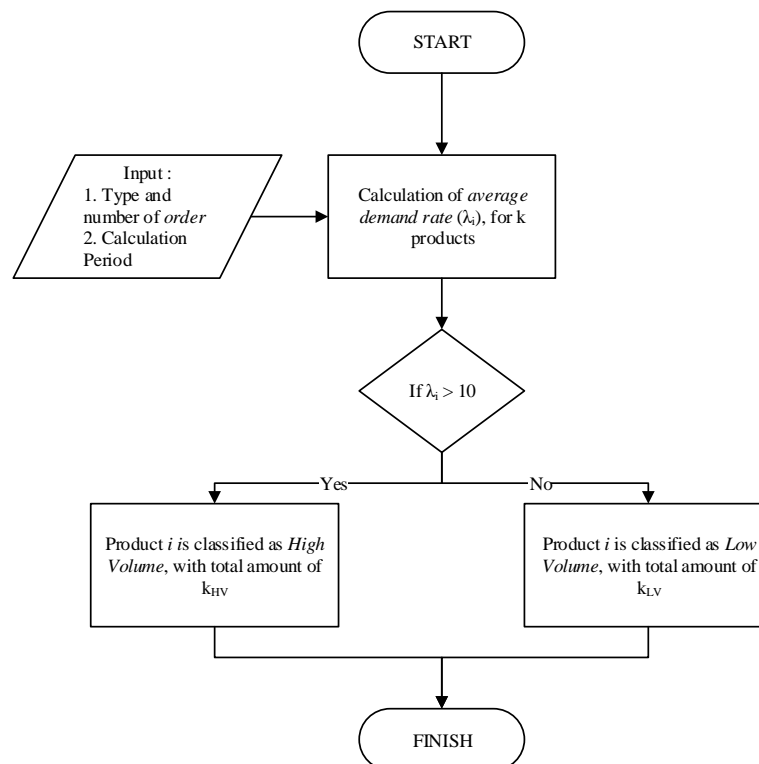


Figure 2 Flowchart of Classification Process of HV-LV

The classification process is based on the average demand rate for each product. Limit value of average demand rate used is 10. This value is obtained by identifying the historical demand data for the last 2 years at the department foundry and also through validation of user's expectations.

The output of this stage is a list of orders that fit into the category of high volume and low volume product. Products with high-volume category have a total amount of k_{HV} with index $i = 1, \dots, k_{HV}$ while low volume product categories have a total amount of k_{LV} with index $i = k_{HV}+1, \dots, k_{LV}$.

3.2 Determine the Classification of MTO and MTS

Classification process of MTS and MTO production policy conducted for each product which has been categorized as High Volume and Low Volume. This process is done by comparing the value of admissible delay of any product with a threshold value. Admissible delay is a value of delay time allowed in production activities. The value of admissible delay affects how the production activities should be carried out. Admissible delay can be calculated with followed formulas:

d_i^a : admissible time

μ_i : average production time for any kind of product

ρ : utilization factor of production facilities, where:

$$\rho = \sum_{i=1}^k \lambda_i / \mu \quad (3)$$

Aggregate demand for the two categories of products are:

$$\lambda_{HV} = \sum_{i=1}^{k_{HV}} \lambda_i \text{ dan } \lambda_{LV} = \sum_{i=k_{HV}+1}^{k_{LV}} \lambda_i \quad (4)$$

Aggregate utilization factor for the two categories of products are:

$$\rho_{HV} = \sum_{i=1}^{k_{HV}} \frac{\lambda_i}{\mu} \text{ dan } \rho_{LV} = \sum_{i=k_{HV}+1}^{k_{LV}} \frac{\lambda_i}{\mu} \quad (5)$$

In this case, the value of admissible delay equal to the average backorder time obtained using Little's Law :

$$E[D_i(s_i)] = d_i^a = \frac{1}{\lambda_i} x \frac{\hat{\rho}_i^{s_i+1}}{1 - \hat{\rho}_i} \quad (6)$$

The value of utilization factor for products i is obtained using the FIFO rule calculation as follows:

$$\hat{\rho}_i = \frac{\lambda_i}{\hat{\mu}_i} = \frac{\lambda_i}{\mu - \sum_{j \neq i} \lambda_j}, \quad i = 1, \dots, k \quad (7)$$

The admissible delay value of each product is to be compared with the threshold value obtained through the following calculation:

$$\tilde{d}_{LV}^{PR} = \frac{1}{\mu - \lambda_{LV}} \quad (8)$$

$$\tilde{d}_{LV}^{FIFO} = \tilde{d}_{HV}^{FIFO} = \frac{1}{\mu - \lambda_{LV} - \lambda_{HV}} \quad (9)$$

$$\tilde{d}_{HV}^{PR} = \frac{1}{\mu - \lambda_{LV} - \lambda_{HV} - \lambda_{LV}(1 - \rho)} \quad (10)$$

The fourth threshold value above has the characteristic values as follows:

$$\tilde{d}_{LV}^{PR} < \tilde{d}_{LV}^{FIFO} = \tilde{d}_{HV}^{FIFO} \text{ dan } \tilde{d}_{LV}^{FIFO} < \tilde{d}_{HV}^{PR} \quad (11)$$

Each product will be classified to MTS or MTO using the rules in Figure 3:

Optimality of MTO/MTS with respect to the scheduling rule.						
d^d values		0	\bar{d}_{LV}^{PR}	$\bar{d}_{LV}^{FIFO} = \bar{d}_{HV}^{FIFO}$	\bar{d}_{HV}^{PR}	∞
			↓	↓	↓	
Rule	Family	Range 1	Range 2	Range 3	Range 4	
FIFO	HV	MTS	MTS	MTO	MTO	
FIFO	LV	MTS	MTS	MTO	MTO	
PR	HV	MTS	MTS	MTS	MTO	
PR	LV	MTS	MTO	MTO	MTO	
The impact of switching from FIFO to PR on the MTO/MTS policy		No effect	The LV products switch from MTS to MTO	The HV products switch from MTO to MTS		No effect

Figure 3 Flowchart of Classification Process of MTS-MTO using Threshold Value

Source : Youssef et.al. (2004)

3.3 Determine The Scheduling of MTO and MTS

The basic scheduling methods used in this paper are FIFO and PR as a continuation of BSCS models used in the previous stage. This method was developed by adding two additional criterias :

- ### 1. Adjustment to Production Capacity of Machine

Normally, the production process on the machine is performed for each unit, but in this case the process of mold making can be done for more than 1 unit by comparing the size of the casting frame to the size of the object to be produced. Meanwhile, the furnace in melting stage can process more than 1 unit per cycle because it operates according to its maximum weight.

If there is no fixed measure for each machine, there is a possibility that the utilization of machine will be decreased. This will cause the decreasing of WIP produced from each machine, thus the process in the machine needs to be done repeatedly. As a result, total production time becomes bigger and can cause delays in the product completion.

- ## 2. Overlapping operations

Overlapping is a technique that is done to minimize the total lead time by dividing production lot into at least two batches and connecting at least two successive work stations [2].

By classifying orders into the category of high volume and low volume, the company can determine which products should be produced in batches. In the existing condition, the activities carried out in batch for almost all products. Batch is formed because of the limit on the quality of mold which can only stand on average for 16 hours before being sent into the furnace for melting process.

The steps of development of the scheduling method can be seen in figure 4.

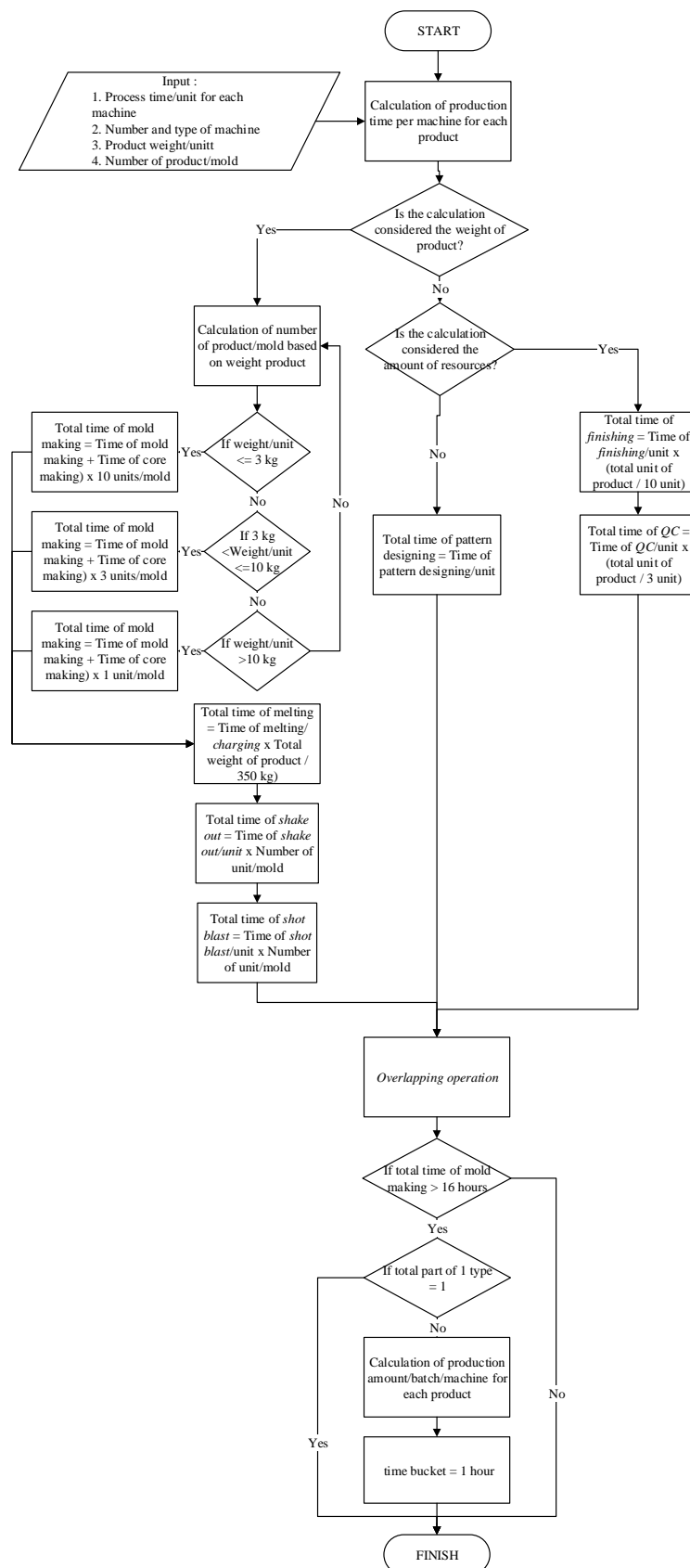


Figure 4 Flowchart of Scheduling Method

3.4 Gantt Chart Construction

The main output of this research is the production gantt chart which shows the order of production process for each product from first to last machine. The construction of gantt chart can be seen systematically in Figure 5

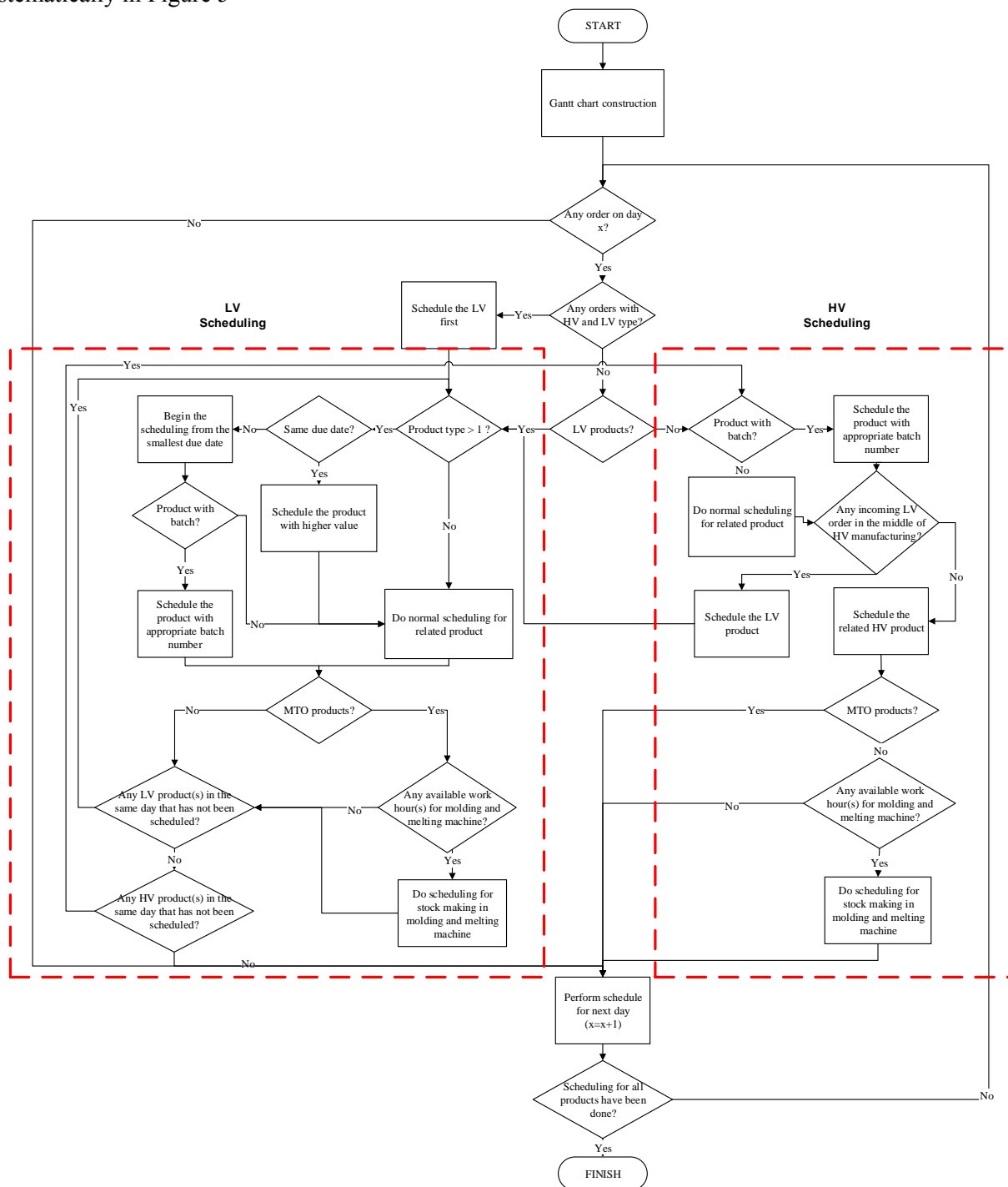


Figure 5 Flowchart of Gantt Chart Construction Based on The New Scheduling Method

4. The Result from Proposed Scheduling Method

The result from new scheduling method will be compared to as-is condition using several performance criterion :

1. Earliness and Tardiness

Earliness and tardiness value shows how much the delays that occur in a production activity. Earliness is a negative delay meanwhile tardiness is a positive delay. The higher the value of earliness, the more the product completed before the due date specified. Meanwhile, the lower the value of tardiness, the less the late product. By using the proposed scheduling method, the value of tardiness decreased while the value of earliness increased as contained in the table 1

Table 1 Comparison of Earliness and Tardiness Value Between New and As-Is Condition

Performance Criterion	Value	
	As-is	New
Earliness	5,30	27,07
Tardiness	12,52	0,63

2. Utility of Work Station

This criteria is used to determine the utilization level of each work station during the production activities. The higher the level of utility, the lower the idle time that occurs in the production activities. The utilization rate resulted from the using of proposed scheduling method is increased, which is caused by changing the scheduling from backward to forward.

Table 2 Comparison of Utilization Rate Between New and As-Is Condition

Machine/Work Station	Utilization Rate	
	As-is	New
Pattern	15,59%	24,17%
Core+Mold	60,06%	86,06%
Melting	15,81%	23,81%
Shake Out	36,61%	56,65%
Shoot Blasting	16,94%	25,52%
Fettling+Finishing	62,59%	94,49%
QC	32,26%	44,15%

3. Number of Finished Product

By using the order data period January to October 2014, obtained the results of the completion of the proposed scheduling order using the method shown in the table 3

Table 3 Comparison Between Finished Products of New and As-Is Condition

Incoming Order Between 10 Months				
Number of Incoming Order	225			
Total Unit of Incoming Order	50307			
Order Status	As-is		New	
	Total Order	Percentage	Total Order	Percentage
Finished before due date	51	22,7%	201	89,3%
<i>Just in Time</i>	23	10,2%	1	0,4%
Finished after due date	81	36,0%	12	5,3%
<i>On Progress</i>	70	31,1%	11	4,9%

5. Conclusion

The method used for classifying incoming product into category of MTS or MTO is based on Base-Stock Control System (BSCS) in which every order that goes into the production system will be classified based on the arrival demand rate to category of High Volume (HV) and Low Volume (LV). Each product has a value of admissible delay that will be compared with the threshold value for each category of product and scheduling methods used in this case. As a result, all orders that entered the system are classified as MTO product when the scheduling method used is FIFO. Whereas when using PR methods, the HV products can be produced optimally by using MTS policy but LV products should be done with MTO policy.

Every classified product within the category of MTS and MTO will be scheduled using the two method based on the concept of BSCS : First In First Out (FIFO) and Priority Rule (PR). In this paper, PR is more feasible to used because it is suitable to the condition in the foundry department. PR methods will be adjusted to the capacity of each machine and there is batch forming using overlapping operation. By using this method, the completion of the production order in the foundry department increased to 89.3% of total incoming orders compared to the as-is condition which has 22.7 % of completion order.

References

- [1] A. Arreola-Risa & G. A. Decroix (2002), "Make-to-Order Versus Make-to-Stock in a Production-Inventory System with General Production Times," *IIE Transactions*, vol. 34, no. 8, pp. 649-662.
- [2] Fogarty, D. W., J. H. Blackstone, & T. R. Hoffmann (1991), *Production and Inventory Management*, South-Western Publishing Company, Cincinnati
- [3] K. Hadj Youssef, Ch. Van Delft, & Y. Dallery (2004), "Efficient Scheduling Rules in a Combined Make-to-Stock and Make-to-Order Manufacturing System," *Annals of Operations Research*, vol. 126, pp. 103-134.