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Minimization of WIP inventory cost at CNC-machining centers through assignment of *m* serial machines and transfer batch size reduction

To cite this article: C R Muhammad *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **830** 032096

Minimization of WIP inventory cost at CNC-machining centers through assignment of *m* serial machines and transfer batch size reduction

C R Muhammad*, A H Nu'man and N Shofia

Departement of Industrial Engineering, Faculty of Engineering, Universitas Islam Bandung, Bandung 40116, Indonesia

*chaznin_crm@yahoo.co.id

Abstract. In the batch production, the use of a single machine for several stages of the processes will result in waiting time of production batch to be long. It will cause an increase in work in process (WIP) inventory cost. CNC-machining centre is a type of CNC machine that can carries out several stages of processes singly. In some cases, this machine is often single used to make a product through several stages of processes, from raw material to end product. One of the reasons to use a single machine is to avoid transfer from one stage (machine) to next machine. However, single use causes inventory to accumulate due to long waiting times. The objective of this research is to reduce the WIP inventory cost at the CNC-machining centre. Scheduling to minimize WIP inventory cost is done through two steps. First step, divide number of stages of processes to be assigned to *m* serial CNC-machining centers. Second step, determine transfer batch size is smaller than the production batch size to be transferred to the next stages. The results of this research indicate that there is a reduction in WIP inventory cost by 53.47 percent. Scheduling multi-stage batch production on *m* machines with small transfer batch size will reduce WIP inventory cost.

1. Introduction

The Advantage of CNC-machining centre is can carry out several processes singly with quick changeover. It result in a tendency to use one machine singly to perform all processes to make a product. In the batch production, the single use will raises problem. The problem is long waiting time. It will cause an increase in WIP inventory. This study is proposed to use *m* machine for *n* stages of processes and then determine transfer batch size. The objective is to reduce the WIP Inventory Cost.

Increased waiting time will cause an increase in flowtime. In batch production, flowtime will increase by increasing production batch size. For multi-stage batch production, the production batch flowtime will be longer if carried out on a single machine. The advantage of CNC machining centre for multi-stages processing will cause problems if used for large production batches, i.e., the batch flowtime is longer by increasing the batch size. If *m* CNC machining centre is available, it should be considered for use in multi-stage batch production. If *m* machines are used serially for multi-stage batch production, smaller transfer batches are required. Smaller transfer batches will be possible to carry out one stage with the next stage simultaneously. This effort will reduce waiting time of production batch.

Research about batch production are carried out on a single machine [1-4] or multi-machine both serial [5,6] and parallel machines [7,8]. The goals of these research are time-based [1-8] and cost based

[9-11]. Research related to batch production scheduling was conducted to obtain the better actual flowtime on one machine [1]. Research on single batch-processing machine (SBPM) to minimize total weighted tardiness [2], to minimize makespan [3]. Research on parallel batch-processing machines was also conducted to minimize the makespan [7]. Research has been conducted to minimize the required number of setup by independent job orders are grouped into multiple class's base on similarity in style [8]. Mathematical modelling of the problem of batch scheduling are also created to minimize earliness and tardiness [4].

Some research are conducted to minimize waiting time and work in process inventory. Study of scheduling jobs in a specially structured flow shop with set up times separated from processing time and each associated with probabilities in order to minimize total waiting time of jobs [5]. Discussion on the problem of scheduling Hybrid Flow Shop (HFS) is also carried out to minimize the total work in process inventory [6]. Another approach is also used to reduce work in process inventory, i.e. value stream mapping [9]. Research has also been conducted on the problem of parallel-batch scheduling that incorporates transportation of raw materials or semi-finished products before processing with waiting time constraints. The goal is to find a schedule to minimize the total flow time and production costs [10]. The research to obtain a minimum total cost consisting of the corresponding holding cost and delivery cost can be achieved by finding an integrated schedule of production and delivery batch so as to meet the due date at the minimum total cost [11].

This research shows how to schedule multi-stage batch production at CNC-machining centre so that the WIP inventory cost is reduced.

2. Method

In multi-stage batch production scheduling, some stages can be divided into *m* machines, for example three stages into three machines. Initially, one batch (J = 1) has a size of 50 units ($Q = Q_{ij}$= 50) and requires three stages of processing (I=3) carried out on one machine. If processing time stage 1 (t_1) is 48 minutes/unit, processing time stage 2 (t_2) is 25 minutes/unit, processing time stage 3 (t_3) 23 minutes/unit, setup time stage 1 (S_1) minutes 35/batch, setup time stage 2 (S_2) 5 minutes/batch, setup time stage 3 (S_3) 15 minutes/batch, then the results of scheduling are illustrated in Figure 1. Next, the improvement effort is carried out through two steps. First step, J = 5 is scheduled on three machines where one machine for one stage. Each move from one stage to the next requires transfer of a number of WIP units (batch transfer size, Q_{ij}). Second step, so that the waiting time in the next stage is shorter, then the transfer batch size is made smaller, for example, Q_{ij}=10 units. The results of scheduling for three machines are illustrated in Figure 2.

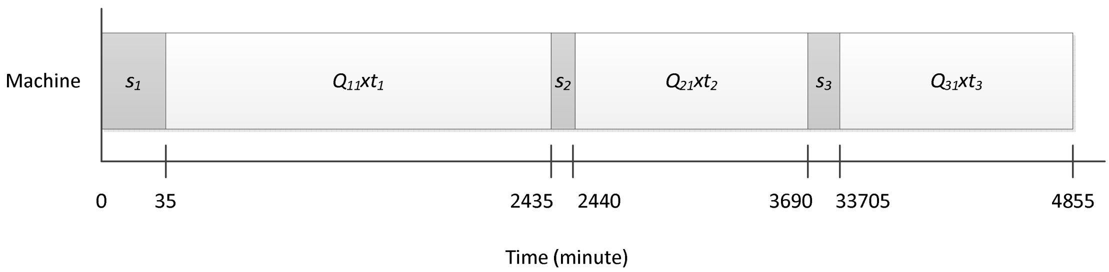

Figure 1. Illustration of batch scheduling (J=1, Q_{ij}=50) on one machine.

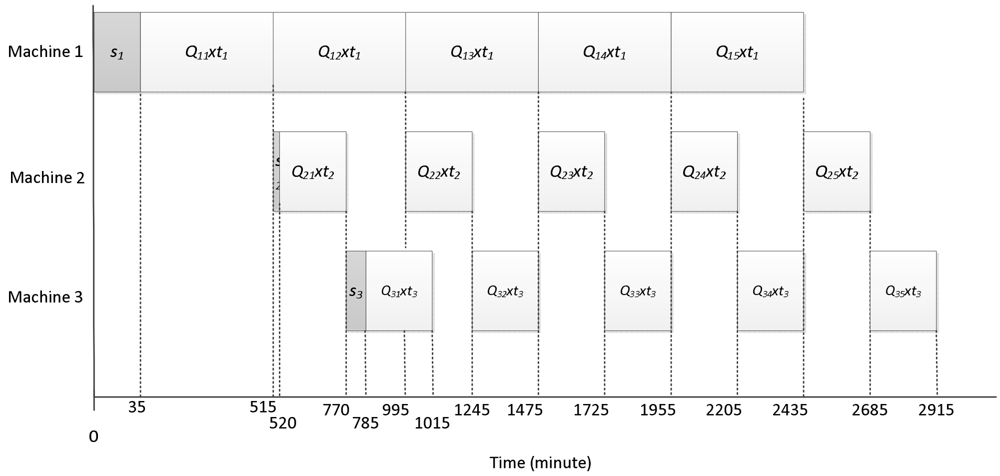

Figure 2. Illustration of batch scheduling (J=5, Q_{ij}=10) on three machines.

For the discussion of batch production scheduling, the following notation is used in this paper:

Q : production batch size
J : number of batch, $j \epsilon J; J = 1,2,3, \dots, Q$
I : number of stage, $i \epsilon I$
m : number of serial machine; $m = 1,2,3, \dots I$
S_i : setup time $\left(\frac{\text{minut}}{\text{batch}}\right)$ of stage i
t_i : processing time $\left(\frac{\text{minut}}{\text{unit}}\right)$ of stage i
Q_{ij} : transfer batch size of batch j stage i
F_{ij} : flowtime $\left(\frac{\text{minut}}{\text{unit}}\right)$ of batch j stage i
W_{ij} : waiting time $\left(\frac{\text{minut}}{\text{unit}}\right)$ of each unit in batch j stage i
W_i : waiting time $\left(\frac{\text{minut}}{\text{batch}}\right)$ of stage i
W_T : total waiting time (minut)
C_{WIP} : work in process inventory cost
H : holding cost

$$F_{ij} = Q_{ij} \times t_i + S_i + \max[F_{i-1j}; F_{ij-1}] \tag{1}$$

$$W_{ij} = F_{ij} - t_i \tag{2}$$

$$W_i = \sum_{j=1}^{J} Q_{ij} \times W_{ij} \tag{3}$$

$$W_T = \sum_{i=1}^{I} W_i \tag{4}$$

$$C_{WIP} = W_T \times H \tag{5}$$

Transfer batch size affects number of transfers. Smaller transfer batch size causes increase in number of transfers, and vice versa. Transfer batch size also affects waiting time. Smaller transfer batch size causes decrease in waiting time, and vice versa. Thus, waiting time and number of transfer are determined by transfer batch size. For the aspect of cost, waiting time affects WIP Inventory Cost.

3. Results and discussion

In this section, scheduling results are presented in Table 1 for three stages (I = 3), one batch (J = 1) performed on one machine (m = 1). Next, the scheduling results are displayed from Tables 2 to Table 4 for three stages (I = 3), five batches (J = 5) performed on three machines (m = 3).

Table 1. Results of scheduling for I=3, J=1 on one machine.

Number of stage, I=3	1	2	3
Batch size (unit)	50	50	50
Setup time/batch (minute)	35	5	15
Processing time/unit (minute)	48	25	23
Flowtime/unit (minute)	2,435	3,690	4,855
Waiting time/unit (minute)	2,387	3,665	4,832
Waiting time/stage (minute)	119,350	183,250	241,600
Total waiting time (minute)		544,200	

Scheduling results I = 3 and J = 1 (Q = 50 units) on one machine are shown in Table 1. From Eq. (3) the waiting time obtained for each unit at each stage, W_1, W_2 and W_3 is 119,350 minutes, 183,250 minutes and 241,600 minutes, respectively. The total waiting time, W_T, is 544,200 minutes.

Table 2. Results of scheduling for i=1, J=5 on Machine 1

Number of batch, J=5	1	2	3	4	5
Batch size (unit)	10	10	10	10	10
Setup time/bath (minute)	35	0	0	0	0
Processing time/unit (minute)	48	48	48	48	48
Flowtime/unit (minute)	515	995	1,475	1,955	2,435
Waiting time/unit (minute)	467	947	1,427	1,907	2,387
Waiting time/batch (minute)	4,670	9,470	14,270	19,070	23,870
Waiting time/stage (minute)			71,350		

Table 2 is the result of scheduling Stage 1 (i = 1) on Machine 1. For example, for Batch 1, from Eq. (1) and Eq. (2), flowtime (F_{11}) and waiting time (W_{11}) for each unit are obtained 515 minutes and 467 minutes, respectively. By using Eq. (1) and Eq. (2) flowtime and waiting time for each unit in Batch 2, 3, 4 and 5 are also shown in rows 5 and 6, columns 3, 4, 5 and 6. Waiting time for Batch 1, Q_{11}xW_{11}, is 4,670 minutes. From Eq. (4), waiting time for Stage 1, W_1, was 71,350 minutes.

Table 3. Results of scheduling for i=2, J=5 on Machine 2

Number of batch, J=5	1	2	3	4	5
Batch size (unit)	10	10	10	10	10
Setup time/bath (minute)	5	0	0	0	0
Processing time/unit (minute)	25	25	25	25	25
Flowtime/unit (minute)	770	1,245	1,725	2,205	2,685
Waiting time/unit (minute)	745	1,220	1,700	2,180	2,660
Waiting time/batch (minute)	7,450	12,200	17,000	21,800	26,600
Waiting time/stage (minute)			85,050		

The results of waiting time calculations for Stage 2 are shown in Table 3. For example, for Batch 2, from Eq. (1) obtained F_{22} = 10x25 + 0 + max [995; 770] = 1,245 minutes. From Eq. (2) obtained W_{22} =

1,245 - 25 = 1,220 minutes. The waiting time of Batch 2, Q_{22}xW_{22}, is 12,200 minutes. From Eq. (3) obtained waiting time of Stage 2, W_2 is 85,050 minutes.

Table 4. Results of scheduling for i=3, J=5 on Machine 3

Number of batch, J=5	1	2	3	4	5
Batch size (unit)	10	10	10	10	10
Setup time/bath (minute)	15	0	0	0	0
Processing time/unit (minute)	23	23	23	23	23
Flowtime/unit (minute)	1,015	1,475	1,955	2,435	2,915
Waiting time/unit (minute)	992	1,452	1,932	2,412	2,892
Waiting time/batch (minute)	9,920	14,520	19,320	24,120	28,920
Waiting time/stage (minute)			96,800		

Table 4 shows the results of Stage 3 scheduling (i = 3). For example, for Batch 5, from Eq. (1) obtained F_{35} = 10x23 +0 + max [2,685; 2,435] = 2,915 minutes. From Eq. (2) obtained W_{35} = 2,915 - 23 = 2,892 minutes. The waiting time of Batch 5, Q_{35}xW_{35}, is 28,920 minutes. From Eq. (3) obtained waiting time of Stage 3, W_3 is 96,800 minutes.

From Table 2 to Table 4, obtained the total waiting time, W_T, is 253,200 minutes.

Scheduling batch production with three stages on one machine to three stages on three machines will reduce waiting time, W_T, from 544,200 minutes to 253,200 minutes, thus decreases by 53.47 percent. So scheduling I=3 on m=3 with small transfer batch size (Q_{ij}=10) will reduce WIP inventory cost, C_{WIP}, by 53.47 percent.

4. Conclusion

The waiting time for a production batch that goes through several stages of the process is determined by use of the number of serial machines and transfer batch size.

Divides number of stages into m serial machines allow a process stage does not wait for all units in the production batch to be completed in the previous stage. Therefore, the production batch can be divided into several transfer batches, so that the waiting time of the production batch at each stage of the process is decreased. The results of this research indicate a reduction in WIP inventory cost by 53.47 percent. Scheduling multi-stage batch production on m machines with small transfer batch size will reduce WIP inventory cost.

Acknowledgments

First of all, thanks to the Dean of the Faculty of Engineering, Universitas Islam Bandung for financial support. Second, thanks also to our colleagues for intellectual support.

References

[1] Sukoyo, Samadhi T M A A, Iskandar B P and Halim A H 2010 Model penjadwalan batch multi item dengan dependent processing time *Jurnal Teknik Industri* **12**(2) 69-80

[2] Niroomand S, Mahmoodirad A and Zavardehi SMA 2016 Single batch-processing machine scheduling problem with fuzzy due-date: mathematical model and metaheuristic approach *Handbook of Research on Modern Optimization Algorithms and Applications in Engineering and Economics* (USA: Engineering Science Reference) chapter 28 751-69

[3] Li XL and Wang Y 2018 Scheduling batch processing machine using max-min ant system algorithm improved by a local search method *Mathematical Problems in Engineering* (London: Hindawi) 1-10

[4] Ogun B and Uslu CA 2018 Mathematical models for a batch scheduling problem to minimize earliness and tardiness *Journal of Industrial Engineering and Management* **11** 3 pp 390-405

[5] Gupta D and Goyal B 2017 Minimization of total waiting time of jobs in n 2 specially structured flow shop scheduling with set up time separated from processing time and each associated with probabilities *Int. Journal of Engineering Research and Application* **7** 6 pp 27-33
[6] Paul SK and Azeem A 2010 Minimization of work-in-process inventory in hybrid flow shop scheduling using fuzzy logic *International Journal of Industrial Engineering* **17** 2 pp 115-27
[7] Ozturk O, Espinouse ML, Mascolo MD and Gouin A 2012 Makespan minimization on parallel batch processing machines with non-identical job sizes and release dates *International Journal of Production Research* **50** 2 (Taylor & Francis) pp 6022-35
[8] Yimer AD and Demirli K 2009 Fuzzy scheduling of job orders in a two-stage flowshop with batch processing machines *International Journal of Approximate Reasoning* **50** pp 117-37
[9] Saraswat P, Kumar D and Sain MK 2015 Reduction of work in process inventory and production lead time in a bearing industry using value stream mapping tool *International Journal of Managing Value and Supply Chains (IJMVSC)* **6** 2 pp 27-35
[10] Gong H, Chen D and Xu K 2014 Parallel-batch scheduling and transportation coordination with waiting time constraint *The Scientific World Journal* (London: Hindawi) pp 1-8
[11] Prasetyaningsih E, Suprayogi S, Samadhi TMAA and Halim AH 2017 Production and delivery batch scheduling with multiple due dates to minimize total cost *Journal of Engineering and Technological Sciences* **49** 1 pp 16-36