SCHEDULING METHODS FOR LOT PRODUCTION IN MULTIVOLUME JIT PRODUCTION SYSTEMS

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Abstract. This paper deals with scheduling methods in JIT Production that includes lot processes. In general, the delays often occurs in multivolume JIT production systems that include lot processes, because set-up time is increased in the multivolume JIT production. To cope with the difficulty, we propose three scheduling methods to decrease delays and the work-in-process-inventory in lot processes. Furthermore, we evaluated the methods by computer simulations.

Keywords. Multivolume JIT production, Scheduling, Lot production, Signal Kanban

1. INTRODUCTION

In many cases, there exist the processes such as press processes in the production systems whose setup times for changing job types are very long. In this paper, we call such processes *lot processes* whose setup times are very long and in which many jobs are processed once until the setup are changed for the other job types. However, the number of setups of the lot processes increase, if the lot processes are included in multivolume JIT(Just-in-time) production systems(Monden 1983). This is because the volume and the operation start time of each jobs are determined by *kanbans* from the subsequent process which is not a lot process. Therefore, utilizations of the lot processes become small and the jobs are often delayed. In conventional JIT production systems, managers try to improve the utilizations by *kaizen*(Kotani 1983). However it is not easy to improve, because they cannot always reduce the setup times dramatically.

In this paper, first, to cope with the difficulties, we propose three schedule methods to generate the processing order of jobs in a lot process. Finally, by using the three scheduling methods, we try to improve the utilizations and to decrease the delay of jobs in the multivolume JIT production system including lot processes.

2. JIT PRODUCTION SYSTEM INCLUDING LOT PROCESSES

In this paper, consider a JIT production system including a press process which is a kind of lot processes. **Fig. 1** shows the flow of jobs, parts, and information such as production orders in the JIT production system. In the production system shown in Fig. 1, first, the jobs are processed using the parts stored in each process. If the number of the stored parts of the first process in the body line decreases to the appropriate value, the process requires the appropriate number of parts from the buffer of the press process using *signal kanbans*. After

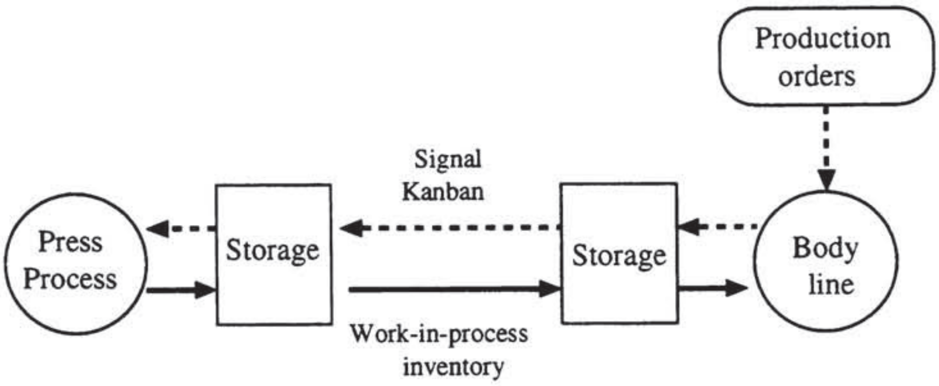

Fig. 1. Flow of production order and work-in-process inventory in the JIT production system.

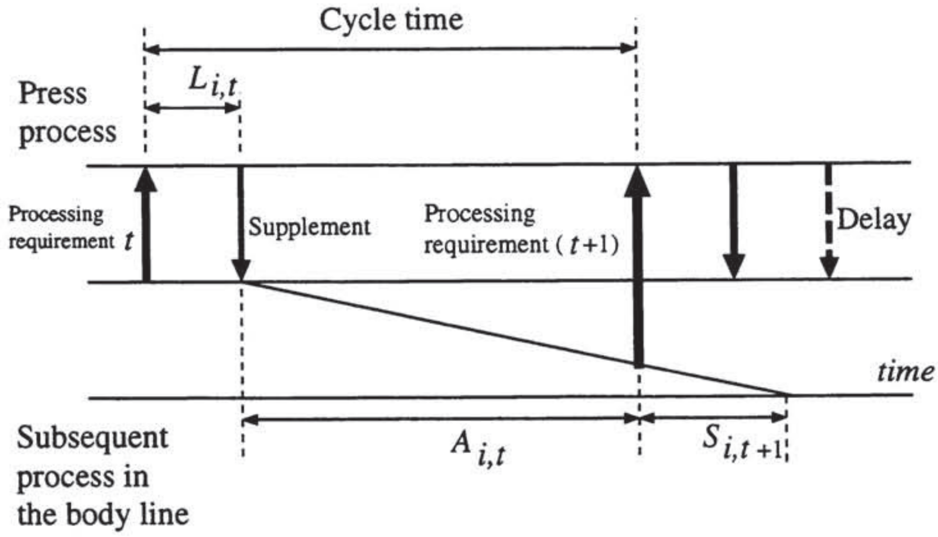

Fig. 2. Graphical explanation of control parameters of JIT production systems.

the required number of jobs are conveyed to the process, the press process produces the parts whose number is as same as that of jobs that has conveyed to the first process in the body line.

In this paper, we model the JIT production system shown in **Fig. 1** to describe the scheduling algorithms in lot processes. In modeling the JIT production system, we consider the press process and the subsequent process of the press process, which is a first process of the body line, because the other processes in the body line are not related with the press process directly in JIT production systems. To model the JIT production system shown in Fig. 1, we define several control parameters. **Fig. 2** shows the graphical explanation of each parameter(Hatono *et al.* 1996).

In Fig. 2, job i for processing requirement t are executed in the press process. We define the processing time of job i for processing requirement t is $L_{i,t}$. Where i and t mean a job number and a sequential number assigned in order of the arrival time of each processing requirement from the subsequent process, respectively. The first process in the body line processes job i using the parts conveyed from the press process. We assume the next processing requirement $t+1$ is sent in $A_{i,t}$. Furthermore, we assume the first process in the body line spent all parts for job i in $S_{i,t+1}$ since the process sent the processing requirement $t+1$ to the press process.

The arrival time of each processing requirement from the subsequent process is Poisson-distributed, if $A_{i,t}$ for each i and t is different each other and the variety of the jobs are sufficiently large(Kotani 1983). Therefore, we assume the arrival time of each processing requirement Poisson-distributed in the JIT production system shown in Fig. 2.

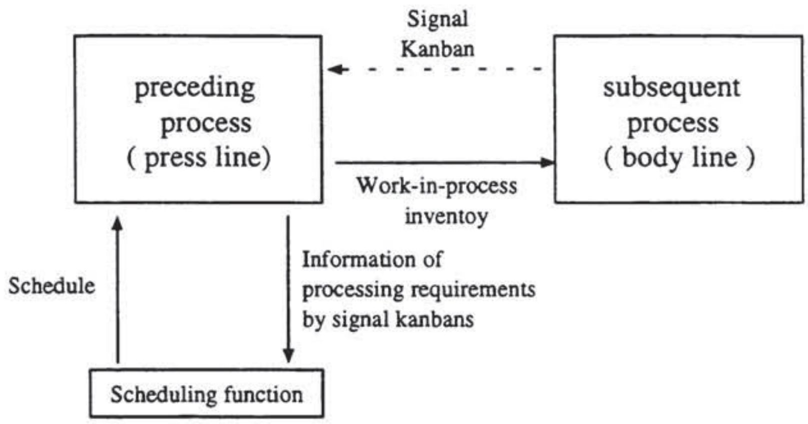

Fig. 3. System configuration of proposed scheduling methods.

3. SCHEDULING METHODS FOR LOT PROCESSES

In conventional JIT production systems, jobs are processed according to the processing requirement using kanbans. However, the number of setups in the processes becomes too large in multivolume JIT production systems including the lot processes. To cope with the difficulty, it seems that it is necessary to introduce a scheduling mechanism to the lot processes in addition to the processing requirements using kanbans (**Fig. 3**). In this paper, we propose three scheduling methods for lot processes. In the following, we describe the outline of the scheduling methods.

3.1 Method 1: Scheduling method in order to avoid delays

If $L_{i,t}$ for the production requirement i is greater than $S_{i,t}$, job i delays. Therefore, to prevent the delay of the jobs, it is necessary to generate the processing orders in order to keep the condition $L_{i,t} \leq S_{i,t}$. However it is difficult to obtain the processing orders to keep the condition $L_{i,t} \leq S_{i,t}$, because the processing requirements arrive at random in general. In this paper, we propose the heuristic scheduling algorithm in order to keep the condition if possible.

[Scheduling algorithm of Method 1]

Step 1. If the number of the processing requirements that arrived while job i is processing is 1, the processing requirement is processed next to job i.

Step 2. If the number of the processing requirements that arrived while job i is processing is greater than 1, the processing requirement whose $S_{i,t}$ and $L_{i,t}$ are smallest is processed next to job i. Goto Step 1.

3.2 Method 2: Scheduling method in order to increase throughput

In method 1, since only the jobs whose processing requirements are arrived at the press process, it seems that it is difficult to increase throughput of jobs. To cope with the difficulties, the jobs without the production requirements are processed during the time between the operation end time of the last job and the arrival time of the next production requirement job in method 2. The jobs to be processed are selected using the algorithms as follows:

[Scheduling algorithm of method 2]

Step 1. When the press machine is idle, generate a *processing jobs list*, in which the estimated processing requirements that will arrive in the near future are registered in order each estimated arrival time of the processing requirement.

Step 2. Process the first processing requirement in the processing jobs list. If processing requirements has arrived when the processing is finished, process each job corresponding to the processing requirement in order of each arrival time and goto Step 1.

Step 3. Delete the requirement from the processing jobs list. If the processing jobs list is empty, goto Step 1. Otherwise, goto Step 2.

In Step 1 of this method, we generate a processing jobs list using the algorithm in order to avoid delays of jobs as follows:

[Algorithm for generating a processing jobs list]

Step 1. If the press machine is idle, calculate estimated arrival time of processing requirement t for each job i $Y_{i,t}$ by using the equation as follows:

$$Y_{i,t} = U_{i,t-1} + A_i \tag{1}$$

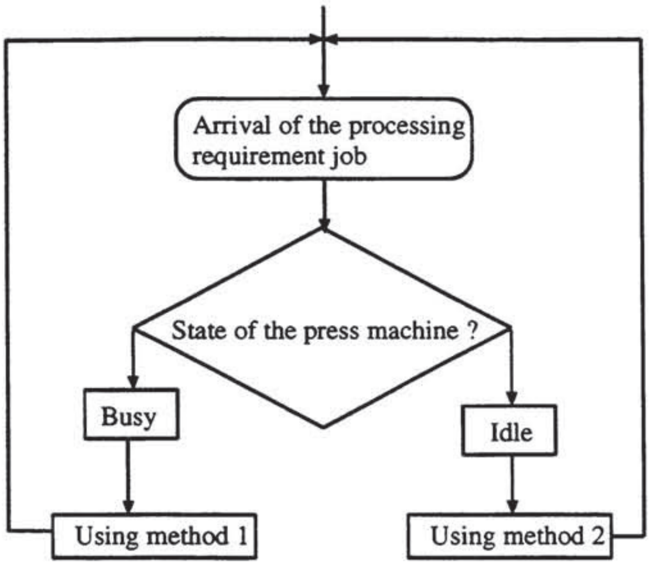

Fig. 4. Flow chart of hybrid method of method 1 and method 2.

Where $U_{i,t-1}$ denotes the conveying time of the job i for processing requirement $t-1$. Otherwise, stop.

Step 2. Add the estimated processing requirements to the processing jobs list in order of each estimated arrival time of processing requirement $Y_{i,t}$.

3.3 Hybrid method of method 1 and 2

As described above, we can decrease the delays of the jobs, but it is difficult to increase the throughput of jobs by using method 1 if the idle times of the press process is relatively long. By using method 2, we can increase the throughput, but it is difficult to prevent the delays if the idle times of the press process is too short because we cannot produce the appropriate amount of the jobs whose processing requirement has not arrived. To cope the difficulties, we propose a hybrid method of method 1 and 2. **Fig. 4** shows the outline of the algorithm of the hybrid method. In the hybrid method, if there is no job to be processed in the lot process when a processing requirement reaches, method 1 is applied, otherwise, method 2 is applied.

3.4 Revised hybrid method

When we use the proposed methods such as method 2 and the hybrid method, it is possible to increase the work-in-process inventory of the press process, because the jobs without the processing requirements are processed in the press process. To cope with this inventory problem, we revise the hybrid method to decreases the work-in-process inventory in the press process. The algorithm of the revised hybrid method is as follows:

[Algorithm of revised hybrid method]

Step 1. When the press machine is idle, generate a *processing jobs list*, in which the estimated processing requirements that will arrive in the near future are registered in order each estimated arrival time of the processing requirement. Let time T be the current time.

Step 2. Process the first processing requirement in the processing jobs list, if the following condition is satisfied.

$$Y_{i,t} - T > G \qquad (2)$$

Step 3. If processing requirements has arrived when the processing is finished, process each job corresponding to the processing requirement in order of each arrival time and goto Step 1. Otherwise, let T be $T+K$ and goto Step 2.

Step 4. Delete the requirement from the processing jobs list. If the processing jobs list is empty, goto Step 1. Otherwise, goto Step 2.

Where G and K denote the parameters to control the level of work-in-process inventory.

4. NUMERICAL EXAMPLES

To evaluate the efficiency of the methods proposed in this paper, we develop a simulation system of the production system shown in Fig. 3. In the simulation system, we assume that the volume of each job is between 300 and 450, and the number of parts that are needed in the subsequent lines in a day is uniformly distributed from 150 to 300. Parameter G and K is 480 minutes and $G \cdot 0.1$, respectively.

Fig. 5 shows the total sum of delay of each job when the number of job types are varied. Where "no control" means that the processing order in the press process is determined by the processing requirements from the subsequent processes. Fig. 5 shows that method 2 and the hybrid method are superior to the other methods. This is because method 2 and the hybrid of method produce the jobs without the processing requirement in the idle time of the press machine, when the number of processing requirements is small. However, in the case that the number of job types becomes greater than 9, the total sum of delay of each job increase rapidly, because the idle time of the press machine becomes too short.

Fig. 6 shows operation rate when the number of job types is varied. In Fig. 6, the hybrid method is superior to the other methods because the the idle time of the

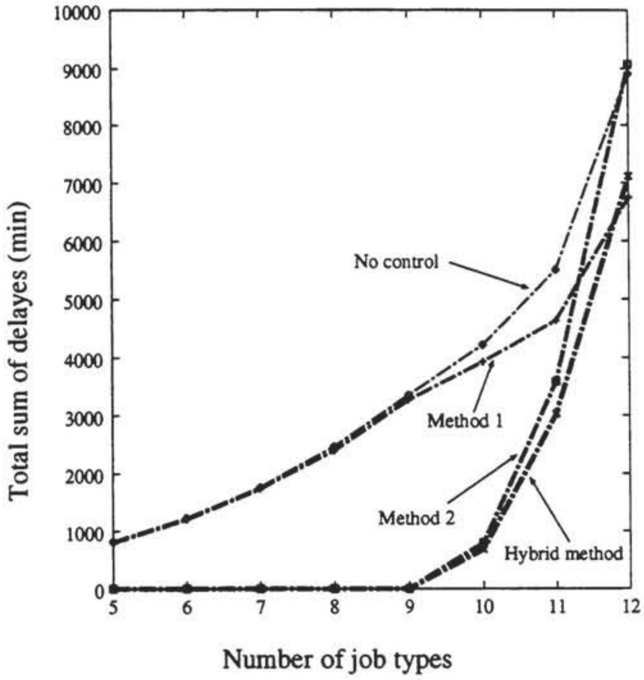

Fig. 5. Total sum of delays when the number of job types is varied

press machine is used to process jobs whose processing requirements is not arrived in the hybrid method. In the proposed methods, the operation rate of the press process does not vary with the number of job types. Therefore, we can keep the operation rate of the press process a constant value by using the hybrid method.

Fig. 7 shows average makespan of jobs when the number of job types is varied. In Fig. 7, each value of makespan in the hybrid method and the revised hybrid method is less than that in "non-control," if the number of job types is less than 11. This is because method 2 and the hybrid of method produce the jobs without the processing requirement in the idle time of the press machine, when the number of processing requirement jobs is small. Furthermore, each value of makespan in the revised hybrid method is less than that in the hybrid method. This is because the amount of the work-in-inventory decreases by using the revised hybrid method.

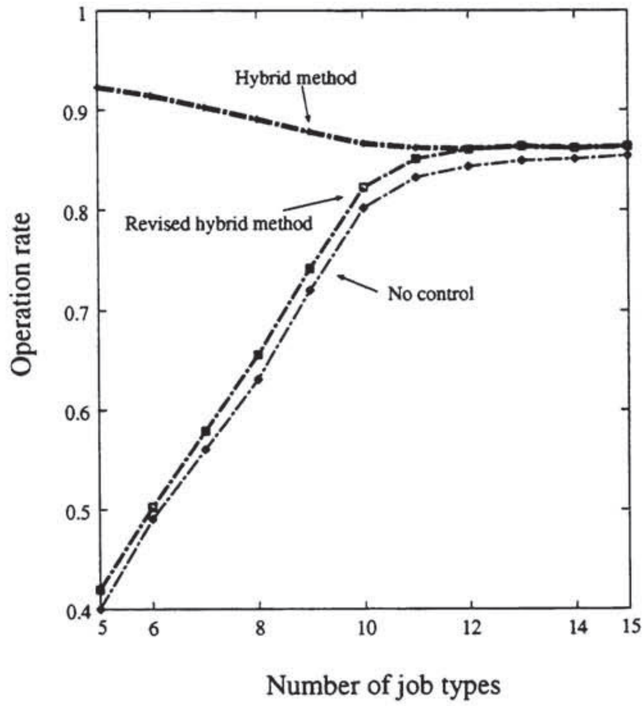

Fig. 6. Operation rate when the number of job types is varied

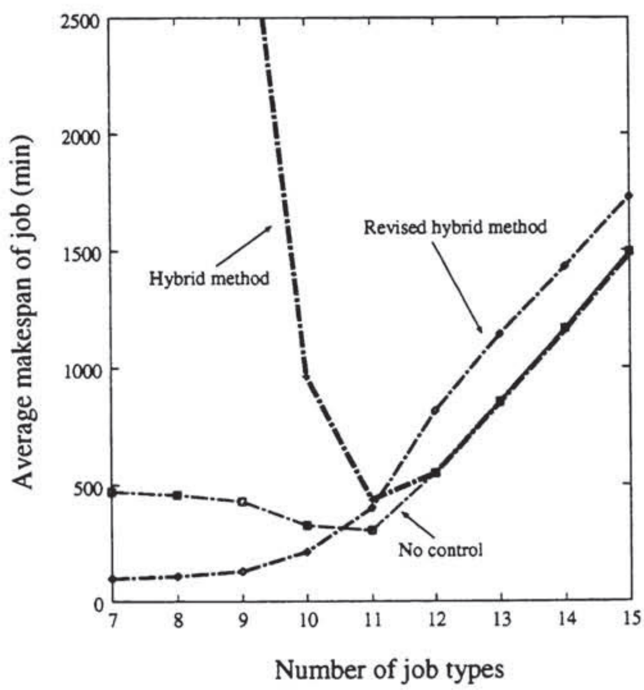

Fig. 7. Average makespan of job when the number of job types is varied

5. CONCLUSION

In this paper, we proposed three scheduling methods to schedule the order of jobs in a lot process to improve the utilizations and to decrease the delay of jobs in the JIT production system including lot processes. Furthermore, we evaluated the methods using computer simulations.

Further research might be focused on applying these methods to the real production systems and revise the algorithm.

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