論文 한국정밀공학회지 제12권 제11호 1995. 11
Journal of the Korean Society of Precision Engineering Vol.12. No.11. November. 1995.

이논문은 1994년 조선대학교에 의하여 지원받은 논문입니다.

적시적정생산시스템에서 그룹개념을 이용한 조립순서 제어

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Sequencing Control By Group Concept For Mixed-Model Assembly Lines In JIT

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ABSTRACT

본 연구는 JIT생산시스템에서 혼합조립라인에 대한 제품순서계획에 대한 연구이다. 본 연구에서 고려하는 조립라인을 효과적으로 수행하기 위해서는 서로 다른 제품들을 조립하기 위한 제품순서가 결정되어야 한다. 필요한 제품을 적시에 적당한 양만큼 생산하는 JIT생산시스템에서의 제품 순서계획의 목적은 라인에서 소비되는 모든 부품들의 소비율을 일정하게 유지시키는 것이다. 본 연구에서는 부품소비율을 일정하게 유지시키면서 동시에 순서계획수립시 계획파괴를 줄일수 있도록 그룹개념을 이용하여 순서계획문제를 정식화하고 이에 대한 해법을 제시하였다.

본 연구에서 개발한 해법의 우수성을 평가하기 위해 총변동과 순서계획의 파괴빈도에 대한 실험을 통하여 기존해법과 비교한 결과 본 연구의 해법이 우수한 결과를 제공하였다.

1. INTRODUCTION

1.1 Background

Recently, a market movement have been characterized by a diversified and specially-oriented society and a short product life cycle. Therefore, most of manufacturing firms worldwide must take a step to adopt a type of multi-product, small-lot-sized production.

JIT production system has been sparked by the significant productivity improvements attributed to it. The JIT philosophy include three principles, (1) reduction of production costs, (2) elimination of waste, and (3) recognition of workers' abilities. The JIT production system strives to reduce work-in-process by producing only the minimum number of required parts. It has been described as a 'demand-pull' rather than a 'schedule-push' system. The JIT production system often uses the mixed-model assembly line for a multi-product, small-lot-sized production, which

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helps to satisfy the customers' diversified demands without holding large inventories. The smoothing of production is the most important condition for production by Kanban and for minimizing slack time in regards to manpower, equipment, and work-in-process : it is the corner stone of JIT production system.

To utilize the mixed-model assembly line effectively, the following steps are required : 1) Determination of a cycle times 2) Computation of a minimum number of processes 3) Preparation of a diagram of integrated precedence relationships among elemental jobs 4) Line balancing 5) Determination of the sequence schedule for introducing various products to the line 6) Determination of the length of the operations of each process.

And the sequence schedule for mixed-model assembly line will much depend upon the goals of the company. Generally, there are two possible goals. First, levelling the load on each process within the line. Second, keeping a constant rate or speed in consuming each part on the line. First goal recognizes that all products do not have the same operation time at each station on the line. If products with relatively longer operation times are successively introduced, delay and line stoppages will result. In this study we consider the second goal. Although both goals are important and need to be considered for all mixed-model assembly line, the second goal is considered to be more important for JIT production system.

Under the pulling system, the variation in production quantities between each process must be minimized. And their respective work-in-process inventories must be minimized. To do so, the quantity used per hour for each part in the mixed-model assembly line must be kept as constant as possible. It should be recognized to develop a sequencing algorithm that may keep the consumption rate for each part in the mixed-model assembly line.

1.2 Objectives

Each product assembled in the mixed-model assembly line requires a variety of parts, often these parts vary from product to product. Scheduling large lots of each product requires large lots of parts. When a part is only needed for certain products, its usage will be high when these products are being assembled and will be low otherwise. This is what we wish to avoid. JIT production system only work when there is a constant rate of usage for all parts. To minimize the variation in the usage of each part, products will be sequenced in small lots using an efficient sequencing algorithm. Therefore, the sequence schedule must be able to keep a constant consumption rate or speed for each part in the line.

When the differences of each product demands are large, the existing algorithm frequently generates the destroy of sequence schedule and the number of calculation is increased. When the destroyed schedules occur, the existing algorithm requires rescheduling.

The objective of this study is to develope a sequencing algorithm for mixed-model assembly line in order to reduce the number of destroyed schedule and the calculation burden of generating a sequence schedule, when the differences of each product demands are large. And in order to evaluate the algorithm, the proposed algorithm is compared with Miltenburg's algorithm[8] by experiment.

1.3 Reviews of Literature

Okamura and Yamashina[1] presented a heuristic procedure for sequencing products with different operation times on a mixed-model assembly line in which parts are transfered by conveyor and their objective function is to minimize line stoppages.

Dar-El and Cother[2] formulated a mathematical model for the mixed-model assembly line, and the objective function of the model is to minimize the overall assembly line length for no operator interference and a compelete experiment was made on five factors to determine their influence on the overall assembly lines.

Toyota Motor Company[3] developed a heuristic sequencing algorithm which was to keep a constant consumption rate of each part for the mixed-model assembly line.

Miltenburg[4] presented a theoretical basis and some algorithms for the sequence schedule on the mixed-model assembly line. But he didn't consider part mix on a mixed-model assembly line.

Inman and Bulfin[5] developed a sequencing schedule which was to minimize variation between ideal due date and real completion time. He used EDD rule to solve the problem.

Sumichrast, Russel and Taylor[6] used TSM(time spread method) to smooth the production loads on each process within the assembly line. The objective of this study was to minimize the production loads of processes.

Miltenburg and Goldstein[7] presented a mathmatical model which was contented with two objectives (line balancing and keeping a constant consumption rate of all parts used by the line) at the same time. They developed a heuristic algorithm(double-stage method), but it was not resolve the destroyed sechedule problem.

Inman and Bulfin[9] presented sequencing algorithm by the measure of intutive level part usage. The measure assigns an ideal due-date to each unit of each part type of each level, and sums the squared deviation between these ideal due-dates and actual compeletion times.

Mejabi and Wasserman[10] introduce some conceps that are useful for analysing JIT systems The basic paradigm was then used to explore the interfacing requirements between various combinations of JIT and scheduled manufacturing system modules.

When the differences of each product demands are large, we present a heuristic algorithm of sequence schedule using group concept which can reduce the number of destroyed schedule and the calculation burden of the sequence schedule.

2. MODEL FORMULATION

We can achieve a constant consumption rate of each part usage by considering only the demand rates for the products. The objective then is to schedule a constant consumption rate of production for each product. The reason is that the choice of a product don't give an effect to the other product structure.

The notations used in the mathematical model are as follows :

d_i : demand of product i $(i = 1, 2, \cdots, n)$

D_T : total demand of all product

$$D_T = \sum_{i=1}^{n} d_i$$

r_i : proportion of product i (demand rate)

$$r_i = \frac{d_i}{D_T}$$

x_{iK} : total production of product i over stages 1 to K

s_{iK} = 1 : product i being produced on stage K

0 : otherwise

Because only one product can be produced on each stage.

Table 1 Example of grouping of products

Product	A1	A2	A3
Demand	6	6	1
Group	G1		G2

Product	A1	A2	A3
Demand	8	6	3
Group	G1		G2

Product	A1	A2	A3	A4	A5
Demand	6	6	5	15	1
Group	G1			G2	G3

$$\sum_{j=1}^{n} s_{ij} = 1, \quad for \quad all \quad K$$

Therefore, x_{iK} and K is as follows :

$$x_{iK} = \sum_{j=1}^{K} s_{iK}$$

$$K = \sum_{i=1}^{n} x_{iK}$$

To minimize the variation of the actual production quantity from the desired production quantity or the variation of the actual production rate from the desired production rate (demand rate), the objective function is as follows

$$Minimize \quad \sum_{K=1}^{D_t} \sum_{i=1}^{n} (x_{iK} - K \cdot r_i)^2$$

This Objective function trys to keep the actual number of units produced(x_{iK}) closed to the desired number of units($K \cdot r_i$) at all times.

3. DEVELOPMENT OF ALGORITHM

3. 1 Sequencing Algorithm

In this model, the assumption of the proposed algorithm is that the structures of all product are independent of each other. Miltenburg's algorithm is product sequence schedule which minimizes the variation of actual production quantity from desired production quantity for all stage. When the difference of quantity of each product is large, his algorithm is frequently destroyed and required a lot of calculation burden. Because the destroyed schedules need rescheduling process.

In attempting to solve these problems and to improve Miltenburg's algorithm, we consider a grouping of products. The group of products consist of products that have similar production requirements. Generally, the grouping method has two criteria. First, the differences of each product demadnds between groups are as large as possible. Second, the differences of each product demands in a group are as small as possible. The number of group and product in a group are determined arbitrally by scheduler. The example of grouping is shown as follows :

The notations used in sequencing algorithm are given as follows :

G_i : production quantity of group i ($i = 1, 2, \cdots, n$)

Q : total production quantity of all groups

$$Q = \sum_{i=1}^{n} G_i$$

X_G : desired proportion of groups

$$X_G = (\frac{G_1}{Q}, \frac{G_2}{Q}, \cdots, \frac{G_n}{Q}) = (x, x, \cdots, x)$$

M_G : the nearest integer number of X_G (actual proportion of groups)

$$M_G = (m_1, m_2, \cdots, m_n)$$

X_{GK} : desired proportion of groups at stage

$$X_{GK} = (\frac{K \cdot G_1}{Q}, \frac{K \cdot G_2}{Q}, \cdots, \frac{K \cdot G_n}{Q})$$

M_{GK} : the nearest integer number of X_{GK}

The objective of sequencing algorithm is to minimize the variation of actual proportion M_{GK} and desired proportion X_{GK}.

3.1.1 SEQUENCING ALGORITHM

The procedures are given as follows :

Step 1 : $K = 1$

Step 2 : Calculate X_{GK}, M_{GK}

Step 3 : Calculate P, $P = \sum_{i=1}^{n} x_i$

Step 4 : Calculate P_m, $P_m = \sum_{i=1}^{n} m_i$

Step 5 : $P - P_m = 0$ Go To Step 6
$P - P_m > 0$ Go To Step 7
$P - P_m < 0$ Go To Step 8

Step 6 : M_{GK} is assigned the sequence schedule at stage K
$K = Q$, Go To Step 9
$K < Q$, $K = K+1$ Go To Step 2

Step 7 : Find i with the smallest $m_i - x_i$ increment the value of this i^* :
$m_{i^*} = m_{i^*}+1$ Go To Step 4

Step 8 : Find i^* with the largest $m_i - x_i$ decrement the value of this i^* :
$m_{i^*} = m_{i^*} - 1$ Go To Step 4

Step 9 : Stop

3.1.2 Heuristic procedure for destroyed sequence schedule

If the destroyed sequence schedule is found, follows this procedures.

Step 1 : Find the first stage l

Step 2 : h : the number of destroyed group i
$l + w$: the first stage where the schedule determined by the sequencing algorithm matches the schedule determined by this heuristic

Carry out Step 3 for $l - h$, $l - h + 1$, $\cdots$, $l + w$

Step 3 : Calculate the variation V_i for each Group Find the Group i^* with the smallest V_i and Group i^* is determined for schedule list

3.2 Numerical Example

Suppose that there are 3 products(n=3) with demand D_i = (6, 6, 1) to be assembled on a mixed-model assembly line and that Miltenburg's algorithm is applied. The sequence schedule obtained by Miltenburg's algorithm is summarized in Table 2.

The sequence schedule is destroyed at stage 6 and 8. At the both stage 6 and 8, the numeric -3 of the product schedule represents the production of -1 unit of product A_3. It shows the lack of product schedule.

Only one product can be assembled during a stage and products assembled earier cannot be destroyed. Therefore, the existing algorithm requires rescheduling at the stage of destroyed schedule. Table 3 gives the result of rescheduled list for the destroyed sequence schedules. In example, the number of destroyed schedules of the existing algorithm are appeared twice and its total variation is 5.0769.

Table 2 Sequence schedule by Miltenburg's algorithm for example

K	X_K			M_K			product schedule	$\sum_{i=1}^{3} (m_{iK} - x_{iK})^2$
1	6/13	6/13	1/13	1	0	0	1	0.5089
2	12/13	12/13	2/13	1	1	0	2	0.0355
3	18/13	18/13	3/13	2	1	0	1	0.5799
4	24/13	24/13	4/13	2	2	0	2	0.1420
5	30/13	30/13	5/13	2	2	1	3	0.5680
6*	36/13	36/13	6/13	3	3	0	1, 2, -3	0.3195
7	42/13	42/13	7/13	3	3	1	3	0.3195
8*	48/13	48/13	8/13	4	4	0	1, 2, -3	0.5680
9	54/13	54/13	9/13	4	4	1	3	0.1420
10	60/13	60/13	10/13	5	4	1	1	0.5799
11	66/13	66/13	11/13	5	5	1	2	0.0355
12	72/13	72/13	12/13	6	5	1	1	0.5089
13		-		6	6	1	2	-

Table 3 Rescheduled list for the destroyed sequence schedules

K	M_K			product schedule	$\sum_{i=1}^{n}(m_{iK}-x_{iK})^2$
5	2	2	1	3	0.5680
6	3	2	1	1	0.9349
7	3	3	1	2	0.3195
8	4	3	1	1	0.7219
9	4	4	1	2	0.1420
10	5	4	1	1	0.5799
11	5	5	1	2	0.0355
12	6	5	1	1	0.5089
13	6	6	1	2	-

The following steps illustrate the proposed sequencing algorithm for example at stage $K = 1$.

Step 1 : $K = 1$

Step 2 : $X_{G1} = (\ 6/7\ \ 1/7\ )$

$M_{G1} = (\ 1\ \ 0\ )$

Step 3 : $k = 6/7 + 1/7 = 1$

Step 4 : $k_m = 1 + 0 = 1$

Step 5 : $k - k_m = 0$

Go To Step 6

Step 6 : $M_{G1} = (\ 1\ \ 0\ )$ is the sequence schedule at stage 1

$k < 7$ ---> $k = k + 1 = 2$, Go To Step 2

Table 4 gives the complete sequence schedule by group concept. In the sequence schedule by proposed algorithm, the product schedule is not destroyed and its total variation is 4.6154. The result shows that the number of destroyed schedule and the calculation burden of product schedule are much more reduced compared with those Miltenburg's algorithm.

4. EVALUATION AND CONCLUSION

In this study, we introduced the objective functions and proposed the sequencing algorithm using group concept for mixed-model assembly lines in JIT systems. The main emphasis was given to sequencing algorithm for reducing the number of destroyed schedule

Table 4 Sequence schedule by proposed algorithm for example

K	X_{GK}		M_{GK}		group schedule	product schedule	$\sum_{i=1}^{n}(m_{iK}-x_{iK})^2$
1	6/7	1/7	1	0	1	1	0.5089
						2	0.0355
2	12/7	2/7	2	0	1	1	0.5799
						2	0.1420
3	16/7	3/7	3	0	1	1	0.7219
						2	0.3195
4	24/7	4/7	3	1	2	3	0.3195
						-	-
5	30/7	5/7	4	1	1	1	0.7219
						2	0.1420
6	36/7	6/7	5	1	1	1	0.5799
						2	0.0355
7	42/7	7/7	6	1	1	1	0.5089
						2	-

and the calculation burden of generating a sequence schedule. In order to evaluate sequencing algorithm, we experimented the algorithm for 100 problems. The number of products is changed from 3 to 20 and the production requirements of each product is changed from 1 to 20. The experiment results indicated that the proposed sequencing algorithm reduced the number of destroyed schedule and the calculation burden of generating a sequence schedule compared with Miltenburg's algorithm for all problems(100 problems). Furthermore, in the total variation of sequence schedule the proposed sequencing algorithm had resulted in a decrease of 13.3% compared with those of Miltenburg's algorithm and the proposed sequencing algorithm had been predominant in 86 problems out of 100, thus meaning a 86% superiority in frequency. As the result of experiments, when the differences of each products are large and the differences of each products in a group are small, the proposed sequencing algorithm has good result.

In anticipation, there should be further research on effective grouping method and sequencing algorithm which is contented with two objectives (line balancing and keeping a constant consumption rate of all parts used by the line) at the same time.

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