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A Simple Model To Optimize General Flow-Shop Scheduling Problems With Known Break Down Time And Weights Of Jobs

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Abstract

A new procedure is proposed to obtain a scheduling sequence having optimal or near optimal make span for a flow-shop scheduling problems involving known break down time and weights of jobs. The case is , n-jobs are to be processed in m-processing centre with different types of processing, the processes that require uninterrupted power supply and no break down in supply is permitted in between, the processes that require power supply and break down in supply is permitted in between (that is, the processing could be continued when the power supply resumes) and the processes that do not require power supply and can be continued during the break down time also. The proposed method to optimize the make span is very simple and easy to understand and hence can be effectively used in the shop floor when scheduling flow-shop problems. The proposed method is illustrated with the help of a numerical example.

Key Words: Flow-shop scheduling; Weights of jobs; Optimal sequence; Make Span; Weighed Mean Flow Time.

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1. Introduction

Any scheduling problem essentially depends upon three important factors namely, job transportation time which includes moving time and idle time , relative importance of a job over another job and breakdown machine time (non- time due any reason). These three factors were separately studied by many researchers. Miyazaki and Nishiyama (1980) had carried out an analysis for minimizing weighted mean flow time in flow-shop scheduling [1]. Chandramouli (2005) proposed a Heuristic approach for n-job, 3-machine flow-shop scheduling problem involving transportation time, breakdown time and weights of jobs. Pandian and Rajendran (2010) improved and simplified the procedure for a constrained FSP for 3 jobs [2, 3].

Having analyzed different situations, in this paper, we propose a new model for flow-shop scheduling problems involving known break down time, weights of jobs and three different types of processes with n-jobs and m-centre. The initial optimal solution to be obtained considering the weights using any simple Heuristic or method. Then, without modifying the sequence, the make span and weighed average flow time can be optimized after imposing the break down time constrains. For a n-jobs two machines problem, the method proposed by Johnson (1954) can be used effectively [4]. Other Heuristics include the Slope Index (SI) method proposed by Palmer (1965), functional algorithm proposed by Gupta (1971) [5, 6]. Both CDS and RA (rapid access procedure) heuristics proposed by Campbell et al. (1970) and Dannenbring (1977) respectively are based on Johnson's algorithm for the 2 machine problem and are simple to use [7, 8]. NEH algorithm proposed by Nawaz et al. (1983) appears to be the best polynomial heuristics in practice [9]. The proposed method is very simple and easy to understand and also, can be used as a tool by the shop floor supervisors to design a schedule for similar flow-shop scheduling problems. With the help of a numerical example, the proposed method is illustrated.

2. A Typical Flow-Shop Problem

Let us consider the following flow-shop problem with n-jobs and m- processing centre which can be stated as follows:

(a) Let n - jobs be processed through m- Processing centre P1, P_2, P_3… P_m in the same order.
(b) Let 'i' denote the job in an arbitrary sequence, i= 1 to n.
(c) All jobs are available for at time zero.
(d) Let each job be completed through the same production stage, in other words, passing is not allowed in the flow shop.
(e) Let P_{i1}, P_{i2}, P_{i3}… P_{im} denote the processing time of Job 'i' in the processing centre P_1, P_2, P_3… P_m respectively.
(f) The processing times may be classified under three categories:
(i)The processes that require uninterrupted power supply and no break down in supply is permitted in between. Let them be, U_1, U_2…
(ii)The processes that require power supply and break down in supply is permitted in between. That is, the processing could be resumed when the power supply returns. Let them be, V_1, V_2…
(iii) The processes that do not require power supply and can be continued during the break down time also. Let them be, M_1, M_2…
(g) Let job 'i' be assigned with a weight w_i according to its relative importance for performance in

the given sequence.

(h) The performance measures are the Make Span and the Weighed Mean Flow Time which is defined by:

$$\frac{\sum_i^n w_i f_i}{\sum_i^n w_i}$$, where f_i is the flow time of job 'i'.

(i) Let the known break down interval is (a, b) and the interval length is (b-a).
This can be conveniently expressed in a Tabular form, for example, as shown in Table 1.

Table 1. A flow shop problem

Job	Times					weight
	P_1	P_2	P_3	…	P_m	w_i
1	P_{11}	P_{12}	P_{13}	…	P_{1m}	w_1
2	P_{21}	P_{22}	P_{23}	…	P_{2m}	w_2
	…			…		
n	P_{n1}	P_{n2}	P_{n3}	…	P_{nm}	w_n

3. New Proposed Procedure

Step 1: Using any simple Heuristic or method, the initial sequence which gives optimal make span to be found out, considering the weights also.
Step 2: The jobs and processing time spans that are affected by the break-down interval time (a, b) to be identified.
Step 3: If any of the affected jobs come under category (iii), they need not be modified and to be ignored.
Step 4: The jobs and processing time spans that are to be modified initially are to be identified using following guide lines:

- First affected any processing time span for a job to be modified (coming from top and moving from left)
- In the subsequent jobs, any affected processing time span that comes before the previous identified processing time (That is, to the left of the previous one) and also first in its row to be modified
- Other spans are not to be modified initially.

A few examples are shown below:

(i)

x	x	x	x	x	x	&	*
x	&	*	*	x	x	x	x
x	x	x	*	x	x	x	x
x	x	x	x	x	x	x	x

(ii)

x	x	x	x	x	&	x	x
x	x	x	x	&	*	x	x
x	x	&	*	*	x	x	x
x	x	x	*	x	x	x	x

(iii)

x	x	x	x	x	x	x	x
x	x	x	x	x	&	x	x
x	x	x	&	x	*	x	x
x	&	*	x	*	x	x	x

Shown as ‘x’ are all un-affected actual processing time spans. Spans indicated as ‘&’ and ‘*’ are affected time spans. But, only the spans shown as ‘&’ are to be modified and shown as ‘*’ are not to be touched initially.

Step 5: Now, categorize the jobs and modify the processing times suitably. Let,
t – existing processing time
t_{new} – new processing time
a – break down time span begin
b - break down time span end
s_1 – existing processing time span begin
s_2 – existing processing time span end

Category (i) : If the process is a continuous one not to be interrupted in any case like moulding, casting, forging, welding, then for any case, add (b - s_1) to the existing processing time, t to get the new Processing Time, $t_{new.}$

Category (ii): If the process need not be a continuous one and not affected by any interruption like packing, machining, threading, drilling, then to get the new Processing Time, $t_{new.}$,

- If the break down starts in between, (b-a) to be added to the existing processing time
- If the break down starts and ends in between, (b-a) to be added to the existing processing time
- If the break down ends in between, (b - s_1) to be added to the existing processing time.
- If the break down starts before and ends after the existing processing time span, then (b - s_1) to be added to the existing processing time

Category (iii): The processes that do not require power supply. Need not be modified and to be ignored.

Step 6: The make span and mean weighed flow time are to be computed. Once again, the jobs and processing time spans affected by the break-down interval time (a, b) to be identified, if any.

Step 7: The iteration process to be continued, steps 2 to 6 to be repeated, till no job is affected by the break-down.

4. Numerical Example

Consider the following example as shown in Table 2 with 4 jobs, with varying weights to be processed in 5 different centres V_1, M_1 ,U_1 , U_2 and V_2 with their corresponding processing times:

Table 2. A Four Jobs, Five Centre Problem

Job	V_1	M_1	U_1	U_2	V_2	w_i
1	10	2	7	2	5	3
2	8	3	6	5	9	5
3	7	1	3	4	5	4
4	5	4	2	1	6	2

The break-down interval being (a, b) = (17, 22).

Step 1: Using any Heuristic algorithm, the optimal sequence can be computed as 3-2-1-4. The make span is computed as shown in Table 3.

Table 3, Initial Make Span of the sequence 3-2-1-4

Job	V_1	M_1	U_1	U_2	V_2	w_i
3	0-7	7-8	8-11	11-15	**15-20**	4
2	7-15	**15-18**	**18-24**	24-29	29-38	5
1	**15-25**	25-27	27-34	34-36	38-43	3
4	25-30	30-34	34-36	36-37	43-49	2

With a make span of 49 units. Mean weighed flow time =

$$\frac{(20x4) + (38-7)5 + (43-15)3 + (49-25)2}{(2+3+4+5)}$$

= .26.21 units

Step 2: The break-down interval being (a, b) = (17, 22) and the affected jobs are:

Job 3: V_2 (15-20)
Job 2: M_1 (15-18), U_1 (18-24)
Job 1: V_1 (15-25)

Step 3: Job 2- M_1 automatically gets ignored as it does not require any power supply.

Step 4: Using the guide lines, the identified processing times that are to be modified are:
Job 3: V_2 (15-20), Job 2: U_1 (18-24) and Job 1: V_1 (15-25).

Step 5:

For **Job 2: U_1 (18-24),** Since the process is a continuous one (U) not to be interrupted, New Processing Time= t + (b - s_1) and t=6, b=22, s_1=18.
New Processing Time = (6) + [(22 – 18)] = 10.

Job 1: V_1 (15-25),
As the process need not be a continuous one (V), not affected by any interruption and the break down starts and ends in between, add (b-a) to the processing time.
New Processing Time = 10 + (22-17) = 15.

Job 3: V_2 (15-20), as the break down starts in between, add (b-a) to the processing time.
New Processing Time = 5 + (22-17) = 10.

Step 6: The problem can be modified as indicated in Table 4:

Table 4, The modified Problem

Job	V_1	M_1	U_1	U_2	V_2	w_i
3	0-7	7-8	8-11	11-15	15-25	4
2	7-15	15-18	18-28	28-33	33-42	5
1	15-30	30-32	32-39	39-41	42-47	3
4	30-35	35-39	39-41	41-42	47-53	2

with a make span of 53 units with a Mean weighed flow time of 29.79 units

Step 7: It can be seen that processing time spans of no other jobs are affected by the Break-Down time and hence no more iterations are required.

The modified final Scheduling problem is shown in Table 5:

Table 5, Final Scheduling Problem

Job	V_1	M_1	U_1	U_2	V_2	w_i
1	**15**	2	7	2	5	3
2	8	3	**10**	5	9	5
3	7	1	3	4	**10**	4
4	5	4	2	1	6	2

with a make span of 53 units and Mean weighed flow time of 29.79 units

In this model, it is assumed that there is no power back up to deal with the power break down as it has been assumed that the production unit is a small scale one. It may please be noted that instead of power break down span, in can be taken as lunch break or tea break also. In such cases, the manual processes (M) are to be treated as the processes that need not be continuous ones (V), not affected by any interruption.

5. Conclusion

The new proposed method optimizes the make span of a scheduling sequence that has been obtained using any effective Heuristic or any other method for the constrained flow-shop scheduling problems of n-jobs on m-centre considering the break-Down times and weights. Three possible cases, continuous, intermittent and manual processes have been considered in a single problem and analyzed for Make Span and Weighed Mean Flow Time requirements with an example. This method is very easy to understand and implement and also will help the shop floor supervisors in scheduling jobs to find an optimal scheduling sequence in a simple and effective manner. Determining a best schedule for given sets of jobs under certain constraints can help decision makers effectively to control job flows and to provide a solution for sequencing problems. Any one efficient but, simple Heuristic can be used in this proposed procedure to compute the initial sequence. The general flow-shop scheduling problem is NP-hard and the complete effectiveness of the proposed procedure for varying problem sizes are under study by the authors.

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