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3-STAGE SPECIALLY STRUCTURED FLOW SHOP SCHEDULING TO MINIMIZE THE RENTAL COST, SET UP TIME SEPARATED FROM PROCESSING TIME INCLUDING JOB WEIGHTAGE

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ABSTRACT

This article describe the development of a new heuristic algorithm which guarantees an optimal solution for specially structured flow shop problem with n-jobs,3- machines, to minimize the rental cost under specified rental policy in which set up times are separated from processes time, including job weightage. Further the processing times are not merely random but bear a well defined relationship to one another. Most of literature emphasized on minimization of idle time/ make span. But minimization of make span may not always lead to minimize rental cost of machines. Objective of this work is to minimize the rental cost of machines under a specified rental policy irrespective of make span.

Keywords: Specially structured flow shop scheduling. Rental policy, Processing time, Rental cost, Job Weightage, Set up time, Utilization Time.

Mathematical subject classification: 90B30, 90B35.

1. INTRODUCTION

Scheduling is a decision making practice that is used on a regular basis in manu facturing and service industries. Its aim is to optimize one or more objectives with the allocation of resources to task over given time periods.

The time that a job spends on a machine include three phases viz setup, processing and removal. In the majority of investigation dedicated to production planning and scheduling, set up time considered to be negligible. But considering set up time separate from processing time have great impact on performance measure. As when there exists idle time on the second machine than the setup time for a job on a second machine can be performed prior to the completion time of this job on the first machine. All the scheduling models beginning from Johnson's work in 1954 upto 1980 there is no reference of job weightage in the literature. The scheduling problem with weights arises when inventory costs for jobs are involved. The weights of a job show its relative priority over some other jobs in a scheduling model. In a flow shop scheduling each job has the same routing throw machines and the sequence of operations is fixed. In a specially structured flow shop scheduling the data is not merely random but bears a well defined relation with one another. Gupta J.N.D [6], studied two stage specially structured flow shop scheduling problem. The basic study of flow shop scheduling was developed by Johnson [7]. Then work was developed by Smith and Dudek [18], Palmer, D.S. [13], SinghT.P. and Gupta Deepak [15], Yoshida and Hitomi [20] etc. while considering various parameters. Maggu and Das [10] consider a two machine flow shop problem with transportation time of the jobs. Yoshida and Hitomi [20] studied the optimal two stage production scheduling with setup time separated from processing time. Gupta Deepak [5] et.al. Studied two stage specially structured flow shop scheduling problems to minimize the rental cost under a specified rental policy. Present Paper extends the study made by Gupta et el [5] by introducing setup time separated from processing time and the concept of weightage of jobs.

In this paper we presents a specially structured flow shop scheduling model to minimize the utilization time of the machines and hence their rental cost under specified rental policy in which the setup times are separated from processing time, including job weightage. Most of the work emphasize on minimization of make span. Here we have discussed the algorithm which shows that minimization of make span does not always lead to minimize rental cost of machines.

2. PRACTICAL SITUATION

Manufacturing industries are the backbone in the economic structure of a nation, as they contribute to increasing G.D.P. / G.N.P. and providing employment. Productivity can be maximized, if the available resources are utilized in an optimized manner. Optimized utilization of resources can only be possible if there is a proper scheduling system making scheduling a highly important aspect of a manufacturing system. The practical situation may be taken in a paper mill, sugar factory and oil refinery etc. where various qualities of paper, sugar and oil are produced with relative importance i.e. weight in jobs, hence weightage of jobs is significant. The majority of scheduling research assumes set up as negligible or part of processing time. While this assumption adversely affects solution quality for many applications which require explicit treatment of setup, includes work to prepare the machine for processing. This includes obtaining tools, positioning work-in-process material, return tooling, cleaning up, setting the required jigs and fixtures, adjusting tools and inspecting material and hence significant. To established a new business or a manufacturing plant or a company one needs huge amount of money to purchase various machines, due to non liquidity of funds one cannot afford to buy all the expensive machinery prefer to take on rent. Renting is an affordable and quick solution for up gradation to new technology, saving working capital and best use of limited resources.

3. NOTATIONS

S : Sequence of jobs 1, 2, 3,….,n

S_k : Sequence obtained by applying Johnson's procedure, k = 1, 2, 3, ------ r.

M_j : Machine j, j= 1, 2, 3.

a_{ij} : Processing time of i^{th} job on machine M_j

s_{ij} : Set up time of i^{th} job on machine M_j

w_i : weight of i^{th} job.

$t_{ij}(S_k)$: Completion time of i^{th} job on machine M_j

$U_j(S_k)$: Utilization time for which machine M_j is required.

$R(S_k)$: Total rental cost for the sequence S_k of all machine

C_j : Rental cost per unit time of j^{th} machine.

4. Definition

Completion time of i^{th} job on machine M_j is denoted by t_{ij} and is defined as:

$t_{ij} = max\ ((t_{i-1,j}\ ,+\ s_{i,j}),\ \ t_{i,j-1}\ \ ) + a_{ij}\ ;\ \ j \geq 2.$ J=2, 3

$t_{i2} = max\ ((t_{i-1,2}\ ,+\ s_{i,2}),\ \ t_{i,1}) + a_{i2}$

$t_{i3} = max\ ((t_{i-1,3}\ ,+\ s_{i,3}\ ,\ \ t_{i,2}\ ) + a_{i3}$

5. RENTAL POLICY (P)

The machines will be taken on rent as and when they are required and are returned as and when they are no longer required.

6. PROBLEM FORMULATION

Let some job i (i = 1,2,……..,n) are to be processed on three machines M_j (j = 1,2,3) under the specified rental policy P. Let a_{ij} be the processing time of i^{th} job on j^{th} machine s_{ij} be the set time of its job on jth machine and w_i be the weight of ith job. such that either $\min(a_{i1}-s_{i2}) \geq \max(a_{i1} - s_{i1})$ Or $\min(a_{i3}-s_{i2}) \geq \max(a_{i2} - s_{i3})$ for all i,j, $i \neq j$

Our aim is to find the sequence $\{S_k\}$ of jobs which minimize the rental cost of the machines while minimizing the utilization time of machines.

The mathematical model of the problem in matrix form can be stated as:

Jobs	Machine M_1		Weight in job	Machine M_2		Machine M_3	
I	a_{i1}	s_{i1}	w_i	a_{i2}	s_{i2}	a_{i3}	s_{i3}
1	a_{11}	s_{11}	w_1	a_{12}	s_{12}	a_{13}	s_{13}
2	a_{21}	s_{21}	w_2	a_{22}	s_{22}	a_{23}	s_{23}
3	a_{31}	s_{31}	w_3	a_{32}	s_{32}	a_{33}	s_{33}
-	-	-		-	-	-	-
N	a_{n1}	s_{n1}	w_n	a_{n2}	s_{n2}	a_{n3}	s_{n3}

Table -1

Mathematically, the problem is stated as:

Minimize :

$$R(S_k) = \sum_{i=1}^{n} A_{i1} \times c_1 + u_2(S_k) \times c_2 + u_3(S_k) \times c_3$$

Subject to constraint: Rental Policy (P) i.e. our objective is to minimize utilization time of machine and hence rental cost of machines.

7. ALGORITHM

Step 1: Check the following structural relationship.

either $a_{i1} - s_{i2} \geq a_{j2} - s_{j1}$ for all i,j, $i \neq j$.

or $a_{i3} - s_{i2} \geq a_{j2} - s_{j3}$ or both

i.e either $\min(a_{i1} - s_{i2}) \geq \max(a_{i2} - s_{i1})$

or $\min(a_{i3} - s_{i2}) \geq \max(a_{i2} - s_{i3})$ or both for all i.

If the conditions are satisfied then go to step 2 else modify the problem to bring in the standered form..

Step 2: convert the problem into two machine problem. Let G and H be two fictitious machines having G_i and H_i as their processing times as:

$G_i = a_{i1} + a_{i2}$

$H_i = a_{i2} + a_{i3}$

Step 3: obtain new reduced problem with processing time Gi & H_i as follow:

Then $G_i' = G_i + max\ (s_{i1}, s_{i2})$

$H_i' = H_i - s_{i3}$

Step 4: **:** Calculate weighted flow time G_i'' & H_i'' as follow

If $\min(G'_i, H'_i) = G'_i$

Then $G_i'' = (G'_i + w_i) / w_i$, $H_i'' = H'_i/w_i$

And

If $\min(G_i, H_i) = H_i$

Then $G_i = G_i/w_i$ $H_i = (H_i + w_i) / w_i$

Step 4: Obtain the optimal sequence S_i (Say) to minimize the make span by applying Johnson's [1954] algorithm on machine G and H with processing time G_i' and H_i' respectively

Step 5: Obtain other feasible sequences by putting 2nd, 3rd,......nth jobs of sequence S_1 in first position respectively and all other jobs of S_1 in same order.
Let the sequence be:
$S_{2,}$ S_3 ------ S_n.

Step 6: Compute CT (S_k) ; k= 1,2-----r by making in – out table for sequences S_k (k= 1,2-----r).
Step 7: Calculate $\sum A_{i1}$, $U_2(S_k)$ & $U_3(S_k)$ of 1st, 2nd and 3rd machines respectively.

Step 8: Calculate

$$R(S_k) = \sum_{i=1}^{1} A_{i1} \times c_1 + u_2(S_k) \times c_2 + u_3(S_k) \times c_3$$

Where C_1, C_2 and C_3 are the rental cost per unit time of machines M_1, M_2 and M_3 respectively.
Step 9: Find min $R(S_k)$; k= 1,2,….,n. let it be minimum for the sequence S_p, then sequence S_p, will be the optimal sequence with rental cost $R(S_p)$.

8. NUMERICAL ILLUSTRATION

Consider 5 jobs, 3 machines flow shop problem in which processing times, set up times with transportation times are given in the table. The rental cost per unit time for machines M_1, M_2 and M_3 are10 units, 3 units and 2 units respectively under the rental policy P.

Jobs	Machine M_1		weight	Machine M_2		Machine M_3	
i	a_{i1}	s_{i1}	w_i	a_{i2}	s_{i2}	a_{i3}	s_{i3}
1	15	6	4	18	2	50	3
2	18	3	2	13	1	43	5
3	30	2	1	20	4	60	1
4	11	5	3	15	4	35	2
5	9	1	5	25	2	65	4

Table :2

Solution: As per step 1: The condition
max (a_{i2} – s_{i3}) ≤ min (a_{i2} – s_{i2}) for all i, satisfies
Thus as per step 2: Convert the problem in two machine problem G and H with G_i & H_i as the processing time as defined in step 2.

Jobs	Machine M_1	Machine M_2
I	G_i	H_i
1	33	68
2	31	56
3	50	80
4	26	50
5	34	90

Table : 3

As per step 3: Calculate processing time G_i' & H_i' as:

i	1	2	3	4	5
G_i'	39	34	54	31	36
H_i'	65	51	79	48	86

Table : 4

As per step 4: Weighted flow time G_i'' & H_i'' for machines G and H as follow :

i	G_i''	H_i''
1	10.75	16.25
2	18	25.5
3	55	79
4	11.33	16
5	8.2	17.2

Table: 5

As per step 4: Optimal sequence S_1 by Johnson method is
S_1 : 5 – 1– 4– 2 – 3

As per step 5: Other feasible sequence are
S_2 : 1 – 5 – 4 – 2 – 3
S_3 : 4 – 5 – 1 – 2– 3
S_4 : 2 – 5– 1 – 4 – 3
S_5 : 3 – 5 – 1 – 4 – 2
From in – out tables for these sequences we have:
For S_1: CT(S_1) = 301; $\sum_{i=1}^{n}$ = 98; U_2 (S_1) = 109; U_3 (S_1) = 267 R(S_1) = 1841.
For S_2: CT(S_1) = 300; $\sum_{i=1}^{n}$ = 98; U_2 (S_2) = 103; U_3 (S_2) = 267 R(S_2) = 1823.
For S_3: CT(S_1) = 293; $\sum_{i=1}^{n}$ = 98; U_2 (S_3) = 107; U_3 (S_3) = 267 R(S_3) = 1835.
For S_4: CT(S_1) = 298; $\sum_{i=1}^{n}$ = 98; U_2 (S_4) = 100; U_3 (S_4) = 267 R(S_4) = 1814.
For S_5: CT(S_1) = 313; $\sum_{i=1}^{n}$ = 97; U_2 (S_5) = 103; U_3 (S_5) = 263 R(S_5) = 1805.

Therefore min {R (S_k)} = R(s_5) = 1805 units and is for sequences S_5. Hence the sequences S_5 : 3 – 5 – 1– 4 – 2 is optimal sequences with min rental cost 1805 units although the total elapsed time is not minimum.

9. CONCLUSION

9.1 The algorithm proposed here for specially structured three stage flow shop scheduling problem is more efficient as compared to the algorithm proposed by Johnson(1954) to find an optimal sequence to minimize the utilization time of the machines and hence their rental cost.

9.2 The study may further be extended by considering various parameters like breakdown effect, job block criteria etc.

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