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Minimization of Makespan in Flow Shop Scheduling Using Heuristics

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ABSTRACT

Production scheduling is one of the most significant issue in production and operations in any manufacturing system that has significant impact on cost reduction and increased productivity. Improper scheduling causes idle time for machines and hampers productivity that may cause an increased price of the product. So the main objective of this study is to minimize the makespan or total completion time. To do this study we have collected our data from Hatil complex limited, Mirpur, Dhaka, Bangladesh. This study presents Palmer's heuristic, CDS heuristic, NEH algorithm for solving the flow shop scheduling problem to minimize the makespan. NEH yields more elaborate results as compared to Palmer and CDS heuristic. Grant chart is used to verify the effectiveness of heuristics. By applying these three techniques we have gotten an optimal result for each case. The use of these techniques makes it possible to generate a schedule that minimizes the makespan.

Keywords: Flow Shop Scheduling, Makespan, CDS, NEH, Palmer's Heuristics.

1. Introduction

A wide range of knowledge of the general flow-shop scheduling problem is provided by the scheduling literature to get permutation schedules with minimization of make span. One of the earliest algorithm known as Johnson's algorithm [1] has been the basis of many flow shops scheduling heuristics. After that the researchers developed different heuristics for make span minimization in the flow shop scheduling for 'm' machine and 'n' job problems. Palmer [2] first proposed a heuristic for the flow shop scheduling problem with the objective of minimization of make span. Palmer's heuristic generates a slope index for jobs and sequences them in a descending order of the index. Campbell et al. [3] proposed Campbell, Dudek, and Smith (CDS) heuristic which is a generalization of Johnson's two machine algorithm and it generates a set of m-1 artificial two-machine problems from an original m-machine problem, then each of the generated problems are solved using Johnson's algorithm. Nawaz et al. [4] proposed Nawaz, Enscore, and Ham (NEH) heuristic algorithm which is probably the most well-known constructive heuristic used in the general flow-shop scheduling problem is based on the assumption that a job with high total processing time on all the machines should be given higher priority than job with low total processing time. Adding a new job at each step and finding the best partial solution it builds the final sequence in a constructive way. A review of flow shop scheduling with make span criterion had been given by Hijazi and Shaghafian [5]. Ibrahim [6] proposed a new heuristic to minimize the mean flow time for static permutation flow shop scheduling problem and showed that for the average flow time measure, the improved Chan and Bedworth's heuristic was the best among the four heuristics. Jin et al. [7] consider a hybrid flow shop with identical parallel machines. They proposed two approaches to generate the initial job sequence and used a simulated annealing algorithm to improve it. An improved heuristic for permutation flow shop scheduling was proposed by Chakraborty and Laha [8]. Ruiz and Stutzle [9] presented a new iterated greedy algorithm that had applied two phases iteratively, named destruction, where some jobs were eliminated from the incumbent solution, and construction, where the eliminated jobs are reinserted into the sequence using the well-known NEH construction heuristic. A model for scheduling a single semi continuous batching machine was developed by Tang and Zhao [10]. Their objectives were to schedule jobs on the machine so that the make span and the total completion time were minimized. Sahu [11] compared Gupta's, RA, CDS & Palmer's Heuristics in Flow Shop Scheduling on 8 jobs & 3 machines, 10 jobs & 8 machines and 10 jobs & 10 machines. He concluded that RA heuristic performs well for the problems considered when compared to other heuristics. Chia and Lee [12] developed the total completion time problem in a permutation flow shop with a learning effect. The concept of learning process played a key role in production environments. In addition, the performances of several well-known heuristics are evaluated when the learning effect is present. Vallada and Ruiz [13] worked on a cooperative meta-heuristic method for the permutation flow shop scheduling problem considering two objectives separately: total tardiness and make span. Damodaran and Velez Gallego [14] propose a constructive heuristic. Modrákand & Pandian [15] presented Flow Shop Scheduling Algorithm to Minimize Completion Time for n-jobs m-machines Problem. Chaudhry & Mahmood [16] considered minimization of makespan (total completion time) for *n* number of jobs to be processed on *m* machines using a general purpose spread sheet based genetic algorithm (GA). They showed that their proposed approach was able to find optimal solution for all the problems with different objective functions.

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Semančo and Modrák [17] showed a comparison of constructive heuristics with the objective of minimizing makespan in the Flow-Shop Scheduling Problem by using NEH; Palmer's Slope Index; CDS; Gupta's algorithm. Sagar et al. [18] presented an efficient heuristic method to minimize total flow time in no-wait flow shop scheduling. Malik &. Dhingra [19] presented comparative analysis of heuristics for make span minimizing in flow shop scheduling by using 5 heuristics for 10 jobs & 5 machines. Agarwa & Garg [20] worked with 5 heuristics named Gupta, RA, CDS, Palmer, NEH heuristic and applied these algorithm to solve 10machine, 10 job problem.

2. Methodology

With a view to minimize the make span the proposed heuristics/algorithm for 4-jobs and 10-machines problem from the real life has been used. Data is shown in table 8 that is collected from Hatil complex limited, Mirpur, Dhaka, Bangladesh which a leading furniture manufacturing company. Then, Palmer's heuristic, CDS heuristic and NEH algorithm are used and compared to get the optimal result.

3. Palmer's Heuristic

In flow shop scheduling, Palmer proposed a heuristic to minimize the make-span measure. He mainly proposed a slope index $S_{j,}$ for each job. The formula for the slope index S_j is shown below.

$$S_j = (m-1)\, t_{j.m} + (m-3)\, t_{j.m-1} + (m-5)\, t_{j.m-2} + \ldots - (m-3)\, t_{j.2} - (m-1)\, t_{j.1}$$

Where j is the job and m is the total number of machines.

Procedure:

Step 1. Compute slope for each job.
Step 2. Arrange the jobs as per the decreasing order of slope.

Solution:

According to the procedure, firstly we have calculated the slope index for each job and have gotten $S_1 = 272$, $S_2 = -87$, $S_3 = 12$, $S_4 = 556$ arranging it as per decreasing order we have gotten $S_4 > S_1 > S_3 > S_2$. So the final sequence is J4-J1-J3-J2. For the original flow shop 4-jobs and 10-machines problem as given in Table 1, using this heuristic the J4-J1-J3-J2 sequence has been calculated and the make-span calculation is displayed in Table 2. Corresponding Gantt chart is shown in Fig.1.

Table 2 Solution of Palmer's heuristic with J4-J1-J3-J2

Job	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
J4	33	53	74	74	74	100	126	233	260	290
J1	66	103	128	128	151	193	231	343	343	373
J3	105	136	136	173	193	230	275	343	389	426
J2	145	176	212	238	268	300	335	343	433	470

Gantt Chart:

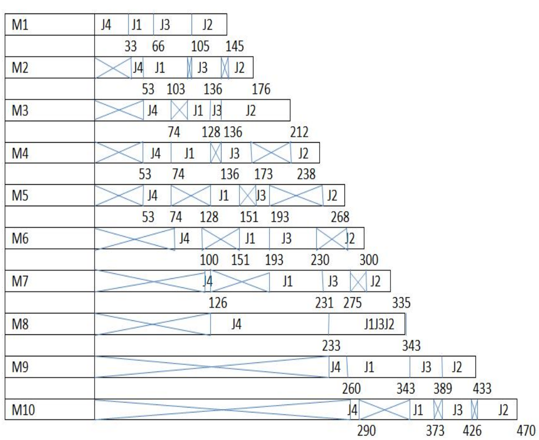

Fig.1 Gantt chart for the sequence J4-J1-J3-J2

In Fig.1 blank rectangle indicates that the machine is on working mode and the crossed rectangle indicates that the machine is on idle mode.

4. CDS Heuristic

CDS heuristics is basically an extension of the Johnson's algorithm. The main objectives of the heuristic are the minimization of make-span for n jobs and m machines in a deterministic flow shop scheduling problem. The CDS heuristic forms in a simple manner a set of an m-1 artificial 2-machine sub problem for the original m-machine problem by adding the processing times in such a manner that combines M1, M2,...,Mm-1 to pseudo machine 1 and M2, M3,... Mm to pseudo machine 2. Finally, by using the Johnson's 2-machines algorithm each of the 2-machine sub-problems is then solved. The best of the sequence is selected as the solution to the original m-machine problem. For the given flow shop problem as stated in table 1 of size10×4 using this heuristic the following sequences and make span has been established.

Procedure

Step 1:

Table 3 Taking M1 & M10

Job	M1	M10
J1	33	30
J2	40	37
J3	39	37
J4	33	30

Table 4 Optimal sequence when taking M1 & M10:

Sequence	Make span
J1-J3-J2-J4	492
J4-J3-J2-J1	487
J1-J2-J3-J4	499
J4-J2-J3-J1	485

Step 2:
Table 5 Taking M1+M2+M3+M4+M5 & M6+M7+M8+M9+M10

Job	M1+M2+M3+M4+M5	M6+M7+M8+M9+ M10
J1	118	220
J2	163	148
J3	127	164
J4	74	216

Table 6 Optimal sequence taking M1+M2+M3+M4+M5 & M6+M7+M8+M9+M10:

Sequence	Make span
J4- J1- J3- J2	470

Step 3:
Table 7 Taking M1+M2+M3+M4+M5+M6+M7+M8+M9 & M2+M3+M4+M5+M6+M7+M8+M9+M10

Job	M1+M2+M3+M4+M5 +M6+M7+M8+M9	M2+M3+M4+M5+M 6+M7+M8+M9+M10
J1	308	305
J2	274	271
J3	254	252
J4	260	257

So, optimal sequence: **J1-J2-J4-J3** and make span: 525

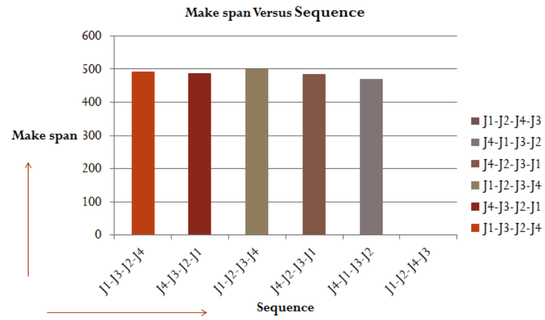

Fig.2 Makespan versus sequence curve for CDS heuristic

5. NEH Algorithm

Step 1: Find the total work content for each job using expression

$$T_j = \sum_{i=1}^{m} P_{ij}$$

Step 2: Arrange the jobs in a work content list according to decreasing values of Tj

Step 3: Select first two jobs from the list and from two partial sequences by inter changing the place of two jobs. Compute C_{max} the value of partial sequences. Oyt Of the two sequences, discard the sequence having larger value of C_{max}, Call the lower value of C_{max} as incumbent sequence.

Step 4: Pick the next job and put in incumbent sequence. Calculate value of C_{max} of all sequences.

Step 5: If there is no job left in work content list to be added to Incumbent sequence, Stop go to step 4.

Table 8 Calculation of total completion time**:**

Job	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	Total
J1	33	37	25		23	42	38	110		30	338
J2	40	31	36	26	30	32	35		44	37	311
J3	39	31		37	20	37	44		46	37	291
J4	33	20	21			26	26	107	27	30	290

Decreasing order in term of total completion time is

Sequence	Make span
J4-J1-J3-J2	470
J1-J4-J3-J2	569
J1-J3-J4-J2	523
J1-J3-J2-J4	492
J4-J1-J2-J3	470
J1-J4-J2-J3	569
J1-J2-J4-J3	525
J1-J2-J3-J4	499

J1>J2>J3>J4

Step 1: Taking J1 & J2, we have,
Sequences: J1-J2 &J2-J1 and makespan 389 and 415 respectively

Step 2: Choosing J1-J2 & take J3
Sequences:
J3-J1-J2 & J1-J3-J2 & J1-J2-J3 and make span 437, 435 and 435 respectively

Step 3: Taking J1-J3-J2 & take J4
Taking J1-J2-J3 & take J4
Sequences:
J4-J1-J3-J2 & J1-J4-J3-J2 & J1-J3-J4-J2 & J1-J3-J2-J4
J4-J1-J2-J3 & J1-J4-J2-J3 & J1-J2-J4-J3 & J1-J2-J3-J4

Table 9 Sequence for NEH algorithm

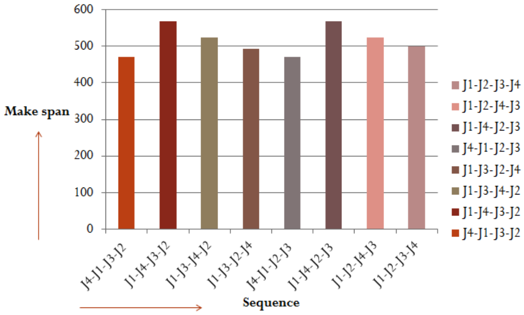

Fig.3 Makespan versus sequence curve for NEH algorithm

6. Result Analysis

Table 10 Comparison among Pamer, CDS and NEH

No. of observation	Technique	Optimal sequence	Make span
01	Palmer's Heuristic	J4-J1-J3-J2	470
02	CDS Heuristic	J4-J1-J3-J2	470
03	NEH Algorithm	J4-J1-J2-J3 J4-J1-J3-J2	470

We have applied three techniques to determine the optimal make span and dramatically we have got the same result for three cases. By applying Palmer's Heuristic and CDS Heuristic we have got only one sequence and by applying NEH Algorithm we have got two sequences and by applying any of the sequence between them we can get our optimum make span. From the above analysis we can say that make span 470 is the most optimum and no other optimum make span less than 470 is possible for the above problem.

7. Conclusion

This study tries to solve the problem of a flow shop scheduling with the objective of minimizing the makespan. The problem of 4 jobs and 10 machines have been considered for comparative analysis among Palmer's heuristic, CDS heuristic and NEH heuristic and we have got the same result by applying all of the three heuristics. From the analysis, it has proved that the make span 470 is the most optimum make span for the given problem and no other optimum make span is possible less than 470. This work can be useful to researchers for selecting the effective and efficient heuristics for solving the flow shop scheduling problems. The work can also be extended by increasing the size of the problems and removing any or all of the assumptions considered.

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