Comparative Analysis of Heuristics for Makespan Minimising in Flow Shop Scheduling

Amar Malik
Department of Mechanical Engineering
University Institute of Engineering & Technology
Maharshi Dayanand University Rohtak, Haryana, INDIA

Ashwani K. Dhingra
Department of Mechanical Engineering
University Institute of Engineering & Technology
Maharshi Dayanand University Rohtak, Haryana, INDIA

Abstract- Scheduling *n* jobs on *m* machines in the flow shop environment is NP hard and also finds prominent place in the field of production scheduling. The present work focus on scheduling the jobs in a flow shop environment with makespan minimization. The five heuristics available in the literature known as, Palmer's (1965), RA (1970), CDS (1970), Gupta's (1971) and NEH (1983) have been analyzed and tested for the problems upto 10 jobs with 3, 4 and 5 machines respectively. The problems are randomly generated in which the processing time ranges between 1 to 10. From the comparative analysis, it has been found that NEH heuristic upto 4 machines problem provides better results and as the size of machines increases, RA considers to be the superior for most of the flow shop scheduling problems.

Keywords – Sequencing, Scheduling, Flow Shop, Heuristics, Makespan

I. INTRODUCTION

Scheduling is the procedure of generating the schedule which is a physical document and generally informs the happening of things and demonstrate a plan for the timing of certain activities. Generally, scheduling problem can be approached in two steps; in the primary step sequence is planned or decides how to choose the next job. In the next step, planning of start time and possibly the completion time of each job is performed.

Flow Shop Scheduling is a decision making procedure that is used on a regular basis in many manufacturing and services industries. Its aim is to optimize one or more objectives with the allocation of resources over given period of time. The resources may be machines in a workshop, crews at a construction site and runways at an airport and so on. The jobs may be operations in a production process, take-offs and landings at an airport, stages in a construction project, and so on. Flow Shop Scheduling plays an important role in most manufacturing and service systems as well as in most information processing environments.

There are a variety of objectives to be minimized for flow shop scheduling. Some of them are Total job completion time, Total Flow time, Makespan, Tardiness based objectives etc.

In the present work, for effective utilization of all the resources flow shop scheduling with makespan criteria has been considered. The five heuristics available in literature viz. CDS, Palmer, RA, Gupta and NEH have been used and considered for the solution of the flow shop scheduling problem upto 10 jobs and 5 machines.

II. LITERATURE REVIEW

Survey of literature shows that most of the heuristics developed for makespan minimization in flowshop scheduling over the last half century. One of the earliest heuristic known as Johnson (1954) considered for the two-machine flow shop problem with the objective of minimizing makespan. After that the researchers developed different heuristics for makespan minimization in the flow shop scheduling for 'm' machine problems.

Palmer [1965] proposed a heuristic algorithm which is a slope order index to sequence the jobs on the machines based on the processing time and known as palmer's heuristic. The idea was to give priority of the jobs so that jobs with processing times that tends to increase from machine to machine will receive higher priority.

Campbell, Dudek and Smith (CDS) [1970] proposed a heuristic that was the extension of Johnson's Algorithm for flow shop scheduling problems with makespan minimization.

Gupta [1971] suggested another heuristic which was similar to Palmer's heuristic. He defined the slope index in a different manner by taking into account some attractive facts about optimality of Johnson's rule for the three machine problems.

Dannenbring [1977] developed a procedure called rapid access which combines the advantages of Palmers slope index and the CDS methods. Its purpose is to provide a good solution as quickly and easily as possible. Instead of solving m-1 artificial two machine problems, it solves only one artificial problem using Johnson's rule in which the processing times are determined from a waiting scheme.

The Nawaz, Enscore, and Ham (NEH) [1983] heuristic algorithm 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. The NEH algorithm does not transform that original m-machine problem in to one artificial two-machine problem. It builds the final sequence in a constructive way, adding a new job at each step and finding the best partial solution.

Rajendran (CR) [1995] implemented a heuristic for flow shop scheduling with multiple objectives of optimizing makespan, total flow time and idle time for machines. For this improvement heuristics, the first sequence was taken from CDS algorithm. The heuristic preference relation is proposed and is used as the basis to restrict the search for possible improvement in the multiple objectives. The decision-making goals seem to be prevalent in scheduling.

Lia et.al [2003] developed efficient composite heuristics models for total flow time minimization in permutation flow shops considering flow shops with total flow time. They proposed a composite heuristics model to minimize the flow time.

Tejpal & Jayant [2007] An extension of Palmer's heuristic for the flow shop scheduling problem While the additional computation required is relatively small, the performance of the algorithm compares very well with that of the more sophisticated and better algorithm of Campbell, et al. (1970) at a fraction of the effort required by the latter.

Tang and Zhao [2008] developed a model for scheduling a single semi continuous batching machine. Their objectives are to schedule jobs on the machine so that the make span and the total completion time are minimized.

Eren and Guner [2008] developed a bi-criteria flow shop scheduling problem with a learning effect. They consider learning effect in a two-machine flow shop. Their objective is to find a sequence that minimizes a weighted sum of total completion time and make span.

Chia and Lee [2009] developed the total completion time problem in a permutation flow shop with a learning effect. The concept of learning process plays a key role in production environments. In addition, the performances of several well-known heuristics are evaluated when the learning effect is present.

A K Sahu [2009] compared Gupta's, RA , CDS & Palmer's Heuristics in Flow Shop Scheduling on 8 jobs & 3 machines, 10 jobs & 8 machines & 10 jobs & 10 machines. He concluded that RA heuristic performs well for the problems considered when compared to other heuristics.

Shu-Hui Yang Ji-Bo Wangb [2011] considered the minimizing the total weighted completion time in a two-machine flow shop scheduling under simple linear deterioration The objective was to find a sequence that minimizes total weighted completion time. For the general case, several dominance properties and two lower bounds are derived to speed up the elimination process of a branch-and-bound algorithm. A heuristic algorithm is also proposed to overcome the inefficiency of the branch-and-bound algorithm.

Quan-Ke Pan and Ling Wang [2012] presented two simple constructive heuristics, namely weighted profile fitting (wPF) and PW, based on the profile fitting (PF) approach . Three improved constructive heuristics, called PF-NEH, wPF-NEH, and PW-NEH, are proposed by combining the PF, wPF, and PW with the enumeration procedure of the Nawaz-Enscore-Ham (NEH) heuristic. The results shows that the proposed constructive heuristics perform significantly better than the existing ones, and the proposed composite heuristics further improve the presented constructive heuristics by a considerable margin.

Sagar et al. [2013] presented an efficient heuristic method to minimize total flow time in no-wait flow shop scheduling. It is based on the assumption that the priority of a job in the initial sequence is given by the sum of its processing times on the bottleneck machines. Empirical results demonstrate the superiority of the proposed method over the best-known heuristics in the literature, while remaining the same complexity order.

III. DIFFERENT HEURISTICS

After review from the literature, it have been found that several heuristics have been used and developed for makespan minimization for 'm' machines flow scheduling problems. Efficient heuristics are still an issue for flow shop scheduling problems and in the present work, an attempt has been made for comparing the five heuristics for makespan minimization in flow shop scheduling. This present work is an extension of the work done by Sahu (2009) who compared the four heuristics compared viz. Gupta's, RA , CDS & Palmer's Heuristics in Flow Shop Scheduling on 8 jobs & 3 machines, 10 jobs & 8 machines & 10 jobs & 10 machines. He concluded that RA heuristic performs well for the problems considered when compared to other heuristics. In the present work, apart from the four heuristics, one more heuristic NEH has been added for comparison with different sets of problems randomly generated upto 10 jobs and 5 machines problems. The detailed procedures for the five heuristics considered are as follows:

Gupta's Heuristic (1971)	**RA Heuristic (1970)**	**CDS Heuristic (1970)**	**Palmer's Heuristic (1965)**	**NEH Heuristic (1983)**

Procedure: Gupta's Heuristic
Input: job list *i*, machine *m*;
Output: schedule *S*;
begin
for $i = 1$ to n
for $k = 1$ to $m-1$
if $t_{i1} < t_{im}$ then
$ei=1$;
else
$ei = -1$;
Step1: calculate Si= $ei / \min\{t_{ik} + t_{i,k+1}\}$;
end
Step2: Permutation schedule is constructed by sequencing the jobs in non-increasing order of *si* such as: $S_{i1} \geq S_{i2} \geq \ldots\ldots \geq S_{in}$
end
Step3: Output optimal sequence is obtained as schedule S.
end
	Algorithm:RA Heuristic
	Input:job list *I*, machine *m*;
	Output: schedule *S*;
	begin
	for $i = 1$ to n
	for $j = 1$ to $m-1$
	$w_{j1}= m-(j-1)$ $w_{j2} = j$;
	$t_{i1}'={}^{m}\sum_{j-1}$ wji*tij and $t_{i2}'={}^{m}\sum_{j-1}$ wj2*tij
	Where weights are defined as:-
	$W_1=\{m,m-1,\ldots\ldots2,1\}$
	$w_2=\{1,2,\ldots\ldots m-1,m\}$
	Step1: Calculate $U = \{i \mid t_{i1}' < t_{i2}'\}$ and $V = \{i \mid t_{i1}' \geq t_{i2}'\}$;
	Step2:Sort jobs in U with non-decreasing order of t_{i1}';
	Step3:Sort jobs in V with non-increasing order of t_{i2}';
	Step4: Output : optimal sequence is obtained as schedule S by U and V
	end
		Algorithm: CDS Heuristic
		Input: job list *I*, machine *m*;
		Output: schedule *S*;
		begin
		for $i = 1$ to n
		for $j = 1$ to $m-1$
		$t_{i1}' = t_{i1} + tij$
		for j = m to 2;
		$t_{i2}' = t_{i2} + tij$
		end
		Step 1: Calculate $U = \{i \mid t_{i1}' < t_{i2}'\}$ and $V = \{i \mid t_{i1}' \geq t_{i2}'\}$;
		Step 2: Sort jobs in U with non-decreasing order of t_{i1}';
		Step 3: Sort jobs in V with non-increasing order of t_{i2}';
		Step4:Output optimal sequence is obtained as schedule S by U and V
		end
			Procedure: Palmer's Heuristic
			Input: job list *i*, *machine m*;
			Output: schedule *S*;
			begin
			for $i = 1$ to n
			for $j = 1$ to m
			Step 1: Calculates $S_i = S_i + (2j-m-1)t_{ij}$;
			Step 2: Schedule is constructed by arranging the jobs in decreasing order of Si as:
			$S_{i1} \geq S_{i2} \geq \ldots\ldots \geq S_{in}$
			Step 3: Output is obtained as S
			end
				Step 1 :Find the total work content for each job using expression
				$T_j = {}^{m}\sum_{i=1} p_{ij}$
				Step 2: Arrange the jobs in a work content list according to decreasing values of T_j
				Step 3:Select first two jobs from the list and from two partial sequences By inter changing the place of two jobs. Compute Cmax the value of partial sequences . Oyt of the two sequences , discard the sequence having larger value of Cmax,Call the lower value of Cmax as incumbent sequence.
				Step 4:Pick the next job and put in incumbent sequence. Calculete value of Cmax 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

In the present work, the 12 different randomly problems have been considered in which processing time varies from 1 to 10. The problems considered are:

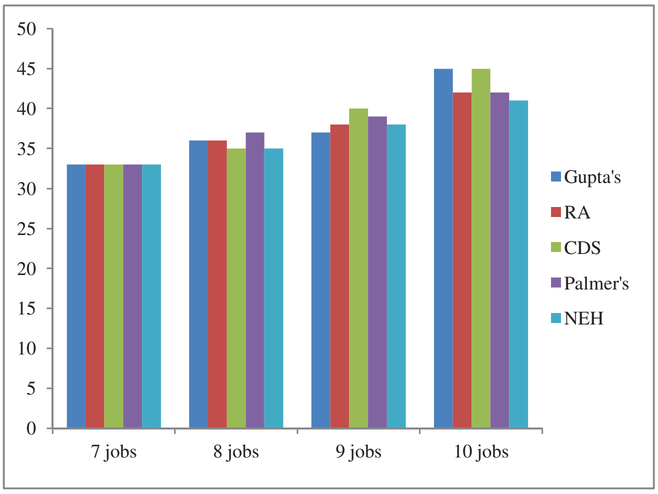
7 jobs and 3 Machines	7 jobs and 4 Machines	7 jobs and 5 Machines	8 jobs and 3 Machines	9 jobs and 3 Machines	10 jobs and 3 Machines
8 jobs and 4 Machines	9 jobs and 4 Machines	10 jobs and 4 Machines	8 jobs and 5 Machines	9 jobs and 5 Machines	10 jobs and 5 Machines

IV. RESULTS & DISCUSSIONS

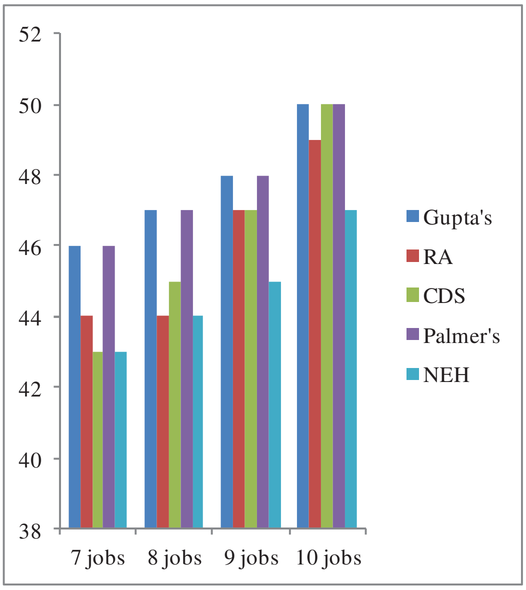
The comparative analysis has been done by considering some assumptions which are:

I. Every job has to be processed on all machines in the order $(j = 1,2,\ldots,m)$
II. Every machine processes only one job at a time
III. Every job is processed on one machine at a time
IV. Set-up times for the jobs are included in the processing times
V. Pre-emption is not allowed.
VI. Machines never break down and are available throughout the scheduling period.
VII. The first machine is assumed to be ready whichever and whatever job is to be processed on it first.
VIII. Machines may be idle

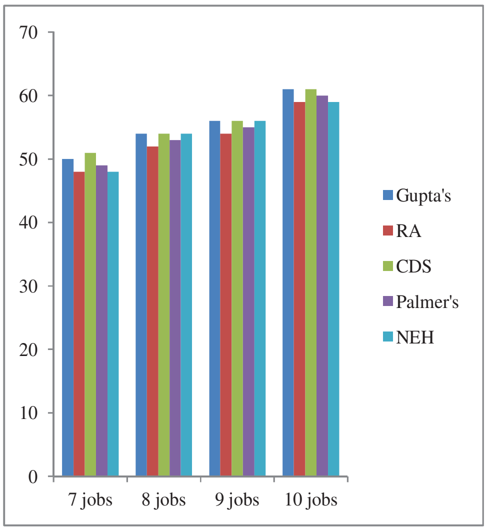
The results have been compiled for all the heuristics considered and shown in figure 1 and 2.



(a)

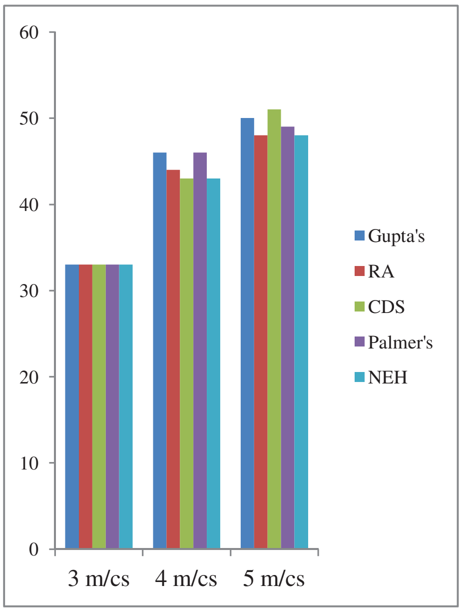


(b)

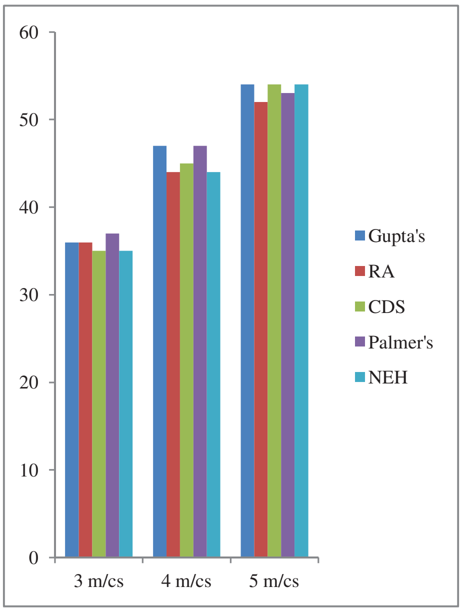


(c)

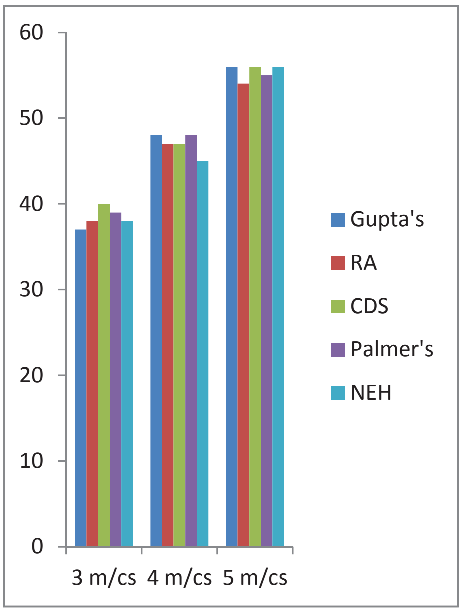
Figure 1 (a) 3 machines problem (b) 4 machines problem (c) 5 machines problem

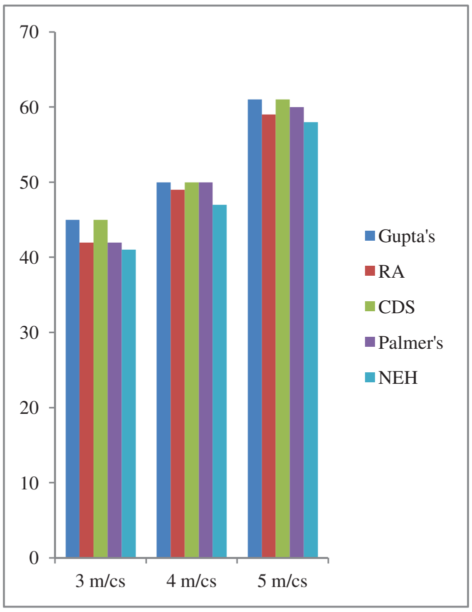


(a)



(b)





(c) (d)

Fig.1 (a) 7 jobs problem (b) 8 jobs problem (c) 9 jobs problem (d) 10 jobs problem

Figure 1 shows the comparison of heuristics by varying the job size for 3, 4 and 5 machines problems and figure 2 shows the comparison by varying the machine size for 7, 8, 9 and 10 job problems. From the comparative analysis, it has been proves that NEH heuristic shows the minimum value of makespan when compared to other heuristics for most of the problems but limited to 4 machines problems and as the machine size increases RA produces the best results.

V. CONCLUSION

In this work, an attempt has been made to solve the flow shop scheduling problem for minimizing the makes pan.The problems upto 10 jobs and 5 machines have been considered for comparative analysis among Gupta's heuristic, RA heuristic's, Palmer's heuristic, CDS heuristic & NEH heuristic. From the analysis, , it has been proves that NEH heuristic shows the minimum value of makespan when compared to other heuristics for most of the problems but limited to 4 machines problems and as the machine size increases RA produces the best results. 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..

REFERENCES

[1] Johnson SM," Optimal two and three stage production schedules with setup times included" Naval Research Logist Quarterly, Vol. 1, Issue 1, pp.61-68,(1954)

[2] Palmer D ," Sequencing jobs through a multi-stage process in the minimum total time – a quick method of obtaining a near optimum" Operation Research Vol. 16, pp.101-107,(1965)

[3] Campbell HR and Smith DM , "A heuristic algorithm for n-jobs m-machines sequencing problem", Manage Science, Vol.16B, pp. 630–637,(1970)

[4] Gupta J," A functional heuristic algorithm for the flow shop scheduling problem" Operation Research Vol. 22, pp.39-47,(1971)

[5] Dannenbring D," An evolution of flow shop scheduling heuristics. Manage Science"Vol. 23, Issue 11, pp.1174-1182,(1977)

[6] Nawaz, M., Enscore Jr, E. and Ham, I.," A heuristic algorithm for the machine, n-jobs flow shop scheduling problem" OmegaVol. II,pp.91-95,(1983)

[7] Rajendran C,"Theory and methodology heuristics for scheduling in flow shop with multiple objectives", European Journal Operation Research, Vol. 82, pp.540 –555,(1995)

[8] Tejpal S. Hundal & Jayant Rajgopal," An extension of Palmer's heuristic for the flow shop scheduling problem", International Journal of Production Research,Vol. 26, Issue 6, pp.1119-1124,(2007)

[9] Tang and Zhao,"Scheduling a single semi-continous batching machine" Omega Volume 36, No. 6, pp. 992-1004, (2008)

[10] Eren and Guner," A bicriteria flow shop scheduling" Applied Mathematical Modeling, Volume 32, Issue 9,pp. 1719-1733,(2008)

[11] Chia and Lee," Minimizing the total completion time in permutation flow shop" Computers & Operations Research 6,pp. 2111-2121,(2009)

[12] Sahu AK, "Efficient heuristics for scheduling tasks on a flow shop environment to optimize makespan" National Institute of Technology, Rourkela INDIA (2009)

[13] Shu-Hui Yang Ji-Bo Wangb," Minimizing total weighted completion time in a two-machine flow shop scheduling under simple linear deterioration" Applied Mathematics and Computation,Vol. 217, No. 9, pp.4819-4826,(2011)

[14] Quan-Ke Pan and Ling Wang, "Effective heuristics for the blocking flowshop scheduling problem with makespan minimization" Omega ,Vol. 40,Issue 2,pp.218-229(2012)

[15] Sagar U. Sapkal&Dipak Laha," A heuristic for no-wait flow shop scheduling "International Journal of advanced manufacturing Technology, **DOI** 10.1007/s00170-013-4924-y (In Press). (2013)