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Constrained Flow Shop Scheduling Problem using an Algorithm Based on Critical Ratio: An Advanced Simulation Study

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Abstract: The paper describes about the development of a new proposed method for scheduling and creation of programmed software for the automated generation of a schedule sequence in a flow shop environment. The 2 machine 'n' jobs flow shop scheduling problem is analysed here using the critical ratio method. The objective of the method is to determine the maximum number of jobs that can meet the due date. The parameter used is critical ratio. The set up time and processing time is taken together as single value for each machine. The algorithm for the new proposed method gives the optimum schedule for a set of jobs. The software used for the proposed system using Matlab. The interface developed is user friendly. The proposed method is very simple for decision makers for scheduling a constrained flow shop scheduling problem. The proposed method is illustrated with help of a numerical example.

Keywords: Flow shop, Critical ratio, Due date

I. INTRODUCTION

Scheduling theory is concerned with optimal allocation of resources to activities over time. Scheduling problems involves jobs that must be scheduled on machines which are subjected to certain constraints to optimize some objective functions. The main goal of scheduling is to obtain a schedule which specifies when and on which machine each job has to machined or processed. Flow shop scheduling concerns processing jobs through a series of machines in exactly the same order. The research on flow shop scheduling problem has drawn a great attention in the last decades with the aim to increase the effectiveness of industrial production.

In a real flow 250 shop process, jobs are usually subject to constraints on release date, i.e., the date when a job can start it's processing, and due date, i.e., the date when a job has to complete its processing. For example, a job could only be processed when the required raw material is available, or the completion time of a job should respect the preferred due date of delivery to customers. A job sequence is considered to be feasible if it is able to satisfy the constraints of jobs on release date and due date

II. LITERATURE REVIEW

The fundamentals in the theory of scheduling was put forward by Johnson(1954), in which he considered n-jobs 2 machine problem with the objective of minimization of total elapsed time. Johnson‟s algorithm was also extended to 3 machine problems also. Dudek and Teuton (1964) gave solution for the n-jobs m-machine problems, but the algorithm may not always guarantee an optimal solution to all problems.Tzung-Pei Hong, Chai-Ying Leeb (1996) expalained about the fuzzy rules and its membership function used.

V. Modrak and R. S. Pandian (2010), expalined about an algorithm to schedule the 5 jobs 6 machine problem taking into crisp value under consideration. P. Pandian and P. Rajendran (2010) proposed a new method for obtaining an optimal schedule for constrained flow shop scheduling 3 machine problem involving transportation time; break down time and weightage of jobs. S. Sharma (2011) proposed a technique for n-jobs 3- machines flow shop scheduling problem in which processing time setup time and its associated probabilities are taken into account for obtaining of the solution. The jobs are attached with their relative weights to indicate their importance D. Guptha, S. Sharma , S.

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Aggarwal (2012) describes the specially structured n-job 3 machine flow shop scheduling problem analysis with optimization in machine rental cost. Vikas S. ,V. H. Bajaj (2013) proposed fuzzy average high ranking method for solving machine problem and illustred a simulation model expalaining it.

N. Tyagi, R. G. Varshney and A. B. Chandramouli (2013) gave a review on various research work in flow shop scheduling till the last six decades and a concise overview of the flow shop scheduling methods evolved during the period. S. Singla, P. Singla, S. Sukhvir (2013) demonstrated a flow shop problem with 3 machines with the objective of minimizing makespan by taking probabilities into consideration.

III. METHODOLOGY

The new proposed method developed is for the scheduling of the 2 machine „n" jobs problem. Assumptions used in the flow shop machining are as follows:

1. Only a single operation is processed by each machine at a time.
2. Once the machining is started on a machine it should be performed till the completion.
3. There is one machine of each type, and all the jobs are available at the initial time.
4. All the jobs follow same sequence of operations.
5. The processing time of the job include both the setup time and the machining time.
6. Specified number of operations is provided for each job and each machine performs one operation only.

The objective behind the proposed method is to determine the maximum number of jobs that gets completed in the specified due date. There will be some tardy jobs irrespective of any schedule; hence the priority includes the schedule or sequence generation that yields fewer amounts of tardy jobs. The method developed is for the scheduling of the 2 machine 'n' jobs problem. The main principle used behind the method iterated value is critical ratio based on which the complete set of schedule is obtained.

Each time the values are being iterated for the generation of the required job out of the listed. Since the manual iteration is tedious and time consuming it is usually done with the help of programming software. Critical ratio is a parameter. It is evaluated by dividing the time until a job"s due date by the total shop time remaining for the job, which is defined as the setup, processing, move and expected waiting time of all the remaining operations including the operation being scheduled. The variable is a useful measure of knowing whether or not a job can meet its due date.

Critical Ratio is,

$$\mathrm{CR} = \frac{\text{Due date of the job} - \text{Current time}}{\text{Remaining process time}}$$

The fig.1 shows the step by step procedure of the methodology.

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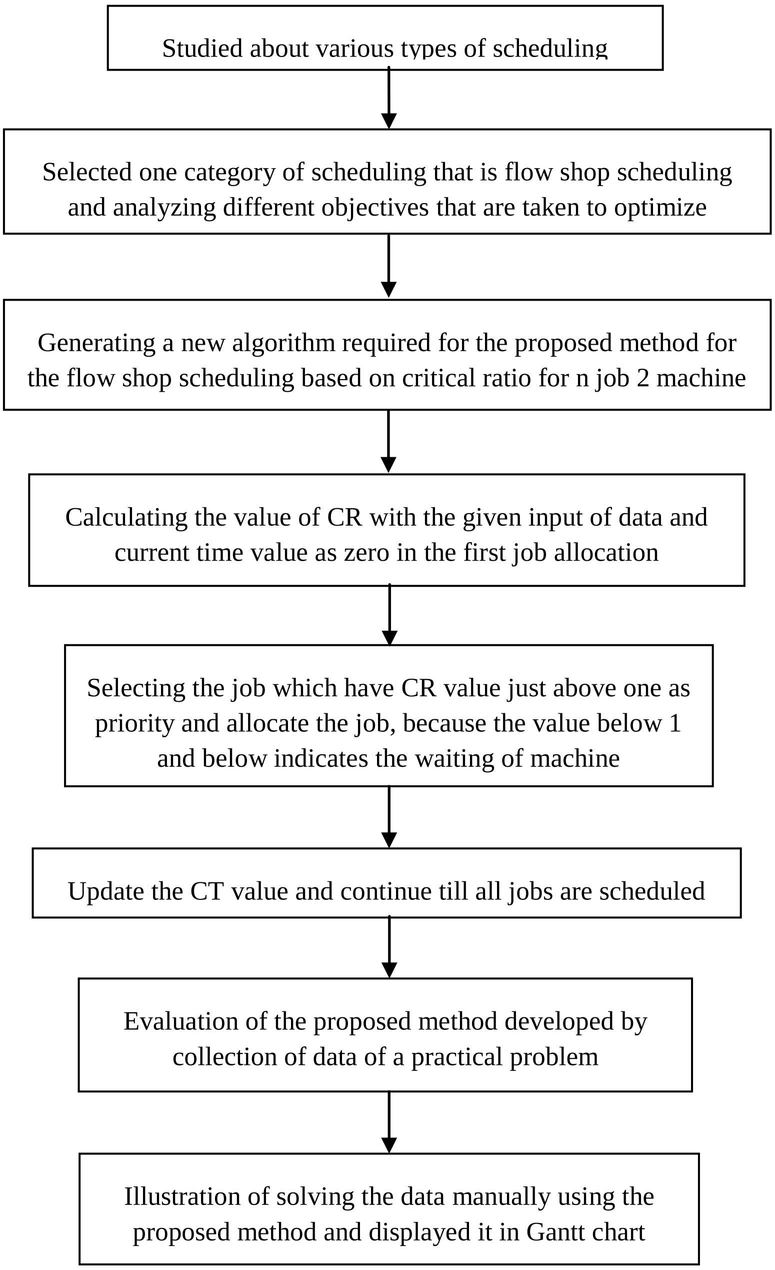

Fig.1 Flow chart of the methodology

3.1 Mathematical Model of the Problem.

The problem consists of 2 machines and n number of jobs to be processed as a flow shop. The processing time of the each job on each machine and due date in which the jobs have to be given is considered as the user input data. This set of input data should be entered by the user manually. Table.1 represents the mathematical model of the problem is as shown below.

Table.1 Tabular representation of problem

Job Number	Machine 1	Machine 2	Due date
1	M_{11}	M_{21}	xx
2	M_{12}	M_{22}	xx
3	M_{13}	M_{23}	xx
-	-	-	-
n	M_{1n}	M_{2n}	xx

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3.2 New Algorithm developed for the scheduling.

- Calculation of Critical Ratio value
- For the job allocation CR have to be calculated and hence initially CT is zero. Calculate the value of CR for all the jobs. Consider the jobs having the values equal to or greater than 1 (value nearer to 1 having higher priority i.e., 1.2 have high priority job than 1.5).
- Critical ratio, C.R = $\frac{DD - CT}{RPT}$

  Where, DD – Due date, CT –Current time, RPT – Remaining processing time
- If same value of CR occurs for two jobs then prioritize them on the basis of shortest processing time.
- Calculate the in-out table after the allocation of first job. For instance it is taken as job number 2. Table.2 represents the in-out table of the first job allocation.

Table.2 Tabular representation of processing times of jobs.

Job Number	Machine 1		Machine 2	
	In	out	In	Out
2	0	M_{12}	M_{12}	$M_{12} + M_{22}$ => T

- Add the out-time of the machine 1 i.e., the time at which them machine one will complete the job completely with the processing times of all jobs that has to go through with machine one.

  In general, it can be written as $M_{1n} + M_{1m} = K_i$

Provided that no need for calculating the allotted job i.e., if the first job allocated is 2 then K_2 need not to be calculated, since it had been scheduled.

- Initialize a variable say T to store the value of out-time of machine 2 i.e., the time at which the machine two completes the job. This is basically for the comparison to check. The value of T changes at each step of job allocation. $T = M_{1n} + M_{2n}$
- The out-time of the machine 2 i.e., T is then subtracted from the above values of K_i values and indicate them as X_i. In general, the statement can be expressed as $T - K_i = X_i$
- The next objective is to find the next set of CR values to determine the allocation of the second job. For instance second iteration the current time is set as an increment to the existing value as $CT = M_{1n} + X_i$ (i = 1, 2, 3…). This is applicable if and only if the value of the value of $X_i > 0$. Otherwise, if $X_i < 0$, then the value of CT remains as M_{1n}.
- Again calculate the next set of CR values for the identification of the next job.
- Allocate the second job which is having CR value equal to or close to just above 1. In case again if same value repeats for more than one job allocates the job having shortest due date.
- Continue this simulation for all jobs having CR values.
- For all other jobs whose values are just below 1 allocate the jobs whose CR values comes just below 1 as first and continue this till all the jobs are allocated.
- After that display the In-Out table of the all the jobs along with the due dates on which the jobs have to be given.
- Finally display the maximum numbers of jobs that are completed in the correct due date and mention the jobs clearly.

3.2 Programming of the proposed model.

The complete set of algorithm is developed using Matlab software and an interface is provided for the user to enter a particular set of data according to his requirement. The system used to check the running of the software is a PC with Intel Pentium dual core processor. The Fig.2 shows the interface developed for the user to enter the data of the processing times of the 2 machines and the due date of each jobs.

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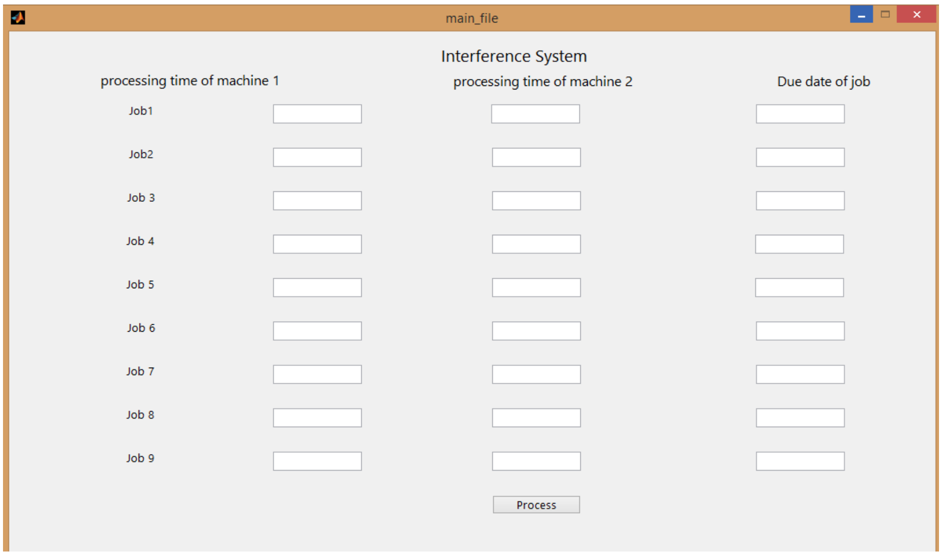

Fig.2 Interface developed for providing input

3.2 Evaluation of the proposed model.

Values entered in the software were obtained as the result of a survey conducted on the processing time taken in an automobile service centre. The processing time of machine 1 is actually wheel balancing and weight addition, if needed and that of machine 2 is wheel alignment checking and correcting. The Table.3 represents the data collected on a survey from a service centre on four wheeler details for the analysis of the new method.

Table.3 The data collected for the validation of the method

Sl NO	Job	Wheel Balancing (min)	Wheel alignment checking and correction (min)	Delivery Time (min)
1	Nano	15	20	40
2	Indica V2	15	20	80
3	Venture	15	20	130
4	Indigo CS	20	30	60
5	Vista tech	20	30	120
6	Manza	20	30	180
7	Safari storm	30	40	75
8	Aria	30	40	150
9	Sumo gold	30	40	230

IV. RESULTS AND DISCUSSIONS

A simulation study has been conducted for 'n' job 2 machine case for minimizing the number of tardy jobs with critical ratio as a parameter for prioritizing the jobs.

Table.6 Evaluation of critical ratios

Job no	M1	M2	DD	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	Job Rank
1	15	20	40	1.1	-	-	-	-	-	-	-	1
2	15	20	80	2.2.	1.7	-	-	-	-	-	-	2
3	15	20	130	3.7	3.1	2.5	1.7	0.5	-0.2	-1.4	-2.5	8
4	20	30	60	1.2	0.9	0.5	-0.1	-0.9	-1.5	-2.3	-3.1	9
5	20	30	120	2.4	2.1	1.7	-	-	-	-	-	3
6	20	30	180	3.6	3.3	2.9	2.3	1.5	-	-	-	5
7	30	40	75	1.0	0.8	0.6	0.2	-0.2	-0.7	-1.2	-	7
8	30	40	150	2.1	1.9	1.7	1.3	-	-	-	-	4
9	30	40	230	3.2	3.0	2.8	2.5	1.9	1.5	-	-	6

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The critical ratio is calculated according to the proposed method. For the initial condition the value of completion time is set as zero and the corresponding values are calculated under CR1 for all the jobs. Out of the values obtained in CR1 the value adjacent to just above 1 is selected and allotted as first job to be scheduled and again repeat it for finding the CR values till all the jobs are scheduled in the same manner. Table.4 shows the calculated values of critical ratio each time of job allocation and ranking of jobs accordingly.

Each time the current time is updated based on the comparison with the previous value. The table depicting the processing times is generated simultaneously along with the each allocation of the jobs in the schedule. Once the job is allocated then it is neglected from the next step of iteration of calculating the critical ratio value. On completion of the repetitive iteration we get the optimum and checked it with the value for the performance parameters. Tardiness is the number of late tasks performed which determine the efficiency of production. The schedule in which the jobs are allocated as per the new method is 1-2-5-8-6-9-7-3-4. The table 5 shows the in-out time of the schedule sequence along with the due date.

Table 5. In-out table of 2 machines system with due date according to proposed method.

Job Schedule sequence	Machine 1		Machine 2		DD(min)
	In (min)	Out (min)	In (min)	Out (min)	
1	0	15	15	35	40
2	15	30	35	55	80
5	30	50	55	85	120
8	50	80	85	125	150
6	80	100	125	155	180
9	100	130	155	195	230
7	130	160	195	235	75
3	160	175	235	255	130
4	175	195	255	285	60

Using the Johnson's algorithm we get the schedule as 3-2-1-6-5-4-9-8-7.

Table.6 Evaluation of schedule as per Johnson's algorithm

Job schedule	Actual due date(minutes)	Obtained due date (minutes)	Job tardy or not
3	130	35	No
2	80	55	No
1	40	75	Yes
6	150	105	No
5	120	135	Yes
4	60	165	Yes
9	230	205	No
8	150	245	Yes
7	75	285	Yes

The table 6 describes the comparison of the actual due date with the obtained due date to check whether the due dates are tardy or not. From the table 6 it is clear that the 4 jobs out of 9 will be completed in due date using Johnson's method. The tardiness can be calculated and can be included for the data interpretation. From the table the number of tardy jobs is 5.

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Table 7 describes the comparison of the actual due date with the obtained due date from the calculation. It helps to evaluate whether the job is tardy or not.

Table.7 Evaluation of tardy jobs as per the new method

Job schedule	Actual due date(minutes)	Obtained due date (minutes)	Job tardy or not
1	40	35	No
2	80	55	No
8	120	85	No
9	150	125	No
3	180	155	No
5	230	195	No
7	75	235	Yes
4	130	265	Yes
6	60	285	Yes

Fig.3 shows the Gantt chart of the new proposed method. The sequence of the jobs and the time required for each jobs are described clearly. The time taken for each job on each machine is displayed.

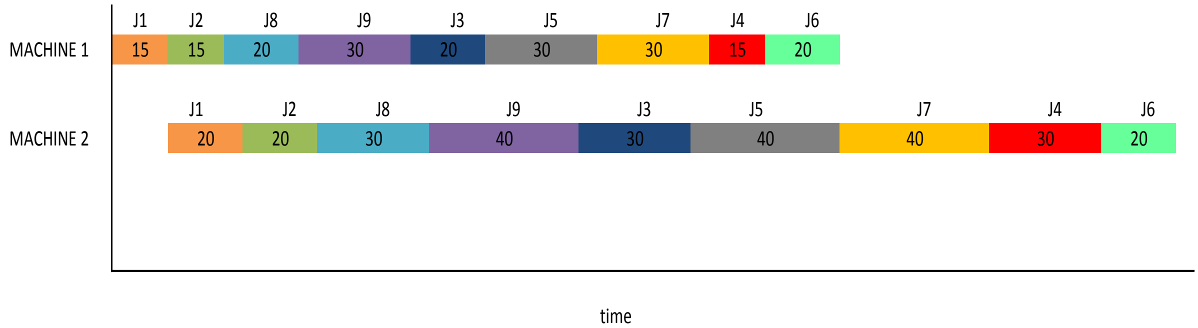

Fig.3 Gantt chart for the illustrated problem as per new method

From the Table.7 it is clear that the 6 jobs out of 9 will be completed in due date using the proposed method. The tardiness can be calculated and can be included for the data interpretation. From the example above the number of tardy jobs is 3. The percentage tardiness of new method is 33.3 which is fairly less compared to that of Johnson's method which is 55.5. Hence the percentage effectiveness of the new method compared to Johnson's method is 22.2 percent. Hence the new proposed method is more efficient compared to Johnson's algorithm.

V. CONCLUSION

The proposed method can be used for 'n' job 2 machine system, which can be expanded to 'm' set of machines. In the problem, 6 out of 9 jobs were completed within the given due date using this method. The calculation time depends on the number of jobs placed, the more number of jobs, the more time it will require for processing. There is a huge scope for the further development of this software. The future work can be expanded by including more machines, jobs and parameters etc. As the number of jobs increases, the complexity of the program and algorithm needed also to increase. Hence for implementing such type of automated scheduling software in large factories more research work is needed and also complex programming is required while taking all logic into consideration.

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