Development of a Scheduling Heuristic for the Fabrication Shop of a Sheet Metal Processing Industry

Ranbir Kalita[#1], Ajoy Krishna Dutta[*2], P. B. Barua[#3]

[#1]*M.E. Student,* [*2]*Assistant Professor,* [#3]*Professor and H.O.D., Department of Mechanical Engineering, Jorhat Engineering College, Jorhat – 7 (Assam), India*

Abstract — *Machine idle time is one of the main causes for lower machine utilization and prevents the use of its full potential and capacity. As a result, the value of average flow time and makespan increases and becomes a reason for production and delivery delays. Since the last few decades, a number of scheduling and sequencing techniques have been developed by many researchers to minimize these causes. Among them, most techniques are concerned with decreasing average flow time and makespan value. In this paper also, a new heuristic technique is developed for decreasing such causes. The results are compared with that obtained by using some standard dispatching rules and found that the developed heuristic algorithm is performing better in minimizing the values of makespan, average flow time and number of machine set ups required.*

Keywords — *Machine idle time, average flow time, makespan, sequencing and scheduling, dispatching rule, heuristics.*

I. Introduction

Sequencing and scheduling techniques are the means for taking decisions regarding when to put a job for processing in a particular machine and at what time to get a desired outflow of finished products. They analyse the information like production/processing time, number of machines involved, number of processing operations, due dates etc. to take such decisions. Analytical techniques generally use mathematical equations; rule based techniques use some priority rules to take decision regarding which job is to be given priority; heuristic techniques use custom developed rules to take such decisions and simulations models can be used to even predict future behaviour by analysing the current data. But, all the techniques are not equally efficient to be used in all situations.

Thus in this project work, the results obtained from the developed heuristic model will be compared with that obtained by some frequently used dispatching rules, like Shortest Processing Time (SPT) rule, Longest/Largest Processing Time (LPT) rule, Slack Time Remaining (STR) rule and Critical Ratio (CR) rule for solving sequencing problems. Earliest Due Date (EDD) rule will not be considered for testing because the due date for all the jobs is the same and any earliness will be considered better. The processing data are collected from fabricating shop of a sheet metal processing industry wish Job Shop layout.

II. Literature Survey

In general, a sequence problem may be defined as the problem of finding that technologically feasible sequence among $(n!)^m$ possible ways for processing n jobs through m machines which will give the minimum value of makespan. A technologically feasible sequence is the one for which all the existing constrains are satisfied while processing n jobs through m machines [1].

In case only a single machine is present and 10 jobs have to be processed through it, then there are 10! = 3628800 available options of processing sequences. But if there are two machines present, then we have 10! x 10! = $(10!)^2$ = 1.31 x 10^{13} different types of sequences to choose from. Thus, with each extra addition of a machine, the available options increase exponentially. In this way, for n jobs to be processed through m different machines, the available number of sequences would be $(n!)^m$ and finding out the optimal sequence among this huge number of available options is not an easy task. Moreover, testing each available sequence is also not an intelligent decision as it will take a lot of time and labour. So for ease, in such situations, sometimes heuristically developed algorithms give fair results which are practically applicable also. Some popular and established heuristic techniques include Genetic Algorithm (GA), Ant Colony Optimization, Bees Algorithm, Tabu Search etc.

In Job Shop Scheduling (JSS) environment, there are n jobs to be processed through m different machines with known processing time and predefined machine sequence. Thus, it is considered to be the most complicated and tough kind of scheduling problem and called as NP-hard. NP-hard hard refers to a category of problem for which there is no fixed procedure to get the optimum result.

P. B. Barua et. al. [2] developed their own heuristic algorithm for finding out the optimal product mix and machine loading sequence to be employed in a manufacturing system using GT cells. For testing the algorithm, the authors used the data collected by Hitomi and Ham. The obtained results were then compared with that obtained by Hitomi and Ham using branch and bound algorithm and found the new results to be better.

K. Luchoomun et. al. [3] in their research work developed a hybridized GA by adding some additional genetic operators to the existing GA using heuristic methods for solving Static JSS problem. They found that the developed hybridized GA was performing better than conventional GA and produced optimal makespan with shorter evolution. The authors also mentioned that GA promises convergence but not optimality.

Vincent Lal and C. Anand Deva Durai [4] in their research work compared five heuristic technique based algorithms and found that none of them was giving optimum result and concluded that the results so obtained are only near optimal.

Nakandhrakumar, R. S. et. al. [5] used a heuristic technique called Tabu Search to solve JSS problem. After testing the algorithm, the authors found that the results obtained are nearly the same with those of the benchmark values set by other researchers and observed that the deviation increases a little when the matrix size increases beyond 5 x 5 and concluded that the method is an effective one to be employed for solving difficult problems.

Kaban, A. K. et. al. [6] in their research work tested 44 dispatching rules comprising 14 single and 30 hybrid dispatching rules. They used ARENA simulation software for comparing the results of these 44 dispatching rules used for solving JSS problem in an automotive industry and found that MTWR (Most Total Work Remaining) is giving better results in all performance measures compared to all single and hybrid rules. Looking at the results obtained, the authors also mentioned that SPT, which is mostly considered as one of the best performer has not performed better that MTWR and LPT is showing the worst results among all considered rules. The authors also concluded that no single dispatching rule is able to achieve all objectives for all performance measures.

Thus, it is seen from the surveyed literature that none of the techniques developed so far to solve sequencing the scheduling problems in a JSS environment is able to give the ultimate optimum result and the results obtained are near optimal only. Besides this, it is also seen from the above literature that there is hardly a rule / algorithm that aims to reduce the number of new machine set ups required while taking any sequencing / scheduling decision. The heuristic technique shown in this paper has been developed taking this fact into account.

To make an initial start, a single machine is selected for study among six other machines present in the fabrication shop of a sheet metal processing industry. The reason being that the selected machine is not dependent on any of the remaining five machines and hence, it gives the freedom to make any sequence of components that are being processed in it and then transferred to other succeeding machines.

The machine is processing a total of 31 components with number of processing operations ranging from 1 – 8 and die-punch involved from 1 – 4 per job. For processing 31 jobs in a single machine, we have 31! = 8.22×10^{33} available sequences. As this is a very large number, so it's not possible to test all the possible sequence to choose the best one. Thus, a heuristic technique is developed to solve the sequencing problem.

III. OBJECTIVE

To develop a heuristic algorithm to minimize machine idle time, makespan value and number of machine set ups required; and compare the results with that obtained by using SPT, LPT, STR and CR rule.

IV. THE ALGORITHM DEVELOPED

The algorithm developed is shown with the help of a flow chart in Figure – 1. The notations used are as explained below:

i = machine index
j = component index; $j = 1, 2, \dots \dots \dots, m$
C_{ji} = Component j belonging to Machine i
$C_{ji}(WIP)$ = jth WIP component belonging to machine i
D_k = kth Die; $k = 1, 2, \dots \dots \dots \dots, 58$
n_k = number of die and/or punch change; $k = 1, 2, \dots \dots \dots, n$
m_i = immediate successor machine; $i = 3, 5, 6$
$p_{n,j,i}$ = processing step number (n) for component (j) in machine (i); $n = 1, 2, \dots \dots \dots, n$
$rp_{n,j,i}$ = remaining processing step number (n) for component (j) in machine (i); $n = 1, 2, \dots \dots \dots, n$

V. RESULTS

The results found are tabulated in Table – 1 with decreasing order of makespan value. As can be seen from Table – 1, the number of M/C setups required is the highest in LPT, while the value decreases gradually with SPT, CR Rule, and STR; and finally reaches the minimum value 15, obtained by using the developed heuristic algorithm. Moreover, the makespan value is also decreasing from LPT being the highest to the heuristic showing the lowest value.

Table – 1
Comparison of the Results Obtained

Dispatching Rule	Number of M/C Setups required	Makespan (min)
LPT	25	3049
SPT	24	3039
CR Rule	23	2979
STR	22	2969
Heuristic	15	2943

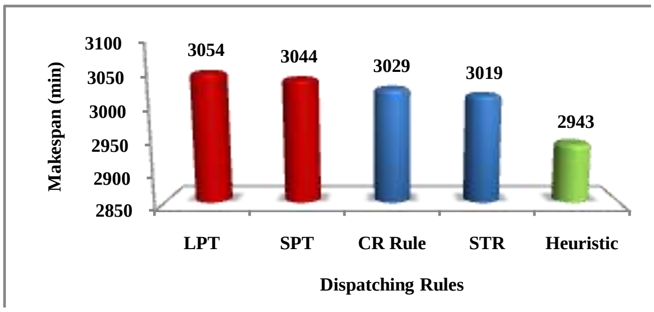

Figure – 2: Comparison of Makespan values

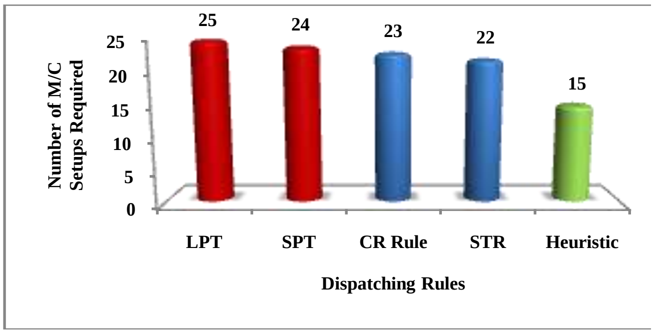

Figure – 3: Comparison of Number of M/C Set up Required

VI. CONCLUSIONS

The performance of the developed heuristic model is found to be better in minimizing the makespan value and number of machine setups required. Also, the performance of the LPT rule is the lowest and this finding is consistent with that explained in the literature survey. Thus, it can be concluded that the standard dispatching rules do not always perform better in all kinds of situations and as such the developed heuristic algorithm is a better one for this situation.

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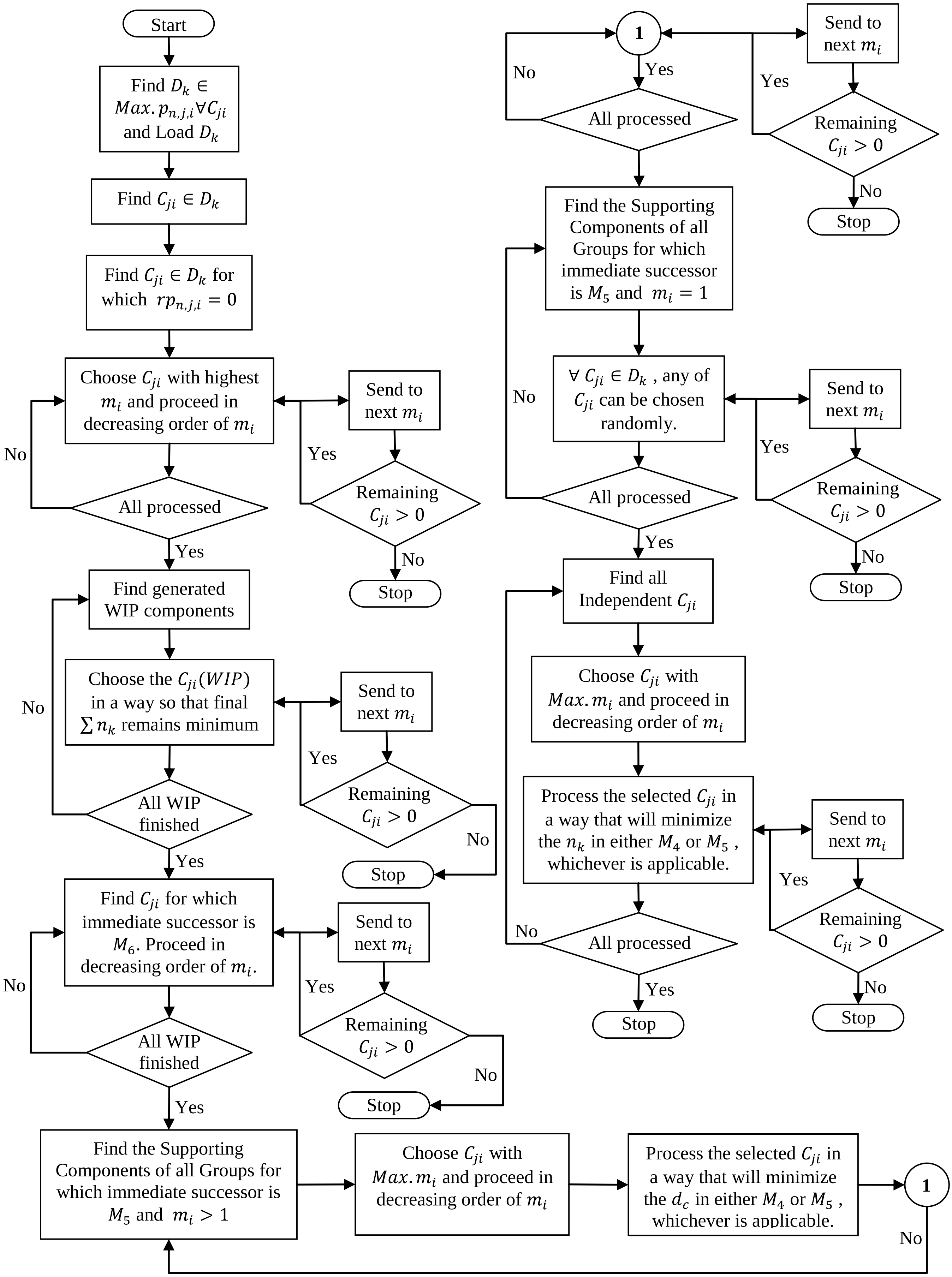

Figure – 1: Flow chart for the heuristic algorithm developed