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# CONCEPT OF LOGICAL SORT FOR IDLE TIME MINIMIZATION OF RENTAL/CRITICAL MACHINE IN FLOWSHOP

**VENNILA SHREE S[1], PUGAZHENTHI R[2], FRANKLIN ISSAC R[3] & PARTHIBAN. A[4]**

[1]*Associate Professor, Department of Commerce, Vels University, Chennai, Tamilnadu, India*

[2, 4]*Associate Professor, Department of Mechanical Engineering, Vels University, Chennai, Tamilnadu, India*

[3]*Research Scholar, Department of Mechanical Engineering, Anna University, Chennai, Tamilnadu, India*

***ABSTRACT***

***In a manufacturing environment, the high initial cost machines are processed on rental basis to meet the economy. The access of such rental or critical machines is constrained. In this research article, an attempt is made to develop a meta-heuristic to reduce the utilization tie of rental/critical machine(s) in the manufacturing (fellowship) environment. The concept of logical sorting and partial sequencing is used to develop the new meta-heuristic, which works on the principle of idle time reduction. The ultimate objective of the proposed meta-heuristic is to minimize the overall time of the manufacturing process with a minimum idle time of rental/critical machine(s). The performance of the proposed meta-heuristic is compared with CDS method and stated that it has achieved 96.7% closer to the CDS method in elapsed time with a zero idle time of the critical machine.***

***KEYWORDS: Flow Shop; Rental Machines; Idle Time; Logical Sort; Meta Heuristic & Critical Machine***

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Original Article

## INTRODUCTION

In fellowship, the products are produced after various stages of manufacturing. Sometimes in complex manufacturing procedure, there will be a need for some special purpose or high initial cost machine. In such occasion, the manufacturer will go to buy or rent decision. In most of the production plant or unit, the decision is taken towards rent. But, the rental machine needs to be utilized properly to avoid unwanted rental charges. For achieving this target, an optimal sequence is required.

The transportation process of the job from one machine to another and the setup time for jobs and tools on machines also play a role while selecting an optimal sequence for flow shop scheduling problems. A heuristic for solving flow shop problems involving transportation time & job block criteria has been developed by Sameer et al [1]. In automatic transportation system the next machine is needed immediately after the machining process over when the previous machine. Thus the transportation time for the job to move from the first machine to the second machine and setup time are also included in the total elapsed time for the second machine and the transportation time from the second machine to the third machine along with setup time is included in the total elapsed time for the third machine and so on.

Practically, it is not possible to find the solution through the enumeration process. Unfortunately, all the available heuristics were not concentrating on this rental or minimizing the particular machine. At the first time, Johnson's rule breaks the enumeration type of problem by applying a simple heuristic, which is developed by

Johnson [2]. In 1982, a radically different approach is proposed by Stinson and Smith [3]. In which, the makespan of the production is reduced by treating job motion as salesman travel. Nawaz et al (1983) have presented a new NEH heuristic to reduce the total processing time, which based on the premise that a job with higher processing time should be given higher priority [4].

Generally, finding an optimal solution of a flow shop by enumeration process is not feasibly one it consumes more time. In reducing the computation time of an optimal solution of flow shop can be achieved by heuristics and Meta heuristics. Pugazhenthi and Anthony Xavier [5] Alas, almost all the available heuristics are concentrating tor reducing makespan time with the same weight-age of machines. But very few researchers were considered machine weight i.e. rental machine or critical machine, bottleneck machine. The critical or rental machines are not a newer or spate machine they are existing in every flow shop manufacturing environment, because of its nature the machine can be identified; Pugazhenthi and Anthony Xavier [6].

Kyparisis et al [7], develop a polynomial time algorithm to solve the 'm' machine flow shop and open shop makespan problems with a critical machine. In the flow shop case, an O (m (nlogn+logm)) algorithm is developed with consideration of all jobs that require processing on the same subset of machines.

Saravanan and Raju [8], the optimization of any hybrid flow shop is not an easy way for an effective outcome; simulation is an effective tool to solve the HFS's of '*n'* jobs processed through '*m*' machines with the size of '*k*' sub lots.

Pugazhenthi and Anthony Xavier [9], improved the of the productivity of the fellow ship production environment by reducing the process cycle time through the simulation methodology. In this, the objective of minimum makespan is achieved by reducing the idle time and/or total flow time.

In this work, a new meta-heuristic proposed to reduce the rental time of the critical machine by reducing the idle time of the critical machine. The partial sequences are generated by a logical sort based on waiting time of the job. The performance of the Logical Sort MetaHeuristic (LSMH) is evaluated by comparing with CDS method [10], in the aspect of elapse time and idle time of the critical machine.

## METHODLOGY

### Notations

i: a Random job.

j: Random machine.

$T_{ij}$: Machining time of an$i^{th}$ job on the $j^{th}$ machine.

$TP_{ij}$: Sum of all the machining time.

$I_{ij}$: Idle time of the$j^{th}$ machine, while processing the$i^{th}$ job.

$ID_i$: Sum of all the idle time of machines.

### Assumption

- Jobs were not depending upon to each other.
- The transportation time between the machines is considered.

- Breakdown time of the machine is not being considered.
- Pre-emission is not allowed.

The general structure of n jobs and m machines problem is shown in Table I.

**Table 1: General Structure of N X M Problem**

| Job | Processing Time on Machines | | | | |
|---|---|---|---|---|---|
| | ***Ma*** | $M_b$ | $M_c$ | ... | $M_m$ |
| $J_1$ | $T_{1a}$ | $T'_{1b}$ | $T'_{1c}$ | ... | $T'_{1m}$ |
| $J_2$ | $T_{2a}$ | $T'_{2b}$ | $T'_{2c}$ | ... | $T'_{2m}$ |
| $J_3$ | $T_{3a}$ | $T'_{3b}$ | $T'_{3c}$ | ... | $T'_{3m}$ |
| .<br>. | .<br>. | .<br>. | .<br>. | .<br>. | .<br>. |
| $J_n$ | $T'_{na}$ | $T'_{nb}$ | $T'_{nc}$ | ... | $T'_{nm}$ |

**Existing CDS Method**

The algorithm converts a given n jobs m machine problem (m>2) into p number n job surrogate problems, where p =m-1. The conversion methodology is stated in Equation 1 and 2. Each surrogate problem is solved using Johnson rule. The sequence of the surrogate problem yielding a minimum value of $C_{max}$ after applying Johnson's rule is selected for scheduling jobs on the machines.

$$T_{j1}^{i} = \sum_{k=1}^{i} T_{j,k}$$

(1)

$$T_{j2}^{i} = \sum_{k=1}^{i} T_{jm-k+1} \qquad (2)$$

**Proposed LSMH**

The proposed LSMH works based on the following procedure. The flow chart of the LSMH is shown in Figure. 1.

**Step 1**: Reduction of the problem by adding transportation time to the machining time on machines.

**Step 2**: Select all the jobs individually and assume it is processed at first.

**Step 3**: Calculate the Sum of the total idle time of M/c A, M/c B to M/c N as given in equation (3).

Ii = Iia + Iib + …………….. + Iim (3)

**Step 4**: Find the minimum of (I1, I2, I3,... In). Select the job corresponding to the minimum idle time for the corresponding M/c. The selected job is decided to be processed at first.

**Step 5**: The selected job is removed from the job sequence list.

**Step 6**: All the other jobs are considered for it is the second position in the sequence, and their idle times on various machines are tabulated.

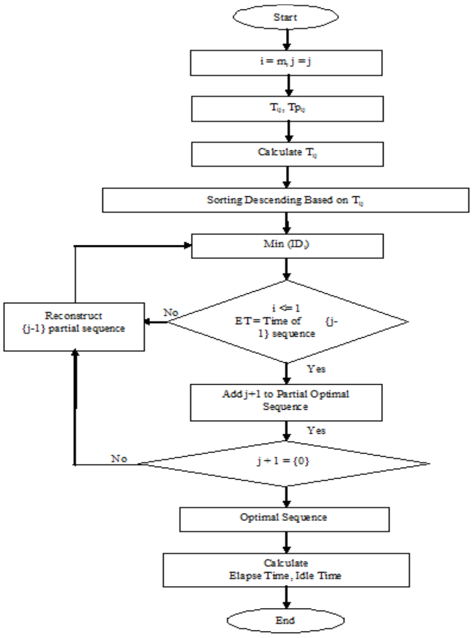


**Figure1: Flowchart of LSMH**

**Step 7**: The job corresponding to the minimum idle time of the corresponding M/c is selected for processing as the second job.

**Step 8:** The process continues till all the jobs are over and an optimal sequence S1 is obtained.

**Step 9**: In-Out table prepared for each sequence and evaluate the completion time of the first job on machine A for each sequence.

**Step 10**: Machines utilization time calculated for all the each sequence.

**Step 11**: The sequence which has less utilization time of the last machine is the corresponding optimal sequence.

**Step 12**: Calculate the rental time.

The above problem will have a number of reduction stages equal to that of the number of jobs. When all the reduction stages are over, the final sequence will give the minimum idle time for the rental machine.

## RESULTS AND DISCUSSIONS

The benchmark problems proposed by Taillard [11] are tested against the newly proposed LSMH and CDS methods for the various sizes of the problems with 20, 50 & 100 jobs through 5 &10 machines. The result is obtained based on elapsed time and idle time of rental/critical machine parameters using Matlab. These results are compared with Lower Bound (LB) of the corresponding problem and tabulated in Table II and graphically represented in Figure. 2 and 3.

From the obtained results, it is evident that the proposed LSMH is 96.7% closer to average LB of each set. Simultaneously, the proposed LSMH has achieved the zero idle time for the rental/critical machine of each set. Since the rental/critical machine is considered based on the highest processing time assigned machine.

**Table 2: Comparison of CDS and LSMH Based on Elapse Time and Idle Time of Rental/Critical Machine**

| Machines X Jobs | Elapse Time to LB (%) | | Idle Time of Rental/Critical Machine (%) | |
|---|---|---|---|---|
| | CDS | LSMH | CDS | LSMH |
| 5 X 20 | 87.20 | 85.32 | 24.6 | 0 |
| 5 X 50 | 87.37 | 84.88 | 27.2 | 0 |
| 5 X 100 | 93.25 | 90.57 | 33.54 | 0 |
| 10 X 20 | 74.62 | 72.76 | 17.33 | 0 |
| 10 X 50 | 78.97 | 75.43 | 19.1 | 0 |
| 10 X 100 | 85.42 | 81.21 | 15.67 | 0 |
| **Average** | **84.47** | **81.70** | **22.91** | **0** |

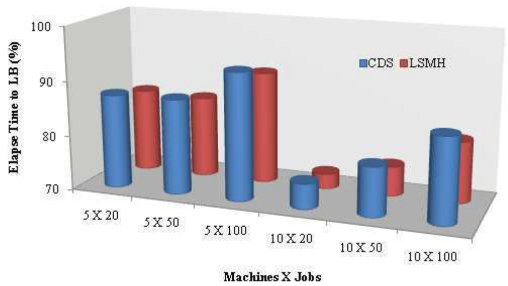


**Figure 2: Comparison of CDS and LSMH Based on Elapse Time**

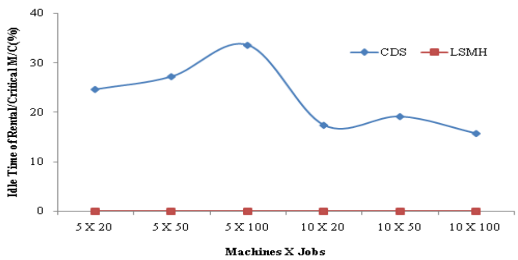


**Figure 3: Comparison of CDS and LSMH Based on Idle Time**

## CONCLUSIONS

This research article proposed a new innovative LSMH, which projects the minimum usage of the rental machines of the 'N' jobs in 'M' machine flowshop manufacturing environment. It reduces the rental time of machines by reducing the idle time, of critical machines in the manufacturing environment. The best sequencing of the job indexing achieved by minimizing the rental time of the machine by reducing the sum of the idle time of the critical rental. The proposed LSMH is evaluated through a set of benchmark problems in MATLAB environment and compared with the result of CDS based on LB on the corresponding problem. The proposed LSMH has achieved 96.7% closer to the CDS method in elapsed time with a zero idle time of the rental critical machine.

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