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HEURISTIC FOR CRITICAL MACHINE ORIENTED BATCH SCHEDULING IN TWO-STAGE HYBRID FLOW SHOP

P. Vivek
Research Scholar, Department of Mechanical Engineering,
Vels Institute of Science Technology & Advanced Studies, Chennai, India

R. Saravanan
Professor & Dean, Mechanical Engineering,
Ellenki College of Engineering and Technology, Hyderabad, India

M. Chandrasekaran
Professor & Director, Dept. of Mechanical Engineering,
Vels Institute of Science Technology & Advanced Studies, Chennai, India

R. Pugazhenthi
Associate Professor, Dept. of Mechanical Engineering,
Vels Institute of Science Technology & Advanced Studies, Chennai, India

T. Vinod kumar
Assistant Professor, Dept. of Mechanical Engineering,
Vels Institute of Science Technology & Advanced Studies, Chennai, India

ABSTRACT

Hybrid flowshop is often encountered in numerous of manufacturing environment in which the batch scheduling is occurred when multiple order have same due date and such orders may be grouped together for processing to increase the machine utilization. The increase of lot size may reduce the makespan and increases machine utilization at the same time increases the complexity of handing and queue length. So the critical machine oriented lot sizing and lot streaming procedure adopted in this research. Batch scheduling of Two stage Hybrid flow shop (m = 2, M(1) = 1, M(2) = 2) is considered in this paper. Applied mathematical model presented. The optimization of lot sizing was carried out by using simulation modelling and analysis. Heuristic developed for scheduling. The groups of jobs orders were varied at five level and found the heuristic solution outperformed for all levels.

Keywords: Critical Machine, Batch scheduling, Hybrid Flow shop, mathematical model, simulation, makespan, queue status.

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1. INTRODUCTION

The manufacturing environment sometimes gets change from flow shop to hybrid flow shop (HFS) by considering the standby machines for production. Hence the Hybrid Flow Shop (HFS) is usually defined as production flow shop with single/multiple parallel machines added in each production stage, As HFS problems combinatorial in nature so these problems are NP hard. So HFS problems usually preferred to solve by polynomial with some special properties and precedence relationships or heuristic method [1,2]. The critical machine based scheduling minimizes the the mean flow time and average queue length.[3]. The real time solution for scheduling with lot streaming can be achieved by simulation modeling and analysis. Which allows the examination of queue status flow status and answer many what if Questions [4]? Maulidya et al. suggested a heuristic for solving a three stage Flowshop batch scheduling with different (unrelated) machines setup [5]. A hybridized with neighborhood search techniques suggested for solving the hybrid flow show with batch processing machine [6]. The constraint is different ready time. But here the case is job processing by prescribed priority from the lot or queue. The Critical machine occurrence on scheduling was recently reported and recommended for high machine utilization [7, 8]. [9] Suggested a mathematical model for solving lot-streaming HFS batch scheduling problem in which they considered priority rule with shortest weighting time and concurrent arrival of jobs. [10] reported that lot streaming received less attention from the researchers, simulation is an best tool to investigate the effectiveness of lot streaming with sequencing rules, lot sizing, scheduling scenarios with respect to the in-process inventory status, machine utilization. Vivek et al [11], developed mathematical model and suggested heuristic for 2 stage HFS lot streaming problem. The simulation is used for lot sizing and validation of the heuristic solutions (group schedules) for similar and variable lot sizes. This research focuses two stage HFS ($M^{(1)} = 2$, $M^{(2)} = 1$, k= 10) batch scheduling problem with uniform lot size case. The objective is to minimize makespan. The problem described in the Figure 1.

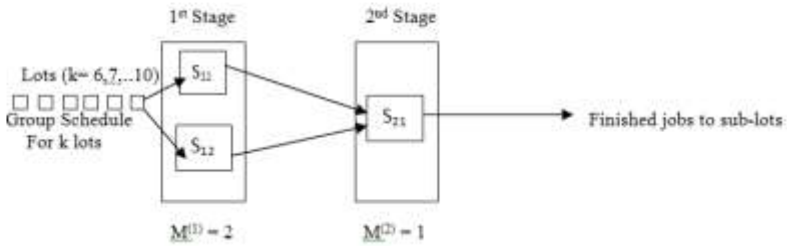

Figure 1 Hybrid flowshop (m = 2, $M^{(1)} = 2$, $M^{(2)} = 1$)

2. APPLIED MATHEMATICAL MODEL

2.1. Assumptions

The following assumptions are made

i. Job flow unidirectional.
ii. Preemption is prohibited.
iii. Loading, unloading and Setup times are included in the processing time.

iv. Initially assumed unlimited intermittent storage capacity.
v. Jobs available at zero time at the first stage.
vi. There is no interruption i.e., facilities available continuously.
vii. Splitting of the individual sub - lot is not permitted for forming the lot. But sub lots may be grouped to form lots with all possible ways.
viii. A lot can be subsequently considered for processing after the completion of the last job of the last lot at all the stages.

2.2. Parameters

J_i = the job J_i (J_i =1, 2, ..., *200*) of provided i^{th} (i = 1, 2, …, k), sub-lot,
k = Number of sub-lots *k(k=6,7,…,10)*
Gs = Group schedule
$J_i \in J$,
J = Total number of jobs to be scheduled,
$(P_m)_{Ji}$ = Processing times of job,
Ji of sub-lot k at m^{th} stage,
m = 1, 2, (m = 2, $M^{(1)}$ = 1, $M^{(2)}$ = 2),
T = Total number of time units in scheduling jobs,
$(C_m)_{Ji}$ = Completion time of job J of sub-lot i at the stage m,

It is a time point $\mathbf{(C_m)_{Ji} = t}$ means that the operation completes at the end of the time unit $\boldsymbol{t}$.

2.3. Decision variables

$$(\delta_m)_{Ji}\, t = \begin{cases} 1 & \text{if } \boldsymbol{Ji} \text{ is processed at the stage } \boldsymbol{m} \text{ in the time unit } \boldsymbol{t}; \\ 0 & \text{other wise} \end{cases}$$

with the above notation, the hybrid flow shop problem (HFSP) under the consideration can be formulated as follows.

The $\mathbf{(C_2)_{Ji}}$ in the model is the final completion time of the male job $\boldsymbol{J}$ of type $\boldsymbol{i}$, $\boldsymbol{C_2}$ after processed at required at the stage ***2***, in other words it is the completion time of a job to the sub-lot ***i.***

2.4. Mathematical Model

The lot may be formed by combining of sub-lots or sub lot alone as per lot streaming strategy; it is chosen based on the available sub-lots. Lot completion time is the completion time of the last job of that lot. Makespan is the completion time of the last job of the last lot in the group schedule (**G_s**). The objective is minimizing makespan and the objective function is:

$$\text{Minimize} \sum_{i=1}^{k} \sum_{J_i=1}^{n} (C_2)_{Ji} \qquad 1$$

Where $\boldsymbol{k}$= 6,7,...,10 and $\boldsymbol{n}$ = 200

Subject to

$$(C_2)_{Ji} \le (C_2)_{Ji} + 1 - (P_2)_{Ji} \qquad J_i \ (J_i=1,2,\ldots,n);\ J_i \in J; \qquad 2$$

$$\sum_{t=1}^{T_m}(\delta_2)_{Ji}t=(P_2)_{Ji} \quad ; t = 1,2,\ldots,T; \tag{3}$$

$$t*(\delta_2)_{Ji}t \le (C_2)_{Ji} \tag{4}$$

$$(C_2)_{Ji}-(P_2)_{Ji}+1 \le t+T(1-(\delta_2)_{Ji}t) \tag{5}$$

$$\sum_{Ji=1}^{n}(\delta_2)_{J_i}t \le M^{(s)} \quad ; \qquad M^{(1)}=1,\ M^{(2)}=2 \tag{6}$$

$$(\delta_2)_{Ji}t \in \{0.1\} \tag{7}$$

$$(C_2)_{Ji} \in \{1,2,\ldots,T\} \tag{8}$$

In this mathematical model, the objective is to find the optimal group scheduling that minimizes the makespan with consideration of critical machine, at the same time it should satisfy the listed constraints in the equation (2) to the equation (8). The equation (2) is precedence constraint, *i.e.*, an operation cannot be started until the operation of the same job at its preceding stage is completed. The equations (3) – (5) defines the time intervals for which a job is processed on a machine at a stage. The equation (6) defines the machine constraint at each stage *i.e.*, machine requirements are satisfied with the number of available machines at that time. The equation (7) & (8) provides the time range of the variables.

2.5. Makespan Computation

Mathematical representation of computation of makespan for the example group schedule $\{L_1(J_1\&J_2) - L_2(J_3\&J_4) - L_3(J_5\&J_6)\}$ is

Mathematical representation of computation of makespan for a sample group schedule $\{L_1(J_1\&J_2) - L_2(J_3\&J_4) - L_3(J_5\&J_6)\}$ is

$$C_j = max\left\{\sum_{j_i=1}^{200}(C_2)_{j_1},\ \sum_{j_i=1}^{200}(C_2)_{j_2}\right\} + max\left\{\sum_{j_i=1}^{200}(C_2)_{j_3},\ \sum_{j_i=1}^{200}(C_2)_{j_4}\right\} + max\left\{\sum_{j_i=1}^{200}(C_2)_{j_5},\ \sum_{j_i=1}^{200}(C_2)_{j_6}\right\}$$

3. HEURISTIC

Step 1. As the inherent sub lot size is same as well as the processing time and processing sequence of jobs within the inherent sub lot is also same. One job per variety is to be considered for computation of Total Processing time T_pThe total processing time T_p of all job verities k (k=1,2,...,k) can be mathematically written as

$$T_p = \sum_{i=1}^{k}\sum_{m=1}^{2} P_{m_{Ji}} \ \forall T;\ T_p \in T$$

a. Compute total processing time for each job variety. t_p.
b. The sum of the processing time for each job variety is T_p.

Step 2: Computation of desired number of lots (N_l)

Total number of sub-lots involved (k).

Case 1. For almost Uniform lot size, the desired number of lots $N_i = \left(\frac{k}{S_{max}}\right)$

If round up to whole number and consider the same as N_i

Case 2. For Non-Uniform lot sizes or customized lot size, the desired number of lots (N_i) to be identified manually and consider.

Step 3: Compute the Average processing time

$$m_p = \frac{T_p}{N_l}$$

Step 4: lot formation

Form the N_l lots with lot size of $\mathrm{S_{max}}$ and $\mathrm{S_{min}}$

Step 5: Group scheduling

a. Check deviations $d_i = t_{pi} - m_p$ where i (i=1,2,..., N_l)
b. compute net deviation $d = \sum_{i=1}^{N_i} d_i$
c. Stop if $d = 0$ else Go to step 4b
d. The schedule is optimal group schedule

4. CASE STUDY

The computational experiments were carried out with real world environment observations i.e., the automobile spare production industry. The industry has worldwide customers and launched huge variety as per demand. Hence the job verities are included according to the delivery schedule. As on date there are possibilities to have six to ten job verities with same lot size was estimated. The maximum number of lots considered depends up on the delivery schedule but as per history of production minimum 6 lots considered. Hence this computation experiments consider at different level that is the job variety levels from six to ten k (k=6,....,10).

4.1. Problem Description

The manufacturing environment is classified as m = 2, $M^{(1)} = 2$, $M^{(2)} = 1$; k= 6,7,...,10 hybrid flowshop Problem. That is the jobs are processed at two stages in the manufacturing shop in which at first stage has two processors/ machines and the next stage contains one machine / processor. Total number of job variety involved is 10. A sub-lot possess similar jobs of 200 with same processing time and processing sequence. Hence, the maximum number jobs to be processed are 2000 jobs with 10 varieties. The job processing times are not similar for all jobs. The job variety and their processing time sequence are furnished in Table 1.

4.2. Critical Machine

The second stage of the Hybrid Flowshop has only one machine and the same is engaging to process the jobs which processed by both machines at the first stage. If the job scheduled is more (if number of sub lot is more in the lot means available job at first stage will be more) at first stage the two machines may be engaged for processing else the first machine is only preferred for processing of all jobs in the first stage. The second stage may be bottle neck when the output of first stage is greater than the second stage. Hence the second stage machine is called Critical machine. The critical machine based scheduling is one, which consider either the capacity or some other constraint related to the critical machine?

4.3. Simulation Modelling

The mathematical model used for creating the simulation model. The Extend v6 software employed to create the model of the production environment. The model is verified and validated by real world data. The model has facilitated to collect statistics of queue status like maximum waits, average waits, maximum length and average length, machine utilization status and flow statistics like mean flow time and completion time.

5. OPTIMIZING LOT SIZE

The lot size is varied 5 levels that are from 2 sub-lots to six sub-lots for estimating the status of queus at the critical machine. The queue statistics collected and presented in table 2 like stage wise Average Queue Length (Avg. Length), Maximum Queue Length (Max Length), Average waits (Avg. Waits) in minutes and Maximum Waits (Max Waits) in minutes. The Table 3 shows the machine utilization rate and ideal time rate.

Table 1 processing times of Jobs

Ji	Stage-1 (min)	Stage-2 (min)
1	5.42	1.5
2	2.7	4.94
3	2.86	2.9
4	4.22	3.94
5	5.86	1.94
6	4.53	3.66
7	1.52	4.57
8	3.02	5.41
9	3.92	5.22
10	3.42	5.38

Table 2 Lot Completion time and Queue statistics

Lot size	Stage 1 Avg. Length (Nos)	Stage 2 Avg. Length (Nos)	Stage 1 Max Length (Nos)	Stage 2 Max Length (Nos)	Stage 1 Avg. Waits (min)	Stage 2 Avg. Waits (min)	Stage 1 Max Waits (min)	Stage 2 Max Waits (min)	Lot completion time (min)
1	2	1	126	1	169.29	0.25	338.58	0.5	545
2	5	4	301	149	303.8	240.3	610.28	478.4	1291
3	9	8	490	248	447.2	386.04	894.88	769.9	1870
4	19	17	705	365	703.91	609.02	1316.9	1135.9	2659
5	36	13	919	302	1072.9	368.22	1902.9	939.44	3048
6	53	22	1117	392	1317.3	530.17	2355.9	1218.7	3781

Table 3 Machine Utilization Rate and machine Ideal Time Rate

Lot Size	Utilization Rate			Ideal Time Rate		
	M/C-S11	M/C-S12	M/C-S21	M/C-S11	M/C-S12	M/C-S21
1	0.018067	0.018067	0.010000	0.981933	0.981933	0.990000
2	0.027157	0.026977	0.042933	0.972843	0.973023	0.957067
3	0.036643	0.036557	0.062267	0.963357	0.963443	0.937733
4	0.050710	0.050623	0.088533	0.94929	0.949377	0.911467
5	0.070157	0.070243	0.101470	0.929843	0.929757	0.898530
6	0.085343	0.085257	0.125870	0.914657	0.914743	0.874130

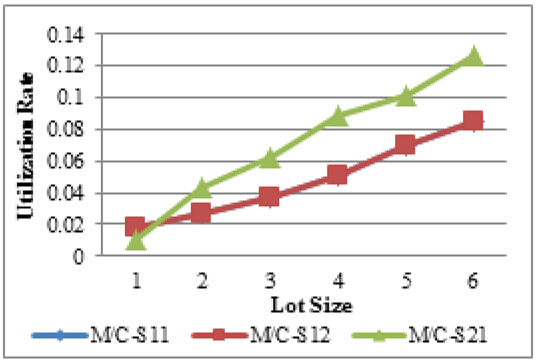

Figure 2 Machine utilization rate Vs Lot size

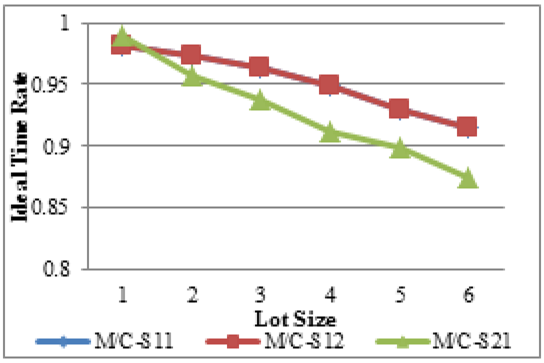

Figure 3 Machine ideal time rate Vs Lot size

Notations used in table 3 are: first Machine at stage one as M/C-S11, the parallel identical machine at stage 1 as M/C-S12. The machine at second stage is denoted as M/C-S21. It is noticed from the observations at Table 3 that the increase of lot size increases the machine utilization (Figure 2) and decreases the machine ideal time rate (Figure 3). But the queue statics restricted to increase the lot size because of queue length and steep increase of lot completion time (Table 2). Hence by considering elimination of human error due to congest jobs with varieties, the maximum lot size is restricted or optimized to two sub lots and minimum lot size is one sub lot.

6. NUMERICAL EXAMPLE

As per case study the job varieties (k) are 15, number of jobs in each variety is 200, the processing time listed in Table 1. The optimized lot size details are: maximum 2 sub-lots (S_{max}) and minimum 1 sub-lot (S_{min})

Step 1**:** Refer Table 1 for Computation of (T_p)

$T_p = \sum_{i=1}^{k} \sum_{m=1}^{2} P_{m\,Ji}$ $\forall T;\ T_p \in T$ T_p= 76.93 minutes

Step 2: Computation of desired number of lots (N_l)

Total number of sub-lots involved (k) is 15. The lot size is almost uniform and odd number of total sub-lots,

Hence the desired number of lots $N_i = \left(\frac{k}{S_{max}}\right) = \frac{10}{2} = 5$

Step 3: Compute the mean processing time $m_p = \frac{T_p}{N_l} = \frac{76.93}{5} = 15.386$

Step 4: Sub-lot formation

a. Computation of total processing time (t_p) by adding all processing time in Table 1.
b. Form the N_l lots with lot size of S_{max} and S_{min}
c. Check deviations $d_i = t_{pi} - m_p$ where i (i=1,2,..., N_l)
d. calculate net déviation $d = \sum_{i=1}^{N_i} d_i$
e. Stop if $d = 0$ else Go to step 4b

$$G_s = \{L_1(J_1 \,\&\, J_2) - L_2(J_3 \,\&\, J_4) - L_3(J_6 \,\&\, J_9) - L_4(J_7 \,\&\, J_8) - L_5(J_{10} \,\&\, J_5)\}$$

d = -0.826-1.466+1.944-0.866+1.214 = 0.00000000000000710543

Hence the G_s is the optimal group schedule. Computation of makespan is sum of the sub group completion time. Hence

C_j = 1291 + 1371 + 1780 + 1898 + 1467 = 7807 minutes.

7. BEST SCHEDULES

The developed heuristic was applied to various maximum sub-lots involved cases i.e., k=6,7,...,10. At each case more than one optimal schedules and its equivalent were found. Here below the case wise they are presented. C_{jL1}, C_{jL2}, C_{jL3}, C_{jL4} and C_{jL5} are the lot completion time in minutes of lot 1, lot 2, lot 3, lot 4 and lot 5 respectively.

7.1. Case -I

In this case maximum sub-lots considered are six. The best group schedules are furnished below and their individual lot completion times (C_{jL1}, C_{jL2} & C_{jL3}) and makespan (***C_j***) can be found in Table 4.

G1= {L1(J1 & J2) - L2(J3 & J6) – L3(J4 & J5)}

G2= {L1(J1 & J2) - L2(J3 & J4) – L3(J5 & J6)}

G3= {L1(J1 & J3) - L2(J2 & J4) – L3(J5 & J6)}

G4= {L1(J1 & J3) - L2(J2 & J6) – L3(J4 & J5)}

Table 4 Lot completion times and makespan for case-I best schedules

Gs	C_{jL1}	C_{jL2}	C_{jL3}	C_j
G_1	1291	1315	1181	3787
G_2	1291	1371	1125	3787
G_3	883	1779	1125	3787
G_4	883	1723	1181	3787

7.2. Case -II

In this case maximum seven sub-lots are considered. The best group schedules are listed here below. The individual lot completion times (C_{jL1}, C_{jL2}, C_{jL3} & C_{jL4}) and makespan (C_j) for each schedule may be found in Table 5.

Table 5 Lot completion times and makespan for case-II best schedules

Gs	C_{jL1}	C_{jL2}	C_{jL3}	C_{jL4}	C_j
G_1	1291	1371	1125	916	4703
G_2	1291	1525	1304	583	4703
G_3	1291	1181	1648	583	4703
G_4	1291	1315	1181	916	4703
G_5	1291	1371	1304	737	4703
G_6	883	1779	1304	737	4703
G_7	883	1779	1125	916	4703
G_8	883	1723	1181	916	4703
G_9	883	1704	1125	991	4703
G_{10}	883	1525	1304	991	4703
G_{11}	883	1181	1648	991	4703
G_{12}	1216	1371	1125	991	4703
G_{13}	1216	1181	1723	583	4703
G_{14}	1304	883	1723	793	4703

G1= {L1(J1 & J2) - L2(J3 & J4) – L3(J5 & J6) – L4(J7)}

G2= {L1(J1 & J2) - L2(J4 & J6) – L3(J7 & J5) – L4(J3)}

G3= {L1(J1 & J2) - L2(J4 & J5) – L3(J7 & J6) – L4(J3)}

G4= {L1(J1 & J2) - L2(J3 & J6) – L3(J4 & J5) – L4(J7)}

G5= {L1(J1 & J2) - L2(J3 & J4) – L3(J7 & J5) – L4(J6)}

G6= {L1(J1 & J3) - L2(J2 & J4) – L3(J7 & J5) – L4(J6)}

G7= {L1(J1 & J3) - L2(J2 & J4) – L3(J5 & J6) – L4(J7)}

G8= {L1(J1 & J3) - L2(J2 & J6) – L3(J4 & J5) – L4(J7)}

G9= {L1(J1 & J3) - L2(J7 & J4) – L3(J5 & J6) – L4(J2)}

G10= {L1(J1 & J3) - L2(J4 & J6) – L3(J7 & J5) – L4(J2)}

G11= {L1(J1 & J3) - L2(J4 & J5) – L3(J7 & J6) – L4(J2)}

G12= {L1(J1 & J7) - L2(J3 & J4) – L3(J5 & J6) – L4(J2)}

G13= {L1(J1 & J7) - L2(J4 & J5) – L3(J2 & J6) – L4(J3)}

G14= {L1(J7 & J5) - L2(J1 & J3) – L3(J2 & J6) – L4(J4)}

7.3. Case -III

In this case maximum sub-lots are eight. The best group schedules for this case are listed below. The each lot completion time of the each best group schedule and its makespan (C_j) shown in Table 6.

G1= {L1(J1 & J3) - L2(J2 & J4) – L3(J5 & J6) – L4(J7 & J8)}

G2= {L1(J2 & J6) - L2(J1 & J3) – L3(J4 & J5) – L4(J7 & J8)}

G3= {L1(J1 & J3) - L2(J5 & J4) – L3(J2 & J6) – L4(J7 & J8)}

G4= {L1(J3 & J6) - L2(J1 & J2) – L3(J4 & J5) – L4(J7 & J8)}

G5= {L1(J1 & J4) - L2(J2 & J3) – L3(J5 & J6) – L4(J7 & J8)}

G6= {L1(J1 & J6) - L2(J2 & J3) – L3(J4 & J5) – L4(J7 & J8)}

Table 6 Lot completion times and makespan for case-III best schedules

Gs	C_{jL1}	C_{jL2}	C_{jL3}	C_{jL4}	C_j
G_1	883	1779	1125	1898	5685
G_2	1723	883	1181	1898	5685
G_3	883	1181	1723	1898	5685
G_4	1315	1291	1181	1898	5685
G_5	1093	1571	1125	1898	5687
G_6	1037	1571	1181	1898	5687

7.4. Case -IV

In this case maximum sub-lots are nine. The best group schedules for this case are listed below. The each lot completion time of the each best group schedule and its makespan (C_j) shown in Table 7.

G1= {L1(J1 & J2) - L2(J4 & J5) – L3(J6 & J9) – L4(J7 & J8) – L5(J3)}

G2= {L1(J1 & J3) - L2(J4 & J5) – L3(J6 & J9) – L4(J7 & J8) – L5(J2)}

G3= {L1(J1 & J3) - L2(J4 & J5) – L3(J2 & J6) – L4(J7 & J8) – L5(J9)}

G4= {L1(J1 & J2) - L2(J3 & J6) – L3(J4 & J5) – L4(J7 & J8) – L5(J9)}

G5= {L1(J1 & J3) - L2(J2 & J4) – L3(J5 & J6) – L4(J7 & J8) – L5(J9)}

G6= {L1(J1 & J4) - L2(J2 & J3) – L3(J5 & J6) – L4(J7 & J8) – L5(J9)}

G7= {L1(J1 & J6) - L2(J2 & J3) – L3(J4 & J5) – L4(J7 & J8) – L5(J9)}

Table 7 Lot completion times and makespan for case-IV best schedules

Gs	C_{jL1}	C_{jL2}	C_{jL3}	C_{jL4}	C_{jL5}	C_j
G_1	1291	1181	1780	1898	583	6733
G_2	883	1181	1780	1898	991	6733
G_3	883	1181	1723	1898	1048	6733
G_4	1291	1315	1181	1898	1048	6733
G_5	883	1779	1125	1898	1048	6733
G_6	1093	1571	1125	1898	1048	6735
G_7	1037	1571	1181	1898	1048	6735

7.5. Case -V

In this case maximum sub-lots are ten. The best group schedules for this case are listed below. The each lot completion time of the each best group schedule and its makespan (C_j) shown in Table 8.

G1= { L1(J1 & J2) - L2(J3 & J4) – L3(J5 & J9) – L4(J7 & J8) – L5(J10 & J6) }

G2= { L1(J1 & J2) - L2(J3 & J4) – L3(J6 & J9) – L4(J7 & J8) – L5(J10 & J5) }

G3= { L1(J1 & J2) - L2(J3 & J6) – L3(J4 & J5) – L4(J7 & J8) – L5(J10 & J9) }

G4= { L1(J1 & J3) - L2(J2 & J4) – L3(J5 & J6) – L4(J7 & J8) – L5(J10 & J9) }

G5= { L1(J1 & J3) - L2(J2 & J6) – L3(J4 & J5) – L4(J7 & J8) – L5(J10 & J9) }

G6= { L1(J1 & J3) - L2(J2 & J10) – L3(J4 & J5) – L4(J6 & J9) – L5(J7 & J8) }

G7= { L1(J1 & J3) - L2(J2 & J10) – L3(J4 & J5) – L4(J6 & J7) – L5(J8 & J9) }

G8= { L1(J1 & J10) - L2(J2 & J3) – L3(J4 & J5) – L4(J6 & J8) – L5(J7 & J9) }

G9= { L1(J1 & J10) - L2(J2 & J3) – L3(J4 & J5) – L4(J6 & J9) – L5(J7 & J8) }

G10= { L1(J1 & J4) - L2(J2 & J3) – L3(J5 & J6) – L4(J7 & J8) – L5(J10 & J9) }

G11= { L1(J1 & J6) - L2(J2 & J3) – L3(J4 & J5) – L4(J7 & J8) – L5(J10 & J9) }

Table 8 Lot completion times and makespan for case-V best schedules

Gs	C_{jL1}	C_{jL2}	C_{jL3}	C_{jL4}	C_{jL5}	C_j
G_1	1291	1371	1436	1898	1811	7807
G_2	1291	1371	1780	1898	1467	7807
G_3	1291	1315	1181	1898	2123	7808
G_4	883	1779	1125	1898	2123	7808
G_5	883	1723	1181	1898	2123	7808
G_6	883	2067	1181	1780	1898	7809
G_7	883	2067	1181	1648	2129	7908
G_8	1379	1571	1181	1817	1960	7908
G_9	1379	1571	1181	1780	1898	7809
G_{10}	1093	1571	1125	1898	2123	7810
G_{11}	1037	1571	1181	1898	2123	7810

8. CONCLUSION

The Hybrid Flowshop batch scheduling problem with fixed lot size is discussed in this paper. A heusritic solution suggested forming the lots and group scheduling. The simulation modelling and analysis is used to evaluate the effectiveness of the heuristic. The heuristic is checked at five levels. The generated schedules were validated with simulation. The proposed heuristics yielded the heuristic solution and also some additional schedules are also generated with minimum deviation from the optimal schedules. This facilitate while execution in the real environment. The constructive mathematical model presented for this problem which can be used to solve the problem some other methods in future.

REFERENCES

[1] Mousavi, S. M., I. Mahdavi, J. Rezaeian, and M. Zandieh. "Bi-objective scheduling for re-entrant hybrid flow shop with learning effect and setup times", Scientia Iranica, 1-23 (2017).

[2] R Franklin Issac, R Saravanan, R Pugazhenthi, R Raju, “A Heuristic for Group Scheduling the Multi-stage Hybrid Flow Shop Problems” Bonfring International Journal of Industrial Engineering and Management Science, 6(4) (2016).

[3] P. Vivek, R. Saravanan R. Pugazhenthi and M. Chandrasekaran, “Minimizing Idle Time of Critical Machine in Permutation Flow Environment With Weighted Scheduling”, ARPN Journal of Engineering and Applied Sciences, 11(5), 473-3483 (2016).

[4] Saravanan R. and Dr, Raju R., “Sequencing and scheduling of non-uniform flow pattern in parallel hybrid flow shop”, International Journal of Advanced Manufacturing Technology, Springer, 49 (1-4), 213-225 (2010).

[5] R Maulidya, Suprayogi, R Wangsaputra and A H Halim , ‘Batch Scheduling for Hybrid Assembly differentiation Flow Shop to Minimize Total Actual Flow Time’ IOP Conference Series: Materials Science and Engineering, Volume 319, conference 1 Materials Science and Engineering (2018) 012042

[6] Yi Tan, Lars Mönch, and John W. Fowler. 2018. A hybrid scheduling approach for a two-stage flexible flow shop with batch processing machines. Journal of Scheduling 21, 2 (April 2018), 209-226.

[7] R.Pugazhenthi and M. AnthonyXavior, “A Survey on Occurrence of Critical Machines in a Manufacturing Environment”, Procedia Engineering, Volume 97, 105-114 (2014).

[8] Vivek, P., R. Saravanan, M. Chandrasekaran, and R. Pugazhenthi. "Critical Machine Based Scheduling-A Review." In IOP Conference Series: Materials Science and Engineering, vol. 183, no. 1, p. 012027. IOP Publishing, 2017.

[9] Ming Cheng, Subhash C. Sarin, Two-stage, Multiple-lot, Lot Streaming Problem for a 1 + 2 Hybrid Flow Shop, IFAC Proceedings 46 (9), 448-453 (2013).

[10] Biao Zhang, Quan-ke Pan, Liang Gao, Xin-li Zhang, Hong-yan Sang, Jun-qing Li, An effective modified migrating birds optimization for hybrid flowshop scheduling problem with lot streaming, Applied Soft Computing, 52, 14-27 (2017).

[11] P Vivek, R Saravanan, M Chandrasekaran, R Pugazhenthi, “Heuristic for Critical Machine Based a Lot Streaming for Two-Stage Hybrid Production Environment” IOP Conference Series: Materials Science and Engineering, 183 (1), 12-30 (2017).

[12] Dr. Sridhar K and Prakash T. Lazarus, Experimental Design of Constraint Satisfaction Adaptive Neural Network for Generalized Job-Shop Scheduling, International Journal of Industrial Engineering Research and Development (IJIERD), Volume 5, Issue 3, May - June (2014), pp. 24-30.

[13] Dr. R. Dillibabu and Suresh. K, Development Of Multi-Agent Systems Based Intelligent Fleet Maintenance Scheduling, International Journal of Industrial Engineering Research and Development (IJIERD), Volume 1 Number 1, May - June (2010), pp. 115-126.

[14] Hymavathi Madivada and C.S.P. Rao, A Review On Non Traditional Algorithms For Job Shop Scheduling, International Journal of Production Technology and Management (IJPTM), Volume 3, Issue 1, January-December (2012), pp. 61-77.