# Minimization of Machine Idle Time and Penalty Cost in Flexible Manufacturing System Scheduling

B. Satish Kumar, G. Janardhana Raju, G. RangaJanardhana

*Abstract-This paper address the application of Jaya algorithm to solve Multi objective scheduling problem in Flexible Manufacturing System(FMS) to Minimize the Combined Objective Function(COF) Value. The effectiveness of this algorithm is tested on the problem of 43 jobs processed on 16 machines taken from literature. The MATLAB code is written to find best sequence and Combined Objective Function value by implementing Jaya Algorithm. Results obtained by Jaya Algorithm are compared with different algorithms such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Shortest Processing Time (SPT), Cuckoo Search (CS) and Modified Cuckoos Search (MCS) for the problem considered. It is observed from the results that COF value for the sequence obtained by Jaya Algorithm is better than other algorithms. It is concluded that the Jaya algorithm is best suitable for solving the Scheduling problem considered in Flexible Manufacturing System.*

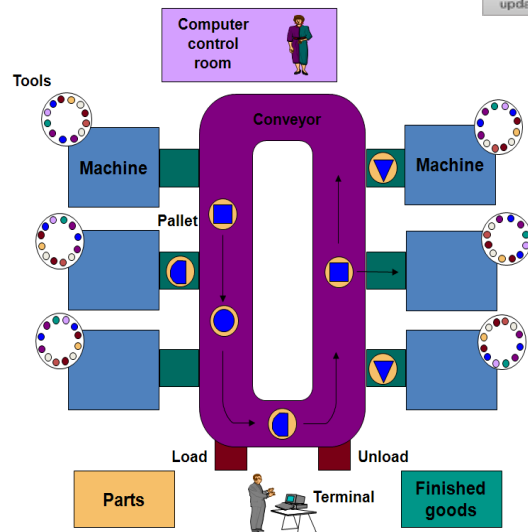*Key Words - Flexible Manufacturing Systems, Combined Objective Function, Jaya Algorithm*

## I. INTRODUCTION

Production scheduling is very much important in today's highly competitive world and fast-changing markets. In Flexible Manufacturing system, scheduling plays a vital role. In FMS, scheduling will be done by considering Single and Multi Objectives. Researchers are trying to find solutions for FMS scheduling problem with desired objectives by developing various algorithms.

In FMS, a group of machines are coordinated and controlled by a common control center. FMS consists of robots, CNC machines and material handling system. Manufacturing of each part requires a specific sequence of operations to be done on specified machines, the parts will move from one cell to another cell by material handling system. After completing the manufacturing of parts inspection will be done at an automatic inspection center and subsequently unloaded from the Flexible Manufacturing System. The Typical layout of Flexible Manufacturing system is shown in Fig. 1.

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**Fig.1. Typical view of FMS**

In FMS, most important objectives are:
- Machine Idle Time Minimization
- Penalty Cost Minimization
- Increasing the Production
- In-process Inventories Minimization
- Setup and Tool Change Time Minimization
- Minimization of Total Elapsed Time

The present work addresses two objectives, i.e., Machine Idle Time Minimization and Penalty Cost Minimization. Equal weightage is given for both the objectives and formulated Combined Objective Function formula.

## II. LITERATURE SURVEY

Effective scheduling is being considered as a primary function to face the competition in the market. Researchers gave importance to the FMS scheduling problem with single and Multi objectives because of global completion in the manufacturing industry.

Sateesh et al. Studied the Different FMS layouts by considering the Different number of AGV's and CART's and Suggested the Suitable Material handling system for a layout at different speeds [1]

Mahesh successfully demonstrated the integration of scheduling with MRP and CRP, to generate a near to optimal production schedule at low cost considering the practical difficulties in a real job shop environment [2]

Kaizhou Gao et al. Applied the Jaya Algorithm for FMS Scheduling to minimize Machine workload. Experiments conducted with real-time data. Results proved that Jaya Algorithm is giving better results than other algorithms [3]

R.Venkat Rao proposed a Jaya algorithm for solving the optimization Problems. This algorithm is applied to the benchmark problem for testing and obtained better Results [4]

Wayan Firdaus Mahmud Used VNS for Solving the two objectives problem in FMS this method is giving the near optimum solution than other methods [6]

Kazim and Syed Mustafa developed codes in C++ for getting an optimum sequence of operation to reduce waiting time of machine and maximize the machine utilization [7]

Burnwal Shashikant applied the Cuckoos search algorithm for scheduling optimization in FMS results found were very effective in comparison with the results obtained by using the other algorithms like GA & PSO [8]

Udhayakumar and Kumanan Used Giffler and Thompson algorithm for FMS scheduling to minimize total processing time the results proved that the PSO algorithm is giving a better solution with reasonable computational time [9]

Deb S and Yang proposed CS to solve the multi objective scheduling problem and it is found that Cuckoos search Algorithm is giving better results than other algorithms [10]. Jerald. J applied the PSO for solving Scheduling Optimization Problem, observed good results [11]

Sankar et al. applied MOGA for Scheduling of 16 machines and 43 jobs problem and observed good results [12].

Satish Kumar et al. applied Jaya Algorithm for solving the Multi objective scheduling problem of 80 parts on 16 machines [13]

**Jaya algorithm**

Jaya algorithm is developed by Dr. R.Venkat Rao in 2015 [4]. Jaya algorithm attempts every time to find the best solution and ignore the worst solution and move forward to find the optimum solution. The main advantage of Jaya algorithm is that it always tries to find an optimum solution and takes less time for iterations. In Jaya algorithm, Let f(x) is the

Objective function to be minimized. At any iteration i, assume that there are 'm' number of design variables, 'n' number of candidate solutions (i.e., population size, k=1,2,…,n). Let the best candidate obtains the best value of f(x) (i.e., f(x) best) in the entire candidate solutions and the worst candidate worst obtains the worst value of f(x) (i.e., f(x) worst) in the entire candidate solutions. Then this value is modified as per the following Eq. (1).

$$X'_{j,k,i} = X_{j,k,i} + r_{1j,i}\left(X_{j,best,i} - \left|X_{j,k,i}\right|\right) - r_{2j,i}\left(X_{j,worst,i} - \left|X_{j,k,i}\right|\right) \text{--------}$$
(1)

All the accepted function values at the end of iteration are maintained, and these values become the input to the next iteration. Flow chart of the Jaya algorithm is shown in Fig: 2. it always tries to get closer to the optimum solution and tries to avoid the worst possible solution.

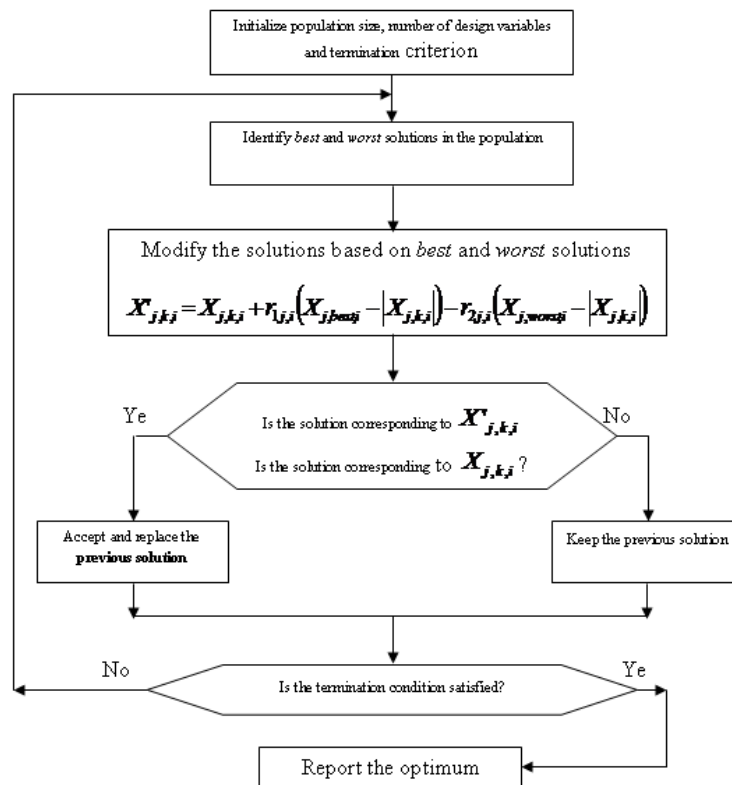### III.    PROPOSED METHODOLOGY FOR SCHEDULING OPTIMIZATION OF FMS



**Fig: 2 Flow Chart of the Jaya Algorithm**

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**Problem Definition**

Table-1 provides all the information required for individual jobs and is taken from the papers of Jerald [11] and Sankar et al. [12]

**The assumptions in this work are as follows:**

• There are 43 varieties of products to be manufactured

• Each type/variety part processing sequence, batch size, deadline, and penalty cost well defined

• Each processing step has a processing time with a specific machine.

• Forty-three jobs have been taken, and processing sequence on different machines has been decided.

• One job will be processed on one machine at a time based the sequence of parts as per the required batch size, no other job will be there at that machine, but other jobs may be processed on other machines if the machines are available.

Combined Objective Function

$$COF = W_1 \times \left( \frac{PC}{MP} \right) + W_2 \times \left( \frac{X_q}{TE} \right) \dots \qquad .(2)$$

$W_1$=Weightage factor for minimizing the total penalty cost

$W_2$=Weight age factor for minimizing the total elapsed time

PC= Total penalty cost

MP=Maximum Penalty

$X_q$=Total machines idle time

TE=Total Elapsed time.

Table -1: Details of processing times, sequence, due dates & batch size etc.

| Part No. | M/c no. (processing time in min) | Due date (days) | Batch size | Penalty cost (Rs./unit/day) |
|---|---|---|---|---|
| 1 | 6 (1)–7 (1)–8 (1)–10 (2) | 17 | 150 | 1 |
| 2 | 2 (1)–6 (1)–8 (2)–9 (2)–14 (4)–16 (2) | 17 | 200 | 1 |
| 3 | 8 (1)–11 (3)–13 (4) | 14 | 800 | 1 |
| 4 | 9 (4) | 26 | 700 | 2 |
| 5 | 4 (5)–5 (3)–15 (4) | 11 | 150 | 1 |
| 6 | 6 (5)–14 (1) | 16 | 700 | 1 |
| 7 | 3 (5)–6 (3)–16 (5) | 26 | 250 | 2 |
| 8 | 5 (4)–6 (5)–8 (1) | 26 | 850 | 2 |
| 9 | 4 (1)–5 (5)–8 (1)–11 (1) | 1 | 100 | 0 |
| 10 | 2 (2)–9 (1)–16 (4) | 20 | 150 | 2 |
| 11 | 8 (4)–12 (2) | 1 | 250 | 1 |
| 12 | 6 (2)–8 (4)–10 (1) | 19 | 1000 | 3 |
| 13 | 6 (1)–7 (5)–10 (4) | 25 | 700 | 4 |
| 14 | 4 (2)–5 (3)–6 (2)–15 (2) | 22 | 1000 | 4 |
| 15 | 5 (4)–8 (3) | 15 | 700 | 5 |
| 16 | 5 (3) | 27 | 750 | 3 |
| 17 | 3 (1)–6 (4)–14 (1) | 20 | 650 | 4 |
| 18 | 9 (2)–16 (3) | 24 | 250 | 5 |
| 19 | 4 (1)–5 (5)–6 (2)–8 (2)–15 (5) | 5 | 450 | 1 |
| 20 | 8 (2)–11 (4) | 11 | 50 | 5 |
| 21 | 4 (5)–5 (5)–8 (4)–15 (4) | 16 | 850 | 3 |
| 22 | 12 (5) | 24 | 200 | 5 |
| 23 | 4 (2)–5 (1)–6 (5)–8 (4) | 14 | 50 | 4 |
| 24 | 8 (4)–11 (4)–12 (5)–13 (4) | 7 | 200 | 5 |
| 25 | 7 (3)–10 (2) | 24 | 350 | 1 |
| 26 | 10 (2) | 27 | 450 | 0 |
| 27 | 8 (5)–11 (5)–12 (4) | 22 | 400 | 1 |
| 28 | 2 (1)–8 (1)–9 (2) | 3 | 950 | 5 |
| 29 | 4 (1)–5 (5) | 7 | 700 | 1 |
| 30 | 11 (3)–12 (5) | 18 | 1000 | 1 |
| 31 | 8 (2)–10 (2) | 2 | 800 | 2 |
| 32 | 2 (3)–6 (4)–9 (3) | 15 | 800 | 1 |
| 33 | 5 (4)–6 (5)–15 (3) | 27 | 500 | 4 |
| 34 | 3 (2)–6 (2) | 12 | 300 | 4 |

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| 35 | 3 (4)–14 (1) | 9 | 900 | 2 |
| 36 | 3 (2) | 20 | 700 | 2 |
| 37 | 1 (5)–2 (2)–6 (3)–8 (3)–9 (2)–16 (4) | 22 | 250 | 4 |
| 38 | 2 (4)–8 (3)–9 (2)–16 (5) | 8 | 50 | 1 |
| 39 | 6 (5)–10 (5) | 9 | 500 | 1 |
| 40 | 2 (2)–6 (4)–9 (4) | 7 | 250 | 5 |
| 41 | 5 (1)–8 (2)–15 (1) | 22 | 800 | 4 |
| 42 | 2 (5)–6 (4)–9 (3)–16 (1) | 19 | 400 | 2 |
| 43 | 1 (3)–5 (2)–6 (2)–8 (2)–15 (3) | 15 | 550 | 3 |

**Jaya Algorithm for FMS scheduling Problem**

The steps in the implementation of Jaya Algorithm are

1. One Excel file is prepared where each part job, its processing time in each machine and due date, penalty cost, and batch size are put in various columns. Mat lab can load this file during coding.

2. Then Code written for Mat lab to calculate COF value by using Equation-2 for different possible sequences

3. In this Mat lab code, Jaya algorithm is incorporated to find the best sequence which gives the best COF Value. This Mat Lab program runs as per the steps mentioned in flow chart of Jaya Algorithm.

4. Mat lab Program was run for 100 iterations and obtained better sequence and COF Value.

## IV. RESULTS

The MAT Lab program has run for 10 iterations, 20 Iterations,30 Iterations,50 iterations, 60 iterations, 70 iterations and finally for 100 iterations. After 50 iterations, program is giving the same sequence and COF Value at 60, 70 and 100 iterations. For best sequence we have got COF value =0.1311. COF values obtained by other researchers using different algorithms are tabulated in Table-2 and compared. Results obtained by different algorithms and sequences are shown in Fig 3. Results show that Jaya Algorithm is giving better COF value.

**Table- 2: COF values obtained by different Algorithms**

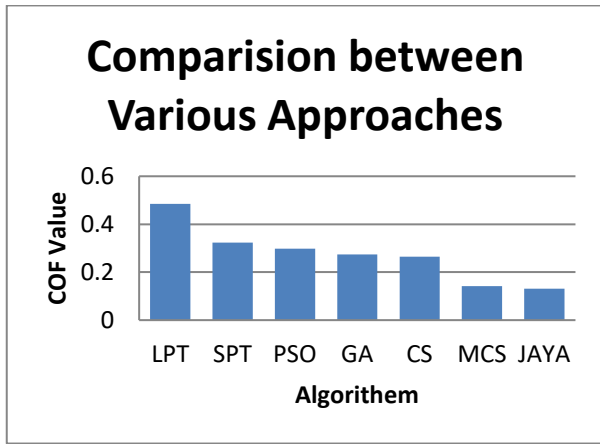| Algorithm/ Method | Sequence | COF Value |
|---|---|---|
| SPT[12] | 20,23,38,1,9,26,22,10,34,18,36,11,25,5,16,2,40,4,41,31,7,24,28 28, 17,6,29,35,37,15,39,42,12,27,33,3,43,19,13,32,30,8,14,21 | 0.324 |
| LPT[12] | 21,14,8,30,32,12,13,19,43,3,33,27,42,39,15,37,35,29,6,17,28, 24,7,31,41,4,40,2,16,5,25,11,36,18,34,10,22,26,9,1,38,23,20 | 0.485 |
| PSO[11] | 27,30,38,10,18,15,34,42,5,33,8,37,23,25,9,2,35,43,20,6,4,36 19,17,24,39,31,12,28,32,26,16,14,22,3,1,11,41,29,40,21,13,7 | 0.2983 |
| GA[12] | 21,28,16,42,39,25,5,23,22,35,36,37,15,1,2,8,4,3,40,20,31,11, 14,30,27,43,17,10,7,26,33,18,29,8,41,32,13,12,24,6,19,38,34 | 0.274 |
| CS[8] | 8,14,28,31,3,42,26,33,22,20,5,24,12,41,18,7,10,19,23,38,4,35, 40,37,21,15,17,39,6,2,34,1,29,27,16,36,30,25,32,13,43,11,9 | 0.2646 |
| MCS | 19,21,28,31,32,24,30,3,39,11,14,15,41,12,13,17,16,33,35,8,43,4, 36,18,40,34,22,37,42,6,29,7,27,25,10,20,2,23,1,5,38,9,26 | 0.1419 |
| JAYA | 10,3,8,11,32,28,43,36,12,19,22,2,1,5,4,21,6,33,29,26,37,7,9,13, 31,39,15,25,23,34,16,18,24,30,35,38,40,17,14,41,20,42,27 | 0.1311 |

**Fig: 3 Comparison of COF value obtained with Various Approaches for Multi Objective Function**

## V.    CONCLUSIONS

In the present work, we are tried to find a better sequence by using the different algorithms to reduce the COF value. It is observed that Jaya algorithm is giving the better Combined Objective Function value than SPT, PSO, CS, GA & MCS. In the future, we are planning to apply the same algorithm for a bigger size problem and Combined Objective Function consisting of three objectives.

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