ISSN (ONLINE): 2349-7084
GLOBAL IMPACT FACTOR 0.238
ISRA JIF 0.351

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 4, APRIL 2015, PP 264-269

Multi Objective Scheduling of Jobs in Flexible Manufacturing System Using Metaheuristic Approaches with Inclusion of Simulation Modeling

A.V. S. SREEDHAR KUMAR [1], V. VEERANNA [2], B. DURGAPRASAD [3]

[1] *Professor, Department of Mechanical Engineering, Balaji institute of engineering and Management Studies, Nellore, Andhra Pradesh, India. Email ID: avs.phd@gmail.com*

[2] *Professor & Dean, Department of Mechanical Engineering, Brundavan Institute of Technology & Science, Kurnool, Andhra Pradesh, India.*

[3] *Professor, Department of Mechanical Engineering, JNTUA college of Engineering, Anantapur, Andhra Pradesh, India.*

Abstract: Manufacturing industries play a vital role in defining the growth and development of a nation. More often than not the health of manufacturing industries is a direct reflection on the economic health and prosperity of a nation. The viability and profitability of any industry depends on how easily and quickly the industry is adapting itself to changes in demand. To adapt quickly to the changes an industry must be lean, flexible and should be capable of utilizing the existing resources to optimum. Optimum utilization of resources can only be possible if there is a proper scheduling system in place. The main objective of this paper is to study the scheduling problems in FMS environment with primary emphasis on metaheuristic approaches and also describes the development of a simulation model for production planning personnel to carry out optimization of scheduling in FMS environment. To illustrate the study in detail, a flexible manufacturing system consisting of 6 Machines producing 3 different parts through 3 different setup of machines and in each setup, 3 alternative routes are considered for this work. The optimization of scheduling process by using Bacterial Foraging optimization algorithm (BFOA, Genetic algorithm (GA) and Differential Evolution (DE) and choose the best for the scenario. In order to impress upon the industry management to take proper decision about the significance of the proposed changes, the best setup and schedule as suggested by metaheuristic approach has been modeled by using the Promodel software and simulated for various runs.

Index Terms*:* Flexible Manufacturing System (FMS), Scheduling, Promodel simulation software, Genetic Algorithm, Differential evolution, Bacterial Foraging Optimization Algorithm (BFOA)

————————————— ◆ ————————————

1. INTRODUCTION

Scheduling of FMS system has remained an active area of research right from the inception of FMS systems. FMS scheduling is acknowledged as one of the most difficult NP-hard problems [1]. "If there are n jobs and m machines the number of theoretically possible solutions is equal to (n!)m. Among these solutions an optimal solution, for a certain measure of performance, can be found after checking all the possible alternatives. But the checking of all the possible alternatives can only be possible in small size problems. For example, a very simple problem of 6 jobs and 6 machines will give 1.3931406 x1016 numbers of alternatives [2]. Above discussions point to the fact that there is a need to find a scheduling solution that are optimum as well as feasible and metaheuristic methods for solving NP-hard optimization problems have become a very useful tool for optimization. Simulation enables more efficient planning of the whole manufacturing process, easy modifications before implementation on the real system.by performing simulation on the model the optimum number of operations are assigned to machines based on selected performance measures [3].

2. MODEL FORMULATION

2.1 Description of the parts

In this work, the participant industry is M/S NELCAST LTD, Gudur which manufactures various Ductile iron castings, Grey iron castings e.t.c. These products cater to the global automotive, construction, mining, railways and general engineering sectors. in this study 3 different wheel hubs are so chosen that they are having similar in their functions with differences in their physical and geometrical properties[4]. Three different parts are being machined on 6 different machines. The parts are manufactured in batches depending on the demand [5,6]. The machining requirements for the parts are Facing, Turning, Drilling, Boring and Tapping. The details of machining operations of Part–1(Wheel hub1), Part-2(Wheel hub 2) and Part-3(Wheel hub 3) as shown in Figure 1(a), (b) & (c) respectively) and also given in Table -1. Processing times of each operation and operation sequence with machine description to perform those operations are described in the Table-2

The setup details can be loaded from an Excel work book in which various details like processing operations, machines involved and routes of each setup, timing of each operation, machine sequence, and batch size, due date, penalty, and reward points are stored. In this work, the orders of CBS (Constant Batch Size) and VBS (Variable Batch Size) are considered to calculate the setup timing of the jobs and operation timing of the jobs are given in Table 6.

(a) (b) (c)

Figure-1: (a) Graphical model of part-1(P1): (b) Graphical model of part-2(P2): Wheel hub 2 and (c) Graphical model of part-3(P3): Wheel hub 3

2.2 Description of the machines in the proposed setup 1:

In this setup 1 consist of the following four machines (M) to accomplish the desired machining operations, on all the three parts.
Machine1-M1(Turning centre-1):Machine2-M2- (Horizontal Machining Center): Machine 3-M3-(Turning centre -2): Machine 4-M4- (Vertical Machining Center).The operations performed, at all the machines via different routes, for each Part in the existing setup-1 are given in the Table-3.

2.3 Description of the machines for proposed setup-2 & setup-3:

Proposed SETUP-2 consists of the following machines
Machine 1-M1 (Turning centre-1): Machine 2 -M2- (Horizontal Machining Center): Machine 3-M3-(Turning centre -2): Machine 4-M4-(CNC Drilling Machine-1)
Proposed SETUP-3 consists of following machines
Machine 1-M1 (Turning centre-1): Machine 2 -M2-(CNC Drilling Machine 1): Machine 3-M3-(Turning centre -2): Machine 4-M4-(CNC Drilling Machine 2)
The operations performed at all the machines via different routes for each part in proposed setup-2 are given in Table-4 and in setup-3 are given in Table-5

3. METHODOLOGIES APPLIED IN THE RESEARCH WORK

The approaches are shared out as follows:

3.1 Genetic Algorithms (GA): parameters used in optimization are as mentioned below [7, 8]

Population Size: 100, Scaling Function: Rank
Selection Function: Uniform, Elite Count: 2
Cross over fraction: 0.8
Mutation Function: Adaptive Feasible
Cross Over Function: Single Point.
Generations: 1000, Time limit: -Inf

3.2 Differential Evolution (DE): The parameter settings for DE is as follows [9]

Population Size: 100; Maximum Iterations: 1000
Mutation Factor: 0.5, Crossover Rate: 0.9

3.3 Bacteria Foraging Optimization Algorithm:

The parameters of algorithm used in this research work are as mentioned below [10].
The number of bacteria: 20
Number of chemo tactic steps: 10
Limit length of a swim: 4
The number of reproduction steps: 4
The number of elimination-dispersal events: 2
The number of bacteria reproductions: 2
The probability that each bacterium will be eliminated / dispersed: 2

4. PROBLEM STATEMENT AND SIMULATION MODEL

Optimal scheduling of the FMS by minimizing the Combined Objective Function (COF), that is, by minimizing the total machining time and minimizing the total penalty cost for realization of the part. However, for computational convenience, the machine setup timings are assumed to be same for all the machines.

Table -1: Processing operations for Part-1, Part-2 & Part-3

S No	Operations For Part-1	Operations For Part-2	Operations For Part-3
1	Facing of face 1 (F11)	Facing of face 1 (F21)	Facing of face 1 (F31)
2	Turning of surface 1 (T11)	Turning of surface 1 (T21)	Turning of surface 1 (T31)
3	Drilling of hole 1 (D11)	Drilling of hole 1 (D21)	Drilling of hole 1 D31)
4	Boring (B11)	Boring (B21)	Drilling of hole 2 (D32)
5	Facing of face 2 (F12)	Facing of face 2 (F22)	Facing of face 2 (F32)
6	Turning of surface 2 (T12)	Turning of surface 2 (T22)	Turning of surface 2 (T32)
7	Tapping (TH11)	Tapping (TH21)	Tapping (TH31)
8	Drilling of hole 2 (D12)	Drilling of hole 2 (D22)	Drilling of hole 3 (D33)
9	---	---	Tapping (TH32)

4.1 Modeling and Simulation of Using Promodel Software

ProModel being an accepted and one of the most widely used manufacturing simulation software has reputation and means to stand as a testimony for correctness and validity of our research work. The ProModel based model is used to simulate the manufacturing setup and results analysed.[11]. This setup as suggested by BFOA was modeled in Promodel and simulated for various runs and different conditions. The snapshot of the model designed in promodel is given in the Figure 2.

ISSN (ONLINE): 2349-7084

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 4, APRIL 2015, PP 264-269

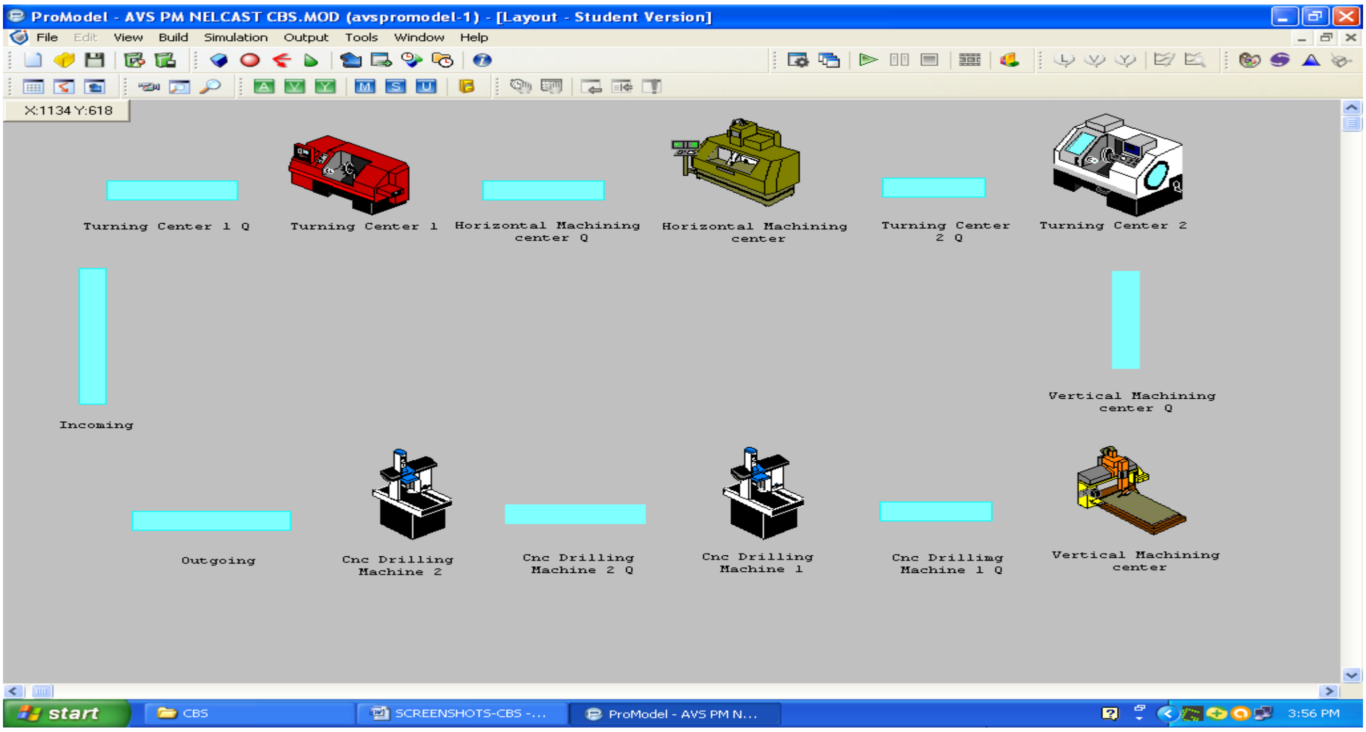

Figure-2 The screen shot of the model designed by using ProModel

Table- 2: Processing times (in seconds) and operation sequence with machine details, L-1: Turning centre-1; L-2: Turning centre -2; C-1: Horizontal Machining Center; C-2: Vertical Machining Center; D-1: CNC Drilling Machine-1; D-2: CNC Drilling Machine-2.

Parts	Operations	L-1	L-2	C-1	C-2	D-1	D-2
P1	F_{11}	60	50	X	X	X	X
	F_{12}	X	40	30	X	X	X
	T_{11}	90	70	X	X	X	X
	T_{12}	X	50	40	X	X	X
	D_{11}	X	X	60	80	100	120
	D_{12}	X	X	30	40	70	75
	B_{11}	X	X	80	60	110	100
	TH_{11}	X	120	100	80	X	X
P 2	F_{21}	40	50	X	X	X	X
	F_{22}	X	80	50	X	X	X
	T_{21}	40	30	X	X	X	X
	T_{22}	X	120	70	X	X	X
	B_{21}	X	X	50	60	100	90
	D_{21}	X	X	40	50	70	80
	D_{22}	X	X	45	50	70	80
	TH_{21}	X	120	110	90	X	X
P 3	F_{31}	40	45	X	X	X	X
	F_{32}	X	90	60	X	X	X
	T_{31}	120	100	X	X	X	X
	T_{32}	X	110	70	X	X	X
	D_{31}	X	X	80	60	120	110
	D_{32}	X	X	60	50	85	90
	D_{33}	X	X	30	30	50	55
	TH_{31}	X	110	90	80	X	X
	TH_{32}	X	60	45	40	X	X

ISSN (ONLINE): 2349-7084

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 4, APRIL 2015, PP 264-269

Table -3: Machines on Routes of Setup1

Parts	Routes
Part 1	Route1:M1(F11,T11) → M2(D11,B11) →M3 (F12,T12) →M4 (D12,TH11) Route2:M3(F11,T11) →M4(D11,B11) →M2 (F12,T12,D12) →M3 (TH11) Route3:M1 (F11,T11)→M4 (D11,B11)→M3 (F12,T12) →M4 (D12,TH11)
Part 2	Route1:M1(F21,T21) →M2(D21,B21) →M3(F22,T22) →M4(D22,TH21) Route2:M3(F21,T21) →M4(D21,B21) →M2(F22,T22,D22) →M3 (TH21) Route3:M1(F21,T21) →M4(D21,B21) →M3(F22,T22) →M4 (D22,TH21)
Part3	Route1:M1(F31,T31) M2(D31,D32,TH31) →M3(F32,T32) →M4(D33,TH32) Route2:M3(F31,T31) M4(D31,D32,TH31) →M2(F32,T32,D33) →M3 (TH32) Route3:M1(F31,T31) M4(D31,D32,TH31) →M3(F32,T32) →M4 (D33, TH32)

Table- 4: Machines on Routes of Setup2

Parts	Routes
Part 1	Route1:M1(F11,T11)→M2(D11,B11)→M3 (F12,T12, TH11) →M4 (D12) Route2:M3(F11,T11)→M4(D11,B11)→M2 (F12,T12,D12) →M3 (TH11) Route3:M1(F11,T11)→M2(D11,B11)→M3 (F12,T12,TH11,) →M2(D12)
Part 2	Route1:M1(F21,T21)→M2(D21,B21) →M3(F22,T22 , Th21) →M4(D22) Route2:M3(F21,T21)→M4(D21,B21) →M2(F22,T22,D22)→M3 (TH21) Route3:M1(F21,T21)→M2(D21,B21) →M3(F22,T22, Th21) →M2 (D22)
Part 3	Route1:M1(F31,T31)→M2(D32,D33)→M3 (F32,T32, TH31,TH32) →M4(D31) Route2:M3(F31,T31,F32,T32)→M4(D31,D32) →M2(D33) →M3 (TH31,TH32) Route3:M1(F31,T31) → M2(D32,D33,) →M3 (F32,T32, TH31, Th32) →M2 (D31)

Table 5 Machines on Routes Of Setup-3

Parts	Routes
Part 1	Route1:M1(F11,T11)→M2(D11,B11)→M3 (F12,T12, Th11) →M4 (D12) Route2:M3(F11,T11)→M4(D11,B11)→M2 (D12)→M3 (F12,T12,TH11) Route3:M1(F11,T11)→M2(D11,B11)→M3 (F12,T12, Th11) →M2 (D12)
Part 2	Route1:M1(F21,T21)→M2(D21,B21) →M3(F22,T22,Th21) →M4(D22) Route2:M3(F21,T21)→M4(D21,B21) →M2(D22) →M3 (TH21, F22,T22) Route3:M1(F21,T21)→M2(D21,B21) →M3(F22,T22, Th21) →M2 (D22)
Part 3	Route1:M1(F31,T31)→M2(D31,D32,) →M3(F32,T32,TH31, Th32,)→M4(D33) Route2:M3(F31,T31,F32,T32)→M4(D31,D32) →M2(D33)→M3(TH31,TH32) Route3:M1(F31,T31)→M2(D31,D32,)→ M3(F32,T32,TH31, TH32)→M2(D33)

4.2 Objective Function

Mathematical model of Combined Objective Function

Minimize

$COF=W_1\times [(X_p/MPP)/ (X_r/MPR)] +(W_2)\times(X_q/TE)$ (1)

$$X_P = \sum_i (CT_i - DD_i) * UPC_i * BS_i \quad (2)$$

$$X_r = \sum_i (DD_i - CT_i) * URC_i * BS_i \quad (3)$$

$$X_q = \sum_j MD_j \quad (4)$$

$$MD_j = TE - \sum_i PT_{ji} \quad (5)$$

Where,
W1=Weight Factor for Customer Satisfaction
W2=Weight Factor for Machine Utilization
Xp=Total Penalty cost Incurred
Xr=Total Reward points Incurred,
CTi=Completion time for job i
DDi=Due Date For job i,
UPCi=Unit Penalty Cost for job i ,
URCi=Unit Reward Point for job i
MPP=Maximum Permissible Penalty
MPR=Maximum Permissible Reward
BSi=Batch Size of job i
Xq=Total Machine Down Time,
TE=Total Elapsed Time
PTji=Processing time of ith job with jth machine
j= Machine Number, i= Job number

In the computation the weight factors W1and W2 are assumed to be equal and hence, W1 = 0.5 and W2 = 0.5. However, different ratios can be applied to them according to the demand of business situation

Table-6: VBS in No's, CBS in No's, Due date in days, Penalty cost in Rs/unit/day and Reward point in Rs/unit/day

Parts	VBS	CBS	Due Date	Penalty cost	Reward point
P1	135	100	12	5	6
P 2	140	100	10	3	2
P3	150	100	11	4	5

5. RESULTS AND COMPARISON

In the present work, The summary of the results are obtained for VBS and CBS problems and best set of results are shown in Tables 8 and 9 and graphical analysis is shown in the figures 3 and 4. From the results it is observed that among the three approaches used in this work, the schedule obtained by the BFOA algorithm gives the optimum COF value, i.e., minimum total penalty cost and minimum machine idleness. A comparison of total machining time obtained from three Meta heuristic approaches is presented in Figure 3 & 4. It is also noticed that the best optimum results are obtained with proposed setups 2 & 3 when compared with setup1. Desired setups for producing of part-1, part 2 & part 3 are given by BFOA is best in

ISSN (ONLINE): 2349-7084

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 4, APRIL 2015, PP 264-269

both VBS and CBS. The machine utilization percentage for the machine as suggested is given Table 7. The results of the research shows that 4 machines such as Turning centre 1, Turning centre 2, Horizontal machine centre and Vertical machine centre as described above are sufficient for the job under study. There is high redundancy in the case of drilling machines. From the results, it can also be observed that for the proposed setup the machine utilization time is very high and the idle time is minimum.

6. CONCLUSIONS

In this paper an attempt has been made to analyze the suitability of new metaheuristic approaches like DE & BFOA for optimizing scheduling of FMS setup problems by comparing the same with GA approach. It can be observed from the results that, the Bacterial Foraging Optimization Algorithm results in better convergence most of the time. Results of the simulation through ProModel are consistent with that of the results expected out of optimization through the designed tool. Such validation plays a crucial role in enabling the management to take a positive decision in accepting the suggestions of this proposed work.

Table-7: Comparison of % utilization of different machines suggested by ProModel software

Machines	% Utilization of Machines for CBS	% Utilization of Machines for VBS
Turning centre-1	17	18.51
HMC	16	28.24
Turning centre-2	36.39	36.39
VMC	6.61	13.22
Drilling machine -1	23.45	0
Drilling machine -2	0	0

Table -8: Desired setup (DS), Desired route (DR) and Total machining time in seconds (TMT) for parts as suggested by the Metaheuristic methods for CBS

Scheduling Technique	Parts	Desired setup	Desired route	Total machining time	With reward			Without reward		
					Idleness value	Penalty value	COF value	Idleness value	Penalty value	COF value
BFOA	P1	1	1	50000	0.2453	0.0293	0.1373	0.4906	0.4215	0.4581
	P2	2	2	47000						
	P3	3	3	70000						
DE	P1	2	2	55000	0.2812	0.2492	0.2652	0.5624	0.4550	0.5077
	P2	2	1	56000						
	P3	1	1	66000						
GA	P1	3	3	64000	0.268	0.265	0.2605	0.536	0.4818	0.5089
	P2	1	3	53000						
	P3	1	1	66000						

Table -9: Desired setup (DS), Desired route (DR) and Total machining time (TMT) for parts as suggested by the Metaheuristic methods for VBS

Scheduling Technique	Parts	Desired setup	Desired route	Total machining time in sec.	With reward			Without reward		
					Idleness value	Penalty value	COF value	Idleness value	Penalty value	COF value
BFOA	P1	1	1	67500	0.350	0.0449	0.1975	0.7001	0.6528	0.6764
	P2	1	2	66500						
	P3	2	3	105000						
DE	P1	2	3	71550	0.3771	0.3794	0.3782	0.7541	0.6898	0.7220
	P2	1	1	74200						
	P3	1	1	99000						
GA	P1	2	3	71550	0.3771	0.3895	0.3833	0.7541	0.7082	0.7312
	P2	2	3	74900						
	P3	2	1	111000						

ISSN (ONLINE): 2349-7084

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 4, APRIL 2015, PP 264-269

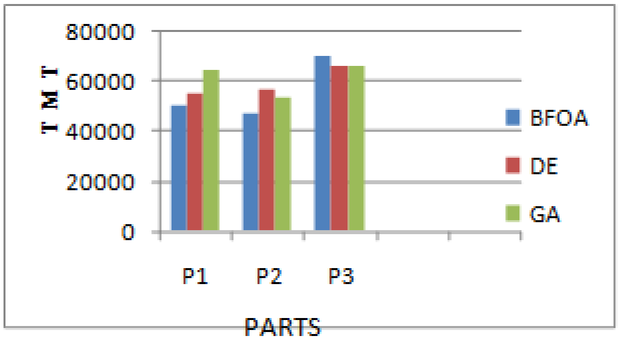

Figure-3: Comparision of Total machining time (TMT) for Part 1, Part2 & Part3 with Metaheuristic approaches for CBS

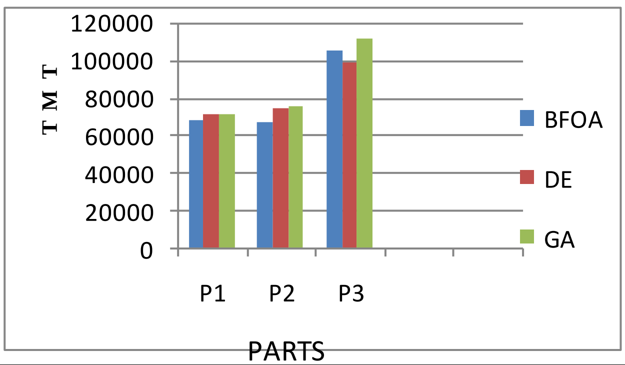

Figure-4: Comparision of Total machining time (TMT) for Part 1, Part2 & Part3 with Metaheuristic approaches for VBS

REFERENCES

[1] Chuda Basnet, Joe H. Mize,(1995) "Scheduling and Control of Flexible Manufacturing System: A Critical Review". Journal of Intelligent Manufacturing, Special issue on Production Planning and Scheduling, pp 1-41.

[2] T. Karthikeyan,(2003) "Modelling and Analysis of Scheduling in Computer Integrated Manufacturing", Ph.D Dissertation, Bharathidasan University, Tiruchirappalli,

[3] Veeranna. V, Dattatreyasarma. B, Chakraverti. G(2006), Optimization of FMS Layout by Heuristic Procedure with Scheduling as a Constraint"Industrial Engg.Journal, 25-28

[4] B.B.Choudhury, D.Mishra and B.B.Biswal, (2009). Appropriate Evolutionary Algorithm for Scheduling in FMS, IEEE Xplore

[5] Jerald.J, Asokan.P, Prabaharan.G, Saravanan.R (2005). "Scheduling optimisation of flexible manufacturing systems using particle swarm optimisation algorithm"*Int J Adv Manuf Technol,* 25: 964–97

[6] Choudhury .B.B, Biswal .B.B, (2007). "Task assignment and scheduling in a constrained manufacturing system using GA" *International Journal Agile System & Management.*

[7] Guohui Zhang, Liang Gao , Yang Shi (2011)An effective genetic algorithm for the flexible job-shop scheduling problem Expert Systems with Applications- 3563–3573

[8] Lee C.Y, Piramuthu S, Tsai Y.K,(1997) "Job shop scheduling with a Genetic algorithm and machine learning" International Journal of production research, vol 4 pp 48-56.

[9] Dervi_s Karabo_GA, Sel_cuk ¨Okdem, (2004). "A Simple and Global Optimization Algorithm for Engineering Problems: Differential Evolution Algorithm" Turk J Elec Engin Vol.12, No.1

[10] Tai-Chen Chen, Pei-Wei Tsai, Shu-Chuan Chu*, and Jeng-Shyang Pan (2007). "A Novel Optimization Approach: Bacterial-GA Foraging "ICICIC '07, IEEE Computer Society, Washington, DC, USA © ISBN:0-7695-2882-1

[11] Suresh Kumar N & Sridharan R,(2009)" Simulation modeling and analysis of part and tool flow control decisions in a flexible manufacturing system" Robotics and Computer-Integrated Manufacturing 25, Elsevier, pp 829–838

BIOGRAPHIES

Mr.A.V.S.Sreedhar kumar did his Masters degree in Manufacturing technology from National Institute of technical teachers training, Chandigarh, in collaboration with Thapar university in the year 2002.He is perusing Ph.D at JNTU, Anantapur, A.P, INDIA. Presently he is a Professor and HOD in Mechanical engineering Department at Balaji institute of engineering and management studies, Nellore, Andhra Pradesh, India. He has published 8 papers in International journals and conferences. He has 16 years of teaching experience and 8 years in industry. His area of research is in FMS, Optimization Techniques and Scheduling Problems e.t.c.,

Dr.V.Veeranna did his Masters degree in Manufacturing technology from National Institute of technology, Tiruchirapalli ,India in the year 1996 and subsequently completed PhD in the area of FMS layout from JNTU, Anantapur ,A.P,INDIA. In the year 2005. Presently he is a Professor and HOD in Mechanical engineering Department at Brundavan Institute of Technology & Science, Kurnool, A.P, India.He has published more than 50 papers at National and International level journals and conferences.

Dr.B.Durga Prasad, Ph.D is working as Professor and HOD in Mechanical engineering Department at JNTU, Anantapur, A.P, INDIA. He has 22 years of teaching experience. He has published more than 50 papers at National and International level journals and more than 40 papers in National and International level conferences. His area of research is in IC Engines, Thermal Engineering and Flexible manufacturing systems.

.