OPTIMUM DESIGN OF LOOP LAYOUT IN FLEXIBLE MANUFACTURING SYSTEM–AN APPROACH OF METAHEURISTICS

[1]K. Mallikarjuna, [2]V. Veeranna and [3]K. Hema Chandra Reddy
[1]Assistant Professor, Dept of Mech. Engg., Ballari Institute of Technology & Management, Bellary, Karnataka, India
[2]Dean, BITS Kurnool, India
[3]Registrar, JNTU, Anantapur, India

ABSTRACT

FMS's is indeed a very promising technology as they provide flexibility, which is essential for many manufacturing companies. FMS can yield a number of dissimilar jobs simultaneously. Each part requires different operations in a certain sequence and workstations can typically perform a variety of operations. A point to be noted here is each variety would be with low volume of production. This paper speaks about multi-objective optimization related to FMS scheduling which act as a constraint in configuring the loop layout in optimum manner by various Meta-heuristics like GA, SA etc. The first objective is concern with flexible batch scheduling problem (FBSP). The next objective is focus on design of loop layout from which optimum machine sequence with minimum total transportation cost is determined. In this paper the authors made an attempt to consider machine arrangements in an optimum sequence with flexible batch scheduling as constraints in an FMS. The various loop layout problems are tested for enactment of objective function with respect to computational time and number of iterations involved in GA and SA. The results of the different optimization algorithms are compared with existing results and conclusions are depicted.

KEYWORDS - *Flexible Manufacturing systems, loop layout, Multi-objective, Genetic Algorithm (GA), Simulated Annealing (SA), Transportation Cost.*

I. INTRODUCTION

With the advent of technology, the market for manufactured products is becoming increasingly international. Manufacturing has thus become highly competitive and companies have had to focus their resources, capabilities, and energies on building a sustainable competitive advantage. Flexible Manufacturing System [**1**] combines collection of machines tools which are termed as numerical control machines that can arbitrarily process a cluster of jobs, taking automated material management and workstation control to balance resource exploitation over which the system can accept automatically to variation in jobs manufacture, amalgams and stages of yield. The objective of FMS is flexibility in production without compromising the quality of products. Flexibility can mean future cost avoidance.

Material handling is important, yet sometimes it is an overlooked aspect of automation. The main function of an MHS is to supply the true materials at the exact locations and at the right time, the cost of material handling has high priority in total cost of production. It means handling cost is equal to **2/3** of the total manufacturing cost [**2**]. This fraction varies depending on type and quantity of production and the degree of automation in the material handling function. Finally Material handling plays an important role in FMS.

The FMS layout involves allocating diverse reserve for attaining full competence. The arrangement has an influence on the make span and cost [**3**] which should be determined in the inception of the FMS [**4**]. In practice most commonly used type of FMS layouts [**5**] are

1) Line or single row layout.
2) Loop layout.
3) Stepladder layout.
4) U-shaped layout.

Among the above layouts, this paper focus on Loop layout design with integrated scheduling using GA and SA.

This paper in specific addresses the multi-objective optimization related to FMS scheduling in loop layout, initially discussing the various layouts with its basic concepts followed by literature review IN section 2, further the description of the problem is done in the section 3 that is multi objective mathematical modeling, objective functions, further proposed methodology is discussed in the section 4 highlighting the GA and SA, followed by configuration of loop layout, data set details for loop layout with FBSP were summarized in the sections 5,6 respectively. The next part is the results and discussions which are dealt in brief and authenticated with relevant graphs. Finally the paper is concluded with remarks based on the results and discussions.

II. LITERATURE SURVEY

During former epoch, FMS layout design with integrate scheduling has got extra emphasis since of its prominence from both hypothetical and real-world points of sight. Early investigation was intended mainly on the origination and explanation of the problem as the mathematical model; such as branch and bound method and dynamic programming [**6**], but these approaches can only be useful for small problems. Heuristic methods can solve the small problem and also combinatorial optimization problems. The heuristic methods are usually computationally efficient, but easily trap into local optimal solution and no assurance that they will catch optimal solutions. Recently, meta-heuristic been applied, such as tabu search, simulated annealing, genetic algorithm and ant colony optimization. Kun Zheng , Dunbing Tang [**7**] discussed the behavior of traffic for the design and realization of multi-AGV system. R. M. satish kumar and P. Ashokan [**4**] introduced an ACO algorithm for the layout design with integrated scheduling by applying priority dispatching rules using Giffler and Thompson [**4**] algorithm. J. Jerald and R. saravnan [8] presented a paper related to adaptive genetic algorithm applied to scheduling of parts and automated guided vehicles in an FMS. They focused on large variety problem [**16** machines and **43** parts] and combined objective function.

Apinanthana Udomsakdigool, Voratas Khachitvichyanukul [**10]** presented the ant algorithm for solving the multi-objective JSP. The algorithm is tested on several benchmark problems and finally concluded that proposed algorithm is able to find the competitive solutions. AyoubInsa Corréa, André Langevin, Louis-Martin Rousseau**[11]** They proposed a hybrid method designed to solve a problem of dispatching and conflict free routing of automated guided vehicles (AGVs) in a flexible manufacturing system by decomposition method to solve a difficult combinatorial integrated scheduling and conflict free routing problem. Nidhish Mathew Nidhiry, Dr. R. Saravanan **[12]** multiple objectives, i.e., minimizing the idle time of the machine and minimizing the total penalty cost for not meeting the deadline concurrently**.** They considered 16 CNC Machine tools for processing 43 varieties of products for meeting required objectives using various meta-heuristics. V. P. Eswaramurthy, A. Tamilarasi **[13].** They presented an application of the global optimization technique called tabu search that is combined with ant colony optimization technique to solve the job shop scheduling problems and performance of the algorithm is tested using well known benchmark problems and also compared with other algorithms in the literature. Yuvraj Gajpal, Chandrasekharan Rajendran.[**14]** developed new ant-colony algorithm (NACO) to solve the flow shop scheduling problem. The objective is to minimize the completion-time variance of jobs. Two existing ant-colony algorithms and the proposed ant-colony algorithm have been compared with an existing heuristic for scheduling with the objective of minimizing the completion-time variance of jobs. Bhatwadekar S.G., and Khire M.Y.**[15]** verified the statistical performance of GA in scheduling and found that the selection of appropriate representation scheme and the selection operator can help in obtaining a near-optimal solution. Mohammad Ranjbar & MojtabaNajafianRazavi [**16**] proposed a new method to synchronously make the arrangementand planning decisions in a job shop situation. A. Noorul Haq T. Karthikeyan M. Dinesh [**17**] addressed the integrated scheduling of FMS, namely, the production scheduling conforming to the MHS scheduling. Samer Hanoun and Saeid Nahava[18], proposed an effective greedy heuristic to minimize the material waste and developed a simulated annealing (SA) algorithm to minimize the total tardiness time**.**

III. PROBLEM DESCRIPTION

- The problem formulation procedure adopted by Hongbo Liu and Ajith Abraham [9] has been used in this research work. We focus on design of loop layout in flexible manufacturing system with [FJSP] job shop scheduling flexible problem as constraint with the following parameters.
- Jobs $J=\{j_1,j_2,\ldots\ldots\ldots\ldots j_n\}$ /batches $B=\{B_1,B_2,\ldots\ldots\ldots\ldots\ldots B_n\}$is a set of n jobs /n batches to be scheduled respectively. Each job J_i consists of a predetermined sequence of operations. $O_{i,j}$ is the operation j of J_i.
- Machines $M=\{M_1,M_2,\ldots\ldots\ldots\ldots\ldots M_m\}$ is a set of m machines
- Slots $S=\{ S1,S2,S3\ldots\ldots\ldots S_m\}$ is a set of N fixed slots

3.1 Multi Objective Mathematical Model

In this section, we introduce the multi objective function and use it to solve the flexible batch scheduling problems which are integrated with loop layout pattern design leads to minimize the make span and to obtain an optimal layout plan for the machines by minimizing the total transportation cost increased in the system.

3.1.1 Notations

The notations which are used to develop a mathematical model of the design of loop layout are defined and interpreted as follows.

i	–	part type index i=1,2,3,……,n
j	–	Process index $j= 1,2,3,\ldots.., n_i$
k	–	Machine index k=1,2,3,……,m
n	–	Number of batches / job
m	–	Number of machines
S_{maxi}	–	Make span of system maximum completion time
$s_{n,m}$	–	Make span of system
$S_{i,j,k}$	–	Partial make span without predecessors
$s_{i,j+1,k}$	–	Enhanced make span with predecessors
$T_{i,j}$	–	The duration (processing time) of operation j of job i
$T_{i,j+1}$	–	The duration of operation j =1of job i
X	-	Corresponding Lay out
M	–	Total number of machines contained in the manufacturing system
m_i	–	Machine in slot n_1
m_j	–	Machine in slot n_N
N	–	Number of slots
$MH_{m1,m2}$	–	Material handling cost between machines m_1 and m_2 (m_1 m_2 = 1,2,3,…….,M)
$RD_{n1,n2}$	–	Rectangular distance between machinery locations n_1 and n_2 (n_1 n_2 = 1,2,3,……N)

$MF_{m1,m2}$ – Amount of material flow among machines m_1 and m_2 (m_1 m_2 = 1,2,3,….M)
LOC_{mi} – Loading cost from loading station to machines
$ULOC_{mi}$ – Unloading cost from unloading station to machines

IV. OBJECTIVE FUNCTIONS

Minimize Make Span $F(S_{maxi})$

Minimize, $F(S_{max}) = S_{n,m}$

Sub to

$S_{i,j,k} \le S_{i,j+1,k} - T_{i,j+1}$, j=1, 2, 3…p-1

$S_{i,j,k} \ge 0$, j = 1, 2, 3 …n

Minimize Total Transportation Cost (Z)

Z=

$$\left[\sum_{m_i=1}^{M} \sum_{m_j=1}^{M} \left(MF_{m1m2} * MH_{m1m2} * RD_{n1n2} \right) + LOC_{mi} + ULOC_{mj} \right]$$

Sub to

$$\sum_{mi=1}^{M} X_{mimj} = 1$$ if machine m_i is at assigned to slot N

= 0 otherwise

$$\sum_{mj=1}^{M} X_{mimj} = 1$$ if machine m_j is at assigned to slot N

= 0 otherwise

$X_{mimj} \in \{0,1\}$, mi, mj = 1,2,…………..N

V. PROPOSED METHODOLOGY

The general explanation of the suggested procedures is shared out as follows.

5.1 Genetic Algorithm

Genetic algorithms are recognized to be capable for overall optimizing. Though, they are not sound fit to accomplish exceptionally adjusted local searches and are liable to converge in advance earlier the best solution has been found. The genetic algorithm is a vigorous technique, based on the natural selection and genetic production mechanism. It processes a group or population of possible solutions within a search space. The search is probability guided and stochastic, rather than deterministic or random searching, which distinguish it from traditional methods. GAs employs the vocabulary taken from the world of genetics itself, and as a result solutions refer to organisms (genotypes) of a population.

5.2 Simulated Annealing Algorithm

One of the commonly used Trajectory based algorithms is the Simulated Annealing (SA).SA is an optimization algorithm that is not fool by false minima and is easy to implement. Simulated Annealing (SA) is a genetic probabilistic meta-heuristic for the global optimization problem of applied mathematics, namely locating a good approximation to the global minimum of a given function in large search space. It is used when the search space is discrete. For certain problems, simulated Annealing may be more effective provided when the goal is to find an acceptably good solution in fixed amount of time, rather than the best possible solution. It is a neighborhood search technique that has produced good results for combinatorial problems. Simulated Annealing was first introduced by Kirkpatrick, C.D. Gelett and M.P. Beechi in 1983 and V. Cerny in 1985 to solve, optimization problem. The integral part of an annealing algorithm is its neighborhood generation scheme, on the basis of which different annealing algorithms are developed.

VI. CONFIGURATION OF LOOP LAYOUT

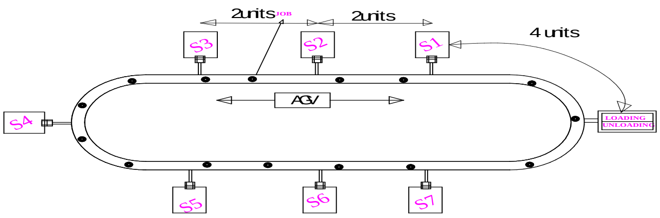

Fig1 Loop Layout Arrangements of FMS for 7 machines

VII. DATA SET DETAILS FOR LOOP LAYOUT WITH FBSP

A Production system with the summary and Batch sizes and the layout of FMS are shown in table1. The data set details of batch varieties and sizes are given in table 2.Let there be parts to be processed on machine for various operations. Which requires the processing time and part routing with the operation sequence of parts which steers the parts on various machines are depicted in table 3 The inter slot between machines i.e., the gap between machines measures in units are given in table 4 The loading/unloading distance matrix specifies distance from machines to load/unload station are shown in table 5, unit material handling cost per unit i.e. the carrying cost of parts between machines is unit cost,. The way of part/batch moves over the machines is given in the same Table 3 as an input for FMS scheduling, where the objective is to arrive at a layout, which determines non-overlapping optimal sequence of machines such that total cost of making required movements is minimized.

7.1 Data set details of Outline of Production system

Table 1: Outline of Production system

Layout Pattern	No. of Machines	No. of batches	No of operations	Load/ Unload stations	No of AGV
Loop	7	7	7	2	1

7.2 Data set details of Batch varieties and sizes (VBS=Variable Batch size)

Table 2: Batch varieties with batch sizes of the Loop layout with 7machines with 7 jobs

Batch number		B1	B2	B3	B4	B5	B6	B7
Batch types	VBS	50	40	60	30	10	25	90

7.3 Data set details of processing time of parts & processing sequence of machines (O= operation, M= Machine number, T= Time in min)

Table 3: Processing time and Process routing matrices for configurations of Loop layout with 7 machines and 7 jobs

Batch	O_1		O_2		O_3		O_4		O_5		O_6		O_7	
	M	T	M	T	M	T	M	T	M	T	M	T	M	T
B_1	2	10	4	12	6	11	5	9	7	7	1	7	3	5
B_2	5	4	4	2	7	4	3	6	1	6	6	5	2	3
B_3	3	7	5	6	1	4	6	9	7	10	2	4	4	3
B_4	2	9	4	2	7	9	6	1	5	9	3	4	1	3
B_5	7	4	6	7	5	6	4	7	2	6	1	10	3	6
B_6	2	9	1	3	6	4	7	3	5	6	4	6	3	6
B_7	4	5	2	4	7	3	6	2	5	7	1	7	3	6

7.4 Data set details of inter-slot distance between machines

Table 4: inter-slot distance matrix for Loop layout with 7 machines

Slots	S_1	S_2	S_3	S_4	S_5	S_6	S_7
S_1	0	2	4	8	12	12	10
S_2	2	0	2	4	8	12	12
S_3	4	2	0	2	4	8	12
S_4	8	4	2	0	2	4	8
S_5	12	8	4	2	0	2	4
S_6	12	12	8	4	2	0	2
S_7	10	12	12	8	4	2	0

7.5 Data set details of Load, Unload Matrices for Loop layout

Table 5: Load, Unload Matrices for Loop layout with 7 machines

Slots	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Load Station	4	6	8	12	10	8	6
Unload Station	6	8	10	12	8	6	4

Transportation Cost per unit distance = 1Rs
Load and Unload cost per unit distance = 1Rs

VIII. RESULTS & DISCUSSIONS

If the standard usual test problems are accessible, the performances of different algorithms can be compared on closely the same set of test problems. For this reason, we chose 4 benchmark problems from Kumanan.et al. [5] (KMN) as the test problems of this study. Kumanan has produced a set of problems with 7 and 9 machines with 2 and 4 jobs. There are four instances for (nxm = 7x7)) totally, there are 4 problem instances

The table 18 shows the results of test problems for variable batch size (VBS) from AKS 1-AKS 4 and is comprehend that, The test problems are solved through the proposed algorithm and the results are compared and found that performance of GA and SA for calculating total transportation cost (TTC) and make span (MAKSP) is varying as per the problem size. By relative analysis, we observed that, solutions are optimized for GA and found that GA affords best solution when compared with SA to all test problems. Further, the computational time of GA is fluctuates as the problem size varies but the computational time of SA is zero for all problems. The table 19 shows the results of test problems for variable batch size (VBS) from AKS 1-AKS 4 and is comprehend that, The test problems are solved through the proposed algorithm and the results are compared and found that performance of GA and SA for calculating Batch waiting time(BWT) and Machine waiting time(MWT) obtained for corresponding problem instances is varying as per the problem size and based on make span(MAKSP) value (i.e., if make span is same for both algorithm ,then waiting times will also be same, vice-versa) . By relative analysis, we observed that, GA shows minimum waiting times when compared with SA to all test problems. Further, the required machine sequences (MASEQ) are depicted in the same table.

Table18: Comparison of arithmetical results of the proposed evolutionary algorithms (for VBS with number of iterations = 100)

Instance -M/c x J/B x Operation	GA			SA		
	MAKSP (min)	TTC(Rs)	CPU (sec)	MAKSP (min)	TTC(Rs)	CPU (sec)
KMN 1-(7x7x7)	3275	4060	15	3390	4960	0
KMN2-(7x7x4)	2190	5900	14	2190	6000	0
KMN 3-(7x7x5)	3080	4130	14	3040	4390	0
KMN 4-(7x7x6)	5220	4100	15	5220	4940	0

Table 19: Comparison of arithmetical results of the proposed evolutionary algorithms for VBS with number of iterations = 100)

Instance (M x J/B x O)	GA			SA		
	BWT (min)	MASEQ	MIT (min)	BWT (min)	MASEQ	MIT (min)
KMN 1 (7x7x7)	B1: 225 B2: 2075 B3: 695 B4: 2165 B5: 2815 B6: 2350 B7: 215	7, 5, 2, 1, 4, 3, 6	M1: 1550 M2: 1500 M3: 1495 M4: 1685 M5: 1195 M6: 1605 M7: 1510	B1: 340 B2: 2190 B3: 810 B4: 2280 B5: 2930 B6: 2465 B7: 330	7, 6, 3, 4, 5, 2, 1	M1: 1665 M2: 1615 M3: 1610 M4: 1800 M5: 1310 M6: 1720 M7: 1625
KMN 2 (7x7x4)	B1: 140 B2: 1550 B3: 690 B4: 1380 B5: 2020 B6: 1715 B7: 390	4, 6, 7, 1, 3, 2, 5	M1: 1875 M2: 975 M3: 960 M4: 210 M5: 1040 M6: 1790 M7: 1035	B1: 140 B2: 1550 B3: 690 B4: 1380 B5: 2020 B6: 1715 B7: 390	4, 3, 1, 7, 6, 2, 5	M1: 1875 M2: 975 M3: 960 M4: 210 M5: 1040 M6: 1790 M7: 1035
KMN 3 (7x7x5)	B1: 1680 B2: 1950 B3: 1470 B4: 2160 B5: 3330 B6: 2580 B7: 1020	5, 2, 6, 3, 4, 1, 7	M1: 3065 M2: 1780 M3: 2900 M4: 2780 M5: 880 M6: 1020 M7: 1765	B1: 1090 B2: 1360 B3: 880 B4: 1570 B5: 2740 B6: 1990 B7: 430	6, 2, 3, 1, 7, 4, 5	M1: 2475 M2: 1190 M3: 2310 M4: 2190 M5: 290 M6: 430 M7: 1175
KMN 4 (7x7x6)	B1: 2420 B2: 3420 B3: 2700 B4: 4380 B5: 4550 B6: 4620 B7: 0	3, 4, 2, 6, 1, 5, 7	M1: 3580 M2: 4065 M3: 2950 M4: 2760 M5: 3745 M6: 2490 M7: 2500	B1: 2420 B2: 3420 B3: 2700 B4: 4380 B5: 4550 B6: 4620 B7: 0	4, 5, 7, 6, 1, 2, 3	M1: 3580 M2: 4065 M3: 2950 M4: 2760 M5: 3745 M6: 2490 M7: 2500

Para - Parameters BWT - Batch waiting time GA - Genetic Algorithm
TTC - total transportation cost MIT - Machine idle time SA - Simulated Annealing
MAKSP- total make span CPU- computational time MASEQ -Machine Sequence

IX. GRAPHS

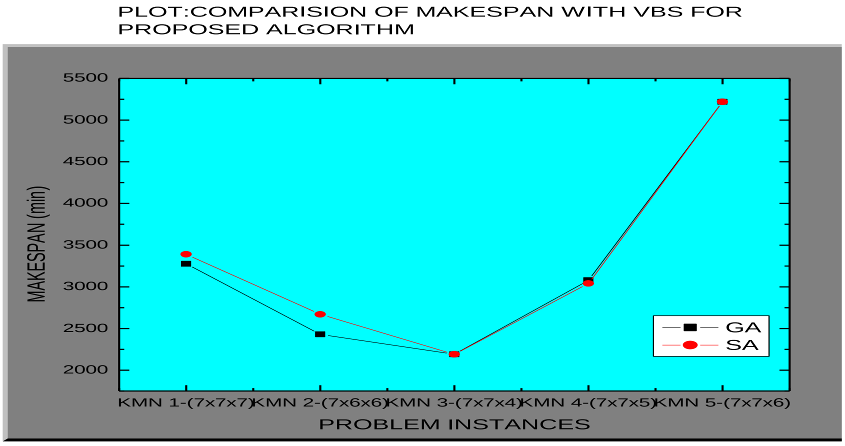

Figure 2 Comparison of make span for VBS by Proposed algorithms

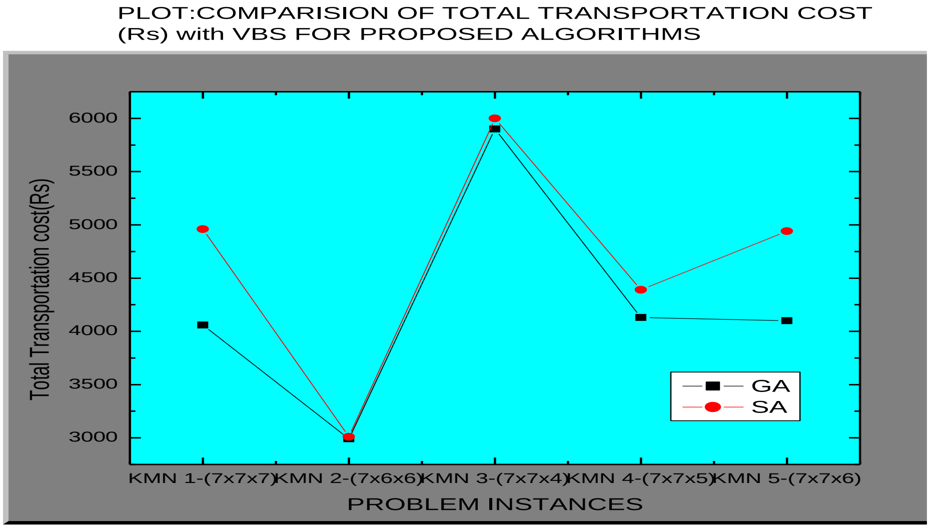

Figure 3 Comparison of total transportation cost for VBS by Proposed algorithms

Comparison of make span for variable batch size (VBS) by the proposed evolutionary algorithms for different problem sizes is depicted in Fig.2. The plot shown in Fig .2 is styled for instance AKS 1- AKS 5. It is observed that, there are moderate variations in results of MAKSP against Problem instances shown in the plot for GA and SA .It is found that, MAKSP is low at small size problems and reaches to high value as problem size increases and also in Fig 2, MAKSP variations are almost closer for both GA & SA. Further, GA curve is fluctuates at lower values than SA curve.
Comparison of total transportation cost by the proposed evolutionary algorithm for variable batch size (VBS) is shown in Fig.3. The plot shown in Fig 3 is styled for instance AKS1- AKS 5. It is observed that, there are moderate variations in results of TTC against Problem instances shown in the plot for GA and SA .It is found that, TTC is low at small size problems and reaches to high value as problem size increases.
Comparison of Batch waiting time (BWT) and Machine waiting time (MWT) for constant batch size (CBS) by the proposed evolutionary algorithms is depicted in Fig.4. The plot shown in Fig.4 is styled for instance which has 7 batches/jobs. It is observed that, BWT & MWT for constant batch size are less for GA when compared with SA.

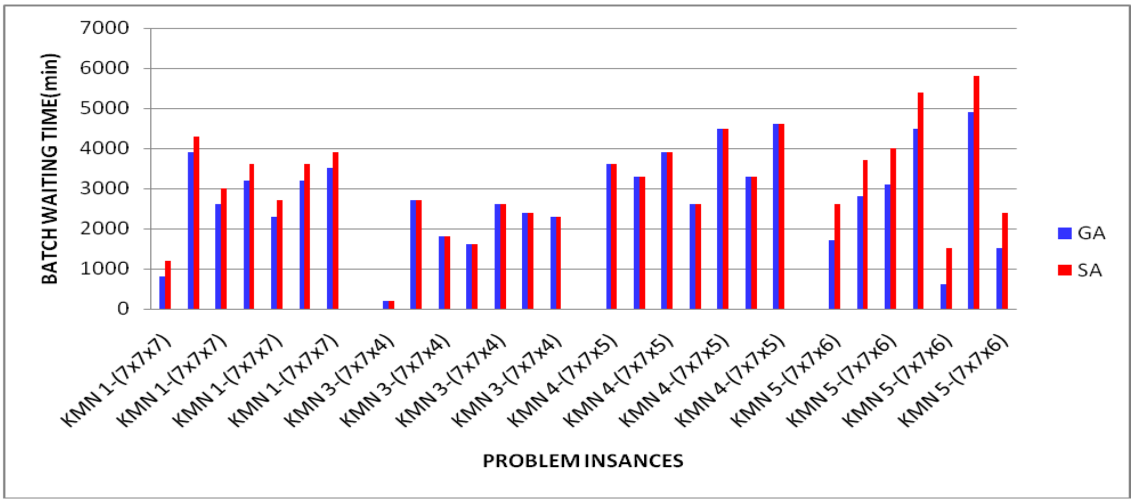

Figure 4: Comparison of proposed algorithm for batch waiting time with constant batch size for the problems with 7 batches.

X. CONCLUSION

Non-traditional optimization algorithms have gained more attention and have been applied to solve combinatorial optimization problems like Loop layout design with integrated scheduling. A necessary code generated and executed in IDE Tool which is an Eclipse based feature for 100 generations by 10 test runs for each problem instance. By means of the proposed objective function, we can find the optimum sequence of machines in the recommended layout of the FMS. The model searches for the optimum layout in FMS and finds itself the optimum numbers of sequences in a Loop. The layout designed here is Loop layout. The model does not limit itself to one solution only, but it can propose several equally good solutions which can differ very much.

From the results, we conclude that Loop layout is optimized using GA is better than SA with constant MHD cost and frequency of trips between machines. The parameter like transportation cost with machine sequences considering scheduling parameters as constraints such as make span (MAKSP) is determined for Loop layout. The experimental results reveal that the proposed Genetic Algorithm is effective and efficient for Loop layout design. From the graph, it is clear that for Loop layout, the total transportation cost is less for lower level problems and reaches to high value as the problem size enhanced. Further, it is conclude that GA provides optimum solutions than SA, but computational time is more than SA.

REFERENCES:

[1].William W.Luggen (1991) flexible manufacturing cells and systems. Prentice-hall, Inc. A division of Simon & Schustes Englewood cliffs, newjersy07632 ISBN 0-13-321738-8.

[2]. Tompkins ja, white ja, bozer ya, janchoco Jmn (2003) facilities planning. 3rdedn, wiley, New York.

[3]. Apple Jm (1977) plant layout and material handling. 3rdedn. The Ronald press co. New York

[4]. R.M. Sateesh kumar, P.Ashokan, S.Kumanan (2008) design of loop layout. Inflexible manufacturing system using non-traditional optimization technique. Int. J.Adv manufacturing technology (2008) 38:594-599.

[5]. MIKELL.P.GROOVER (1992) Automation, Production systems and computer-integrated manufacturing. Prentice-Hall Inc. ISBN-0-87692-618-9.

[6]. Ruey-Mawchen+ and Shin-Tang Lo++ (2006) using ant colony system to solve resource constrained project scheduling problems. Int-J.comp sci & network secu vol.6 No-11, November 2006.

[7]. Kun Zheng , Dunbing Tang (2013) Distributed control of multi-AGV system based on regional control model. Int.J. Prod. Eng. Res. Devel. DOI 10.1007/s11740-013-0456-4.

[8]. Jerald.J, Ashokan.p, Saravanan.R (2006) simultaneous scheduling of parts and AGV in an FMS environment using adaptive genetic algorithm. Int.J.Adv Manufacturing technology (2006) 29:584-589.

[9]. Hongbo Liu, Ajith Abraham, Crina Grosan, Ningning Li, a novel variable neighbourhood particle swarm optimization for multi-objective flexible job-shop scheduling problems. . Digital Information Management, 2007. ICDIM '07. 2nd International Conference on Volume: 1, D O I : 10.1109/4444214 , Page(s): 138 - 145

[10] Apinanthana Udomsakdigool, Voratas Khachitvichyanukul.Ant colony algorithm for multi-criteria job shopscheduling to minimize makespan, mean flow time and mean tardiness,International Journal of Management Science and Engineering Management, 6(2): 117-123, 2011

[11] AyoubInsaCorréa, André Langevin, Louis-Martin Rousseau,Scheduling and routing of AGV: A hybrid approach , Int. J. of Comp & Operations Research 34 (2007) 1688–1707, doi:10.1016/j.cor.2005.07.004.

[12] Nidhish Mathew Nidhiry, Dr. R. Saravanan , Evaluation of Genetic Algorithm Approach for Scheduling Optimization of Flexible Manufacturing Systems International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622,Vol. 2, Issue 4, July-August 2012, pp.437-446.

[13]V. P. Eswaramurthy, A. Tamilarasi.[8], Hybridization of Ant Colony Optimization Strategies in Tabu Search for Solving Job Shop Scheduling Problems. International Journal of Information and Management Sciences20 (2009), 173-189.

[14] Yuvraj Gajpal, Chandrasekharan Rajendran,An ant-colony optimization algorithm for minimizing the completion-time variance of jobs in flowshops, Int. J. Production Economics 101 (2006) 259–272

[15] Bhatwadekar S.G., and Khire M.Y.[10], "Statistical Verification of Performance of GA in scheduling." International journal of Engg Science and Technology vol.2 (12), 2010, 7087-7092

[16] Mohammad Ranjbar & MojtabaNajafianRazavi (2012) , A hybrid metaheuristic for concurrent layout and scheduling problem in a job shop environment, Int J AdvManuf Technol (2012) 62:1249–1260, DOI 10.1007/s00170-011-3859-4.

[17] A. Noorul Haq T. Karthikeyan M. Dinesh, Scheduling decisions in FMS using a heuristic approach, Int J Adv Manuf Technol (2003) 22: 374–379,DOI 10.1007/s00170-002-1474-0
[18] Samer Hanoun and Saeid Nahava, A greedy heuristic and simulated annealing approach for a bicriteria flowshop scheduling problem with precedence constraints a practical manufacturing case, Int J Adv Manuf Technol (2012) 60:1087–1098, DOI 10.1007/s00170-011-3650-6

AUTHORS BIOGRAPHY:

K. Mallikarjuna was born on 21stJan 1978, received his B.Tech. Degree in Mechanical Engineering from S.K. University, Anantapur, India, in 2000 and M.Tech Degree in Machine Design from JNT University, Hyderabad, India, in 2006. He is currently an Associate Professor in the Department of Mechanical Engineering, Ballari Institute of Technology and Management, Bellary, Karnataka. He published 5 research papers in National and International Journals and presented 7 papers in National and International conferences.

V. Veeranna did his A.M.I.E in Mechanical Engineering in 1989, obtained his M.Tech from R.E.C Trichy in Manufacturing Technology in the 1995 and was awarded Ph.D from J.N.T.U Hyderabad for his research work on Flexible Manufacturing Systems in the year 2005. He has been in teaching for the last 24 years out of which he served as the Principal of Engineering Colleges for 4 years. He published 10 research papers in National and International Journals and presented 15 papers in National and International conferences. His areas of research interests include Manufacturing Engineering and Flexible Manufacturing systems. He is a fellow of Institution of Engineers, India.

K. Hemachandra Reddy received the B.E. Degree in Mechanical Engineering from SVU, Tirupati, India. M.Tech in HEAT POWER ENGG and Ph.D. in I.C.Engines from JNT University, Hyderabad. He has more than 23 years of experience in the field of Mechanical Engineering in different cadres and produced 15 Ph.D’s. He has been honored with State Award as the Best Teacher from Government A.P., for the year 2011 and with Broad Outlook Learner Teacher Award (BOLT) by Air-India for the year 2006- 07.He is currently REGISTRAR of JNT University, Anantapur, India. He has to his credit more than 100 research papers presented in conferences and published in journals of national and international repute