AGV's and Machines in Flexible Manufacturing Process

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ABSTRACT

Today Flexible Manufacturing System (FMS) seem to be a very promising technology as they provide a variety of flexibility that is essential for design of planning for simultaneous scheduling of machines and automated guided vehicles (AGVs) to stay competitive in the highly dynamic and changing design environment. A synchronous material transfer is one of the most often phenomenon in most of the FMS. Material transfer between machines is performed by a number of identical automated guided vehicles (AGVs). In the literature reported, the subject of design of planning for simultaneous scheduling of machines and automated guided vehicles (AGVs) using non optimization technique system has generally been set out either as a comparison of various vehicle dispatching rules in relation to a prespecified schedule and on a particular layout [or in relation with the design jobset. Egbelu and Tanchoco evaluated a number of dispatching rules for AGVs via a simulation scheduling model applied to a particular layout. Simultaneous scheduling of machines and automated guided vehicles in FMS becomes difficult due to the sequence dependent nature of travel times for dead heading trips between successive loaded trips of AGVs. The problem is NP hard and is attempted by a heuristic algorithm which considers both machine and vehicle scheduling constraints and determines the starting and completion times of operations for each. The trips between the workstations together with the vehicle assignment with an objective to minimize the makespan, mean makespan, mean tardiness and CPU time. The model of AGV'S studied in this work is different from traditional AGVS. Traditional AGV'S is usually applied in a limited space such as workshops and terminal yards, but in non-traditional AGV system where vehicles are controlled by computer. Unit load and buffer storage are mostly considered in a traditional AGVS. In comparison, this model expands the applications of AGVS, where vehicles are not necessary to be driverless, demand quantity is measured by the unit of weight or volume, buffer storage does not exist in the system.

Keyword: - Flexible Manufacturing System, Simultaneous scheduling, Machines, AGV's, Metaheuristics, Differential Evolution, Simulated Annealing, Tabu Search.

1. SIMULTANEOUS SCHEDULING OF MACHINES AND AGV'S IN FMS: SCHEDULING

The primary goal of design of process planning for simultaneous scheduling of machines and AGV'S using optimization technique is to achieve a high level of productivity and flexibility which can only be done in a fully integrated manufacturing environment. The work machines and automated guided vehicles (AGV) are connected to optimize parts flow and the central control computer which controls material movements and machine flow. An FMS is modelled as a collection of workstations and automated guided vehicles (AGV). In this work process plan is designed to optimize minimum makespan, mean makespan, mean tardiness and CPU time for simultaneous scheduling of machines and AGV's. These are determined using non-traditional optimization techniques using differential evolution (DE), simulated annealing (SA) Algorithm and Tabu search Algorithm. The FMS layout along with the distances between the machines and from the load/unload station are all shown for different problems. The FMS consists of given no. of machines and 2 AGV 's. The job set details are also given. AGV move with a maximum speed of 40 m/min. The travel times are computed and are presented in Table in which the loading and unloading times of the job are included.

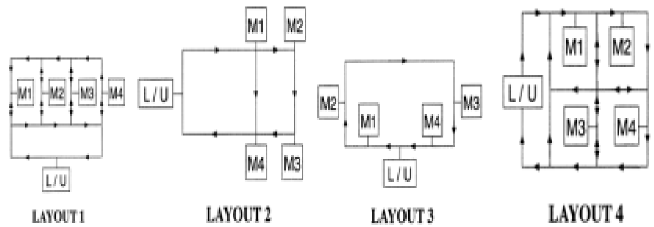

Figure -1 a) FMS layout 1 b) FMS layout 2 c) FMS layout 3 d) FMS layout 4

1.1 Methodology

In this study, a flexible manufacturing system (FMS) in which material transfer between machines is performed by a number of identical automated guided vehicles (AGVs) is considered, and the problem of design of planning for simultaneous scheduling of machines and AGVs using non-traditional optimization technique is addressed. Considered 4 different layouts and 10 job sets consisting of 1- 10 different job sets and operations on machines to be performed. The problem is formulated as a nonlinear mixed integer programming model. Its objective is makespan minimization, mean makespan, mean tardiness and CPU time. The formulation consists of constraint sets of a machine scheduling sub problem and a vehicle scheduling sub problem which interact through a set of differential evolution algorithm and simulated algorithm constraints for the material handling trip starting times. An iterative procedure is developed where, at each iteration, a new machine schedule is generated by a differential evolution algorithm and simulated algorithm procedure.

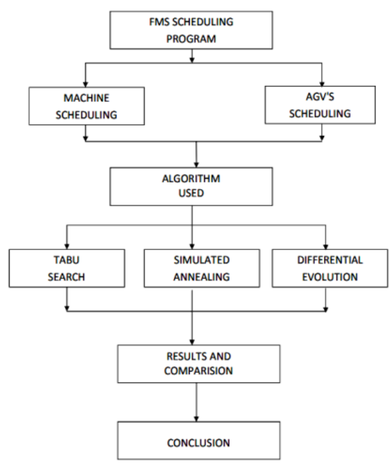

Figure 2: Block Diagram showing different components & Sequence of present work

1.2 Travel Time Matrix

Introduction Time Matrix For all the problems of proposed methods (DE, SA and TS) the Travel time matrix for layout 1, layout 2 layout 3 layout 4 and existing layout which are useful for calculating makespan, mean makespan and tardiness CPU for all layouts, and those values are same for all the problems and it can also be observed that the optimized results obtained for particular problem using travel time matrix, Processing times and Routings for all layouts.

From – To	L/U	M1	M2	M3	M4
L/U	0	6	8	10	12
M1	12	0	6	8	10
M2	10	6	0	6	8
M3	8	8	6	0	6
M4	6	10	8	6	0

Travel Time Matrix for Layout 1

From – To	L/U	M1	M2	M3	M4
L/U	0	4	6	8	6
M1	6	0	2	4	2
M2	8	12	0	2	4
M3	6	10	12	0	2
M4	4	8	10	12	0

Travel Time Matrix for Layout 2

From – To	L/U	M1	M2	M3	M4
L/U	0	2	4	10	12
M1	12	0	2	8	10
M2	10	12	0	6	8
M3	4	6	8	0	2
M4	2	4	6	12	0

Travel Time Matrix for Layout 3

From – To	L/U	M1	M2	M3	M4
L/U	0	4	8	10	14
M1	18	0	4	6	10
M2	20	14	0	8	6
M3	12	8	6	0	6
M4	14	14	12	6	0

Travel Time Matrix for Layout 4

2.PROCESSING TIMES AND ROUTINGS

Processing Time Matrix and Machine Routing are same for all the problems of proposed methods (DE, SA and TS). And those values are same for all the problems and it can be also be seen that the optimized results obtained for particular problem using Processing Time Matrix and Machine Routings of job set 1 to job set 4.

Job No.	M/C Routing		M/C Routing		M/C Routing	
	M/C	PT	M/C	PT	M/C	PT
1	1	8	2	16	4	12
2	1	20	3	10	2	18
3	3	12	4	8	1	15
4	4	14	2	18	-	-_

Processing Time Matrix for Job Set 1

Job No.	M/C Routing		M/C Routing		M/C Routing	
	M/C	PT	M/C	PT	M/C	PT
1	1	10	4	18	-	-
2	2	10	4	18	-	-
3	1	10	3	20	-	-
4	2	10	3	15	-	-

Processing Time Matrix for Job Set 2

Job No.	Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT
1	1	16	3	15	-	-
2	2	18	4	15	-	-
3	1	20	2	10	-	-
4	3	15	4	10	-	-

Processing Time Matrix for Job Set 3

Job No.	Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT
1	4	11	1	10	2	7
2	3	12	2	10	4	8
3	2	7	3	10	1	9
4	2	7	7	8	1	12

Processing Time Matrix for Job Set 4

Job No	Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT
1	1	6	2	12	4	9
2	1	18	3	6	2	15
3	3	9	4	3	1	12
4	4	6	2	15	-	-
5	5	3	1	9	-	-

Processing Time Matrix for Job Set 5

Job No	Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT
1	1	9	2	11	4	7
2	1	19	2	20	4	13
3	2	14	3	20	4	9
4	2	14	3	20	4	9
5	1	11	3	16	4	8
6	1	10	3	12	4	10

Processing Time Matrix for Job Set 6

Job No	Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT
1	1	6	4	6	-	-
2	2	11	4	9	-	-
3	2	9	4	7	-	-
4	3	16	4	7	-	-
5	1	9	3	18	-	-
6	2	13	3	19	4	6
7	1	10	2	9	3	13
8	1	11	2	9	4	8

Processing Time Matrix for Job Set 7

Job No	Machine Routing		Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	2	12	3	21	4	11	4	6
2	2	12	3	21	4	11	-	-
3	2	12	3	21	4	11	-	-
4	2	12	3	21	4	11	-	-
5	1	10	2	14	3	18	4	9
6	1	10	2	14	3	18	4	9

Processing Time Matrix for Job Set 8

Job No	Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT
1	3	9	1	12	2	9
2	3	16	2	11	4	9
3	1	21	2	18	4	7
4	2	20	3	22	4	11
5	3	14	1	16	2	13

Processing Time Matrix for Job Set 9

Job No	Machine Routing		Machine Routing		Machine Routing		Machine Routing	
	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	11	3	19	2	16	4	13
2	2	21	3	16	4	14	-	-
3	3	8	2	10	1	14	4	9
4	2	13	3	20	4	10	-	-
5	1	9	3	16	4	18	-	-
6	2	19	1	21	3	11	4	15

Processing Time Matrix for Job Set 10

2.1 Results for t/p>0.25

Parallel scheduling of machines, tools and automated guided vehicles (AGVs) in flexible manufacturing systems for solving FMS scheduling Problem in minimizing makespan, mean tardiness, mean flow time total empty trip travel time of AGVs are described. It is observed in literature that scheduling problems involving tools and AGVs are cumbersome NP hard complex problems and hence effective Metaheuristics are needed to yield outcome. Here scheduling is designed with 10 different job sets with different processing sequences, and process times. By these combinations with different layouts considered totally 16 bench mark problem instances. Existing layout is also compared with four layouts on the basis of same parameter for all problem instances 2 AGV's are considered for shipping materials from one machine to another as per precedence constraints.

The digits that follow PI indicate the layout and E indicate Existing layout and job set. Here considered two conditions defined as (t/p ratio) (i) Total travel time matrix(t) of each layout to the processing time (p) of concern job set should be greater than 0.25 (t/p>0.25) (ii) Total travel time matrix(t) of each layout to the processing time (p) of concern job set should be less than 0.25(t/p<0.25). Therefore, the results obtained for t/p ratio greater than 0.25.

No. Of Generation	Layout No.	Mean Makespan (min)		
		DE	SA	TS
	Layout1	105	116	112
	Layout2	86	121	124
	Layout3	102	111.5	118
10	Layout4	89	118.5	123
	Layout1	101	105	108
	Layout2	74	102	104
	Layout3	84.5	109.5	115
15	Layout4	81	103.5	116

Comparison of mean makespan

No. Of Generation	Layout No.	Mean Tardiness (min)		
		DE	SA	TS
	Layout1	4.6	12.6	14.8
	Layout2	4.8	12.1	13.5
	Layout3	5.5	11.25	15.6
10	Layout4	5	13.75	16.4
	Layout1	4.5	12.2	13.8
	Layout2	3.6	11.6	13.1
	Layout3	2.75	4.75	6.2
15	Layout4	4.5	11.25	9.25

Comparison of mean tardiness

No. Of Generation	Layout No.	CPU Time		
		Mean Makespan (min)		
		DE	SA	TS
10	Layout1	04 min	08 sec	06sec
	Layout2			
	Layout3			
	Layout4			
15	Layout1	30 min	09 sec	08sec
	Layout2			
	Layout3			
	Layout4			

Comparison of CPU time

Problem No	STW	UGA	AGA	SGA	SFHA	DE	SA	TS
PI11	96	96	96	96	90	**88**	**96**	**98**
PI12	105	104	102	100	96	**94**	**102**	**104**
PI13	115	105	99	99	105	**98**	**103**	**105**
PI14	118	116	112	112	119	**112**	**120**	**119**
PI15	89	87	87	87	87	**87**	**90**	**90**
PI16	120	121	118	118	118	**118**	**121**	**120**
PI17	119	118	115	111	128	**120**	**124**	**129**
PI18	161	152	161	161	137	**129**	**140**	**148**
PI19	120	117	118	116	111	**108**	**122**	**116**
PI110	153	150	147	147	148	**146**	**152**	**150**

Literature review and proposed methods

Layout No.	STW	UGA	AGA	PGA	SFHA	**DE**	**SA**	**TS**
Layout1	119	117	115	114	113	**110**	**117**	**118**
Layout2	99.6	96.4	96	96	92	**80.5**	**88.9**	**90**
Layout3	103	101	100	100	93	**83.6**	**91.6**	**103**
Layout4	128	125	123	123	127	**124**	**124**	**125**

Literature Comparison layout of makespan

Layout No.	STW	UGA	AGA	PGA	SFHA	**DE**	**SA**	**TS**
Layout1	8.3	7.8	8.4	8.8	8.5	**7.6**	**8.8**	**8.8**
Layout2	9.8	9.5	10.5	9.6	7.9	**7.6**	**10.5**	**11.5**
Layout3	10.2	9.5	10.4	10	7.3	**7.8**	**10**	**10.5**
Layout4	8.6	8.1	8.3	8.1	8.6	**8.5**	**8.6**	**8.6**

Comparison of mean tardiness

2.2 Results for t/p<0.25

No. Of Generation	Layout No.	Mean Makespan (min)		
		DE	SA	TS
10	Layout1	288.2	306	329.7
	Layout2	289.2	306.6	337.5
	Layout3	302.2	314.1	341.1
	Layout4	296.3	314.8	335.2
15	Layout1	279.2	302	327.7
	Layout2	282.8	302	335.5
	Layout3	296.2	310.1	339.1
	Layout4	294.3	310.1	335.2

Comparison of mean makespan

No. Of Generation	Layout No.	Mean Tardiness		
		DE	SA	TS
10	Layout1	21.4	25.2	25.6
	Layout2	22.4	25.3	25.8
	Layout3	23.2	26.4	27
	Layout4	18.3	22.7	23.6
15	Layout1	20.5	24.6	24.8
	Layout2	21.3	24.6	25.3
	Layout3	22.8	25.8	26.5
	Layout4	18.1	22	22.5

Comparison of mean tardiness

No. Of Generation	Layout No.	CPU Time		
		DE	SA	TS
10	Layout1 Layout2 Layout3 Layout4	06 min	09 sec	7sec
15	Layout1 Layout2 Layout3 Layout4	35min	13 sec	11 sec

Comparison of CPU time

Problem No	STW	UGA	AGA	SGA	SFHA	DE	SA	TS
PI110	126	126	126	126	119	**97**	**154**	**163**
PI120	148	148	148	148	128	**129**	**164**	**168**
PI130	150	148	148	148	128	**102**	**148**	**154**
PI140	121	119	119	119	112	**110**	**138**	**152**
PI150	102	102	102	102	100	**102**	**124**	**146**
PI160	186	186	186	186	143	**129**	**169**	**188**
PI170	137	137	137	137	137	**121**	**142**	**157**
PI180	292	271	292	292	247	**243**	**276**	**292**
PI190	176	176	176	176	185	**171**	**171**	**177**
PI1100	238	236	238	238	123	**128**	**184**	**190**

Comparison of makespan with literature

Layout No.	STW	UGA	AGA	PGA	SFHA	DE	SA	TS
Layout1	167	164	167	167	145	**138**	**164**	**167**
Layout2	164	162z	163	163	144	**141**	**163**	**164**
Layout3	165	163	164	164	145	**143**	**163**	**165**
Layout4	190	187	188	188	169	**160**	**188**	**187**

Comparison of mean makespan with literature

Layout No.	**STW**	**UGA**	**AGA**	**PGA**	**SFHA**	**DE**	**SA**	**TS**
Layout1	22.4	21.3	22.4	22.4	15.4	**15.2**	**22.4**	**22.4**
Layout2	22.4	21.2	22.5	22.5	15.1	**14.9**	**22.5**	**22.5**
Layout3	22.5	21.5	22.5	22.5	15.6	**15.3**	**19.5**	**22.5**
Layout4	18.75	18.58	19.5	19.5	15.25	**15.25**	**21.5**	**19.5**

Comparison of mean tardiness

3. PLOTS FOR t/p>0.25

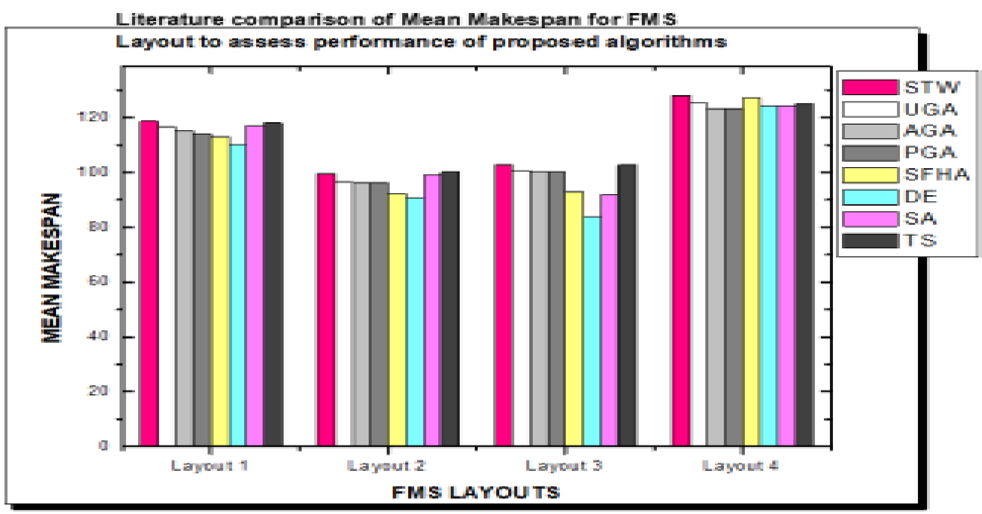

Chart -1: Plot for Literature comparison of Mean Makespan

4. CONCLUSIONS

Simultaneous scheduling of machines and AGV's in an FMS environment has an important issue considered in this research for diminishing the makespan for different objectives which leads to improve in through input. Considered different standard problems gathered from literature for measuring the effectiveness of proposed methodology. Here Flexibility in manufacturing system plays key role in improving the utilization of resources for yielding good products in terms of part varieties and part mix which will enhance production volume. Therefore, it is treated as good substitute to move against the threats from other manufacturing competitors globally and can be implemented effectively. It is known that in an FMS very complex issues may come out from scheduling only because it involves material handling and assigning other systems rather than machines which leads to further complexity.

i.In this work of getting optimum results of scheduling of machines and AGVs, elapsed time minimize and total time also reduced all the time results of differential evolution are better than other proposed methods and methods available in literature.

ii. Optimal and better solutions can be determined within fewer iterations of differential evolution when compared with another algorithm

iii. It is concluded that mean makespan and mean tardiness values of layouts 2 are better in DE when compared to other algorithms but for layout 1 and 3 and 4 marginally inferior. Layout 2 is suggestive for feasible manufacturing.

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