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A hybrid approach to solve simultaneous scheduling problems in FMS

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Abstract: **Flexible Manufacturing System (FMS) executed number of advantages as far as decreasing cost, increased utilization of machine, condensed work-in-process levels, and so on. Notwithstanding, there are various issues faced during the life cycle of an FMS. In particular, the scheduling task, Scheduling of an FMS is a intricate problem to solve subsequently it has made enthusiasm among the scientists. Despite the fact that FMS scheduling problem was viewed before, scheduling of material handling system was not considered effectively. It is observed from the literature that for solving the simultaneous scheduling problems in FMS most of the researchers implemented Genetic algorithm (GA). In addition to Genetic Algorithm (GA) metaheuristics like Differential Evolution (DE), have been proved to be very effective in global optimization. In the current work a new hybrid metaheuristic (HDE) is proposed by amalgamating two metaheuristics namely Differential Evolution and Sheep Flock Heredity Algorithm (SFHA) for solving the simultaneous scheduling problems. The performance of the proposed algorithm HDE is assessed by solving 82 bench mark problems considered from the literature. The coding was done using java programing language.**

Keywords - AGVs, FMS, Differential Evolution, Metaheuristic algorithms, Operational Completion Time (makespan), Sheep Flock Heredity Algorithm.

I. INTRODUCTION

A Flexible Manufacturing System (FMS) is a profoundly automated manufacturing system appropriate for the concurrent creation of a wide assortment of part types in low to mid volume amounts at a low cost while keeping up a high caliber of the completed items. FMS executed number of advantages regarding decreasing cost - expanded use of machine-- condensed work-in – process levels and so forth. Anyway there are various issues faced during the life cycle of an FMS and these functions are characterized into: design- planning- scheduling- and controlling. Specifically the scheduling task and controlling issues during the manufacturing operation are of significance owing to the dynamic nature of the FMS in respect of flexible parts- tools- assignments. In FMS scheduling decisions that should be made incorporate not only sequencing of jobs on machines but also the routing of the jobs through the system. Apart from the machines different resources in the system like Automated Guided Vehicle (AGV) and Automated Storage/Retrieval System (AS/RS) must also taken in consideration. The AGVs effectiveness relies upon vehicle management system.

II. LITERATURE REVIEW

Bilge and Ulusoy [1] addressed scheduling of machines and material handling system in an FMS simultaneously. A Sliding time window approach is used to solve the problem. The procedure is tested on 90 example problems. Abdelmaguid et al.[2] developed a new hybrid genetic algorithm/heuristic for solving simultaneous scheduling of machines and identical AGVs. The algorithm is implemented to a set of 82 bench mark problems considered from literature and the comparison of the results indicates the superior performance with the developed coding. Reddy and Rao [3] made an attempt to schedule machines and vehicles in FMS using evolutionary algorithms with minimization of makespan- mean flow time and mean tardiness as an criterion. The proposed hybrid GA algorithm problems yielded better results when compared with other algorithms. Gnanavel babu et al. [4] proposed a new metaheuristic Differential Evolution algorithm for solving simultaneous scheduling of machines and two identical AGVs in FMS. Algorithm is tested on problems presented by various researchers and the obtained makespan is compared. Anandaraman et al. [5] addressed the scheduling of machines an AGV and two robots in a FMS with objectives to minimize the makespan, mean flow time and mean tardiness. The scheduling optimization is done using sheep flock heredity algorithm(SHFA) and Artificial immune system and the results obtained using the two algorithms are compared. Nouri et al. [6] proposed hybrid metaheuristic based on clustered Holonic Multiagent model. Computational results are presented using three sets of bench mark instances. Md Kamal et al. [7] presented a comprehensive literature review of the flexible job shop scheduling problem solved using GA. The survey is further extended by the inclusion of the hybrid GA techniques. Lundy et al.[8] proposes a model and proves that the algorithm converges with probability arbitrarily close to 1. Finally described a version of the algorithm that terminates in polynomial time and allows a good deal of practical confidence in the solution. Storn [9] proposes a new heuristic approach for minimizing possibility non linear and non differentiable continous space functions. Which converges faster and with more certainity than both adaptive Simulated annealing and the Annealed Nelder & Mead approach. Hyunchul [10] proposed anew evolutionary computation algorithm based on sheep flock heredity for solving large scale scheduling problem. This algorithm is able to find better solution than those of the simple genetic algorithm through thermal generator maintenance scheduling examples. Nageswara rao et al.[11] implemented three priority rules in solving simultaneous scheduling problems and the results are analyzed. Prakash babu et al.[12] implemented NEH heuristic to solve simultaneous scheduling problems in FMS. The heuristic is tested on 82 bench mark problems considered from literature. Prakash babu et al.[13] proposed new Fuzzy heuristic for solving simultaneous scheduling problem to minimize makespan. The algorithm is tested on 82 bench mark problems considered from literature. Prakash babu et al. [14] proposed a new hybrid metaheuristic JAYA (HJAYA) algorithm for solving simultaneous scheduling problems. The algorithm is implemented to 82 bench mark problems considered from the literature and results are compared. Prakash babu et al. [15] proposed a new hybrid metaheuristic hybrid Teaching Learning based optimization (HTLBO) algorithm for solving simultaneous scheduling problems. The algorithm is implemented to 82 bench mark problems considered from the literature and results are compared. Prakash babu et al. [16] implemented Differential evolution to solve simultaneous scheduling problems in FMS with minimization of makespan as criterion. It is tested on 82 bench mark problems considered from the literature and the results obtained are compared with the previously proposed algorithms.

III. PROBLEM DESCRIPTION

Bilge and Ulusoy (1995) proposed a numerical example for simultaneous scheduling of machines and AGVs in FMS environment which incorporates four layouts- ten jobsets process times and travel time information as an input.

IV. OBJECTIVE FUNCTION

The objective is to minimize the makespan, referred to as the maximum completion time of all the jobs
Operation completion time $O_{ij} = T_{ij} + P_{ij}$
Where T_{ij} and P_{ij} are travel time, processing time for j^{th} operation of the i^{th} job, respectively.

$$Job\ Completion\ time\ C_i = \sum_{i=1}^{n} O_{ij}$$

Makespan = Max $(C_1, C_2, C_3,\ldots\ldots\ldots\ldots C_n)$

V. OPTIMIZATION PARAMETERS CONSIDERED

Population Size = Double the no of operations
Iterations completed = 1000

VI. PROCEDURE FOR SIMULTANEOUS SCHEDULING OF MACHINES AND AGV,S

Jobs are scheduled based on the operation sequence derived by the algorithms. The problem considered needs scheduling of material handling system along with that of machines. The steps implemented to obtain the makespan value for a given sequence of operations is indicated in the below flow chart.

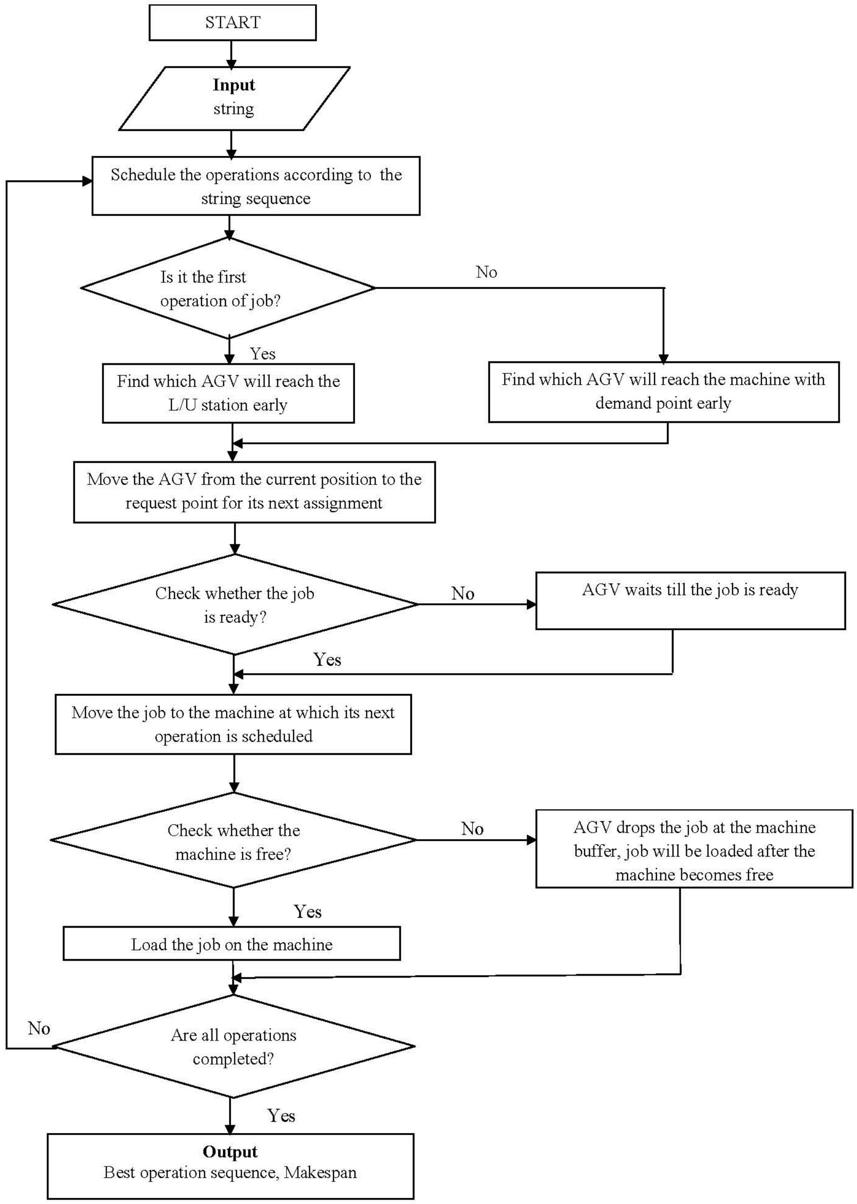

Fig1: Simultaneous scheduling of machines and AGV,s

VII. PROPOSED ALGORITHM

Since amalgamating of any two algorithms yields superior results, Differential Evolution is amalgamated with Sheep Flock Heredity Algorithm. Differential Evolution (DE) Algorithm was developed by Storn and Price (1995). The main working principle behind DE is the calculation of vector differences between randomly chosen population members. Sheep Flock Heredity Algorithm (SFHA) was developed by Hyunchul Kim (2001).This algorithm is based on the genetic inheritance. The cross over and mutation concepts hired from SFHA are incorporated into DE and the resulting algorithm is named as hybrid differential Evolution algorithm (HDE) in this work.The below flow chart indicates the steps involved in the proposed hybrid algorithm.

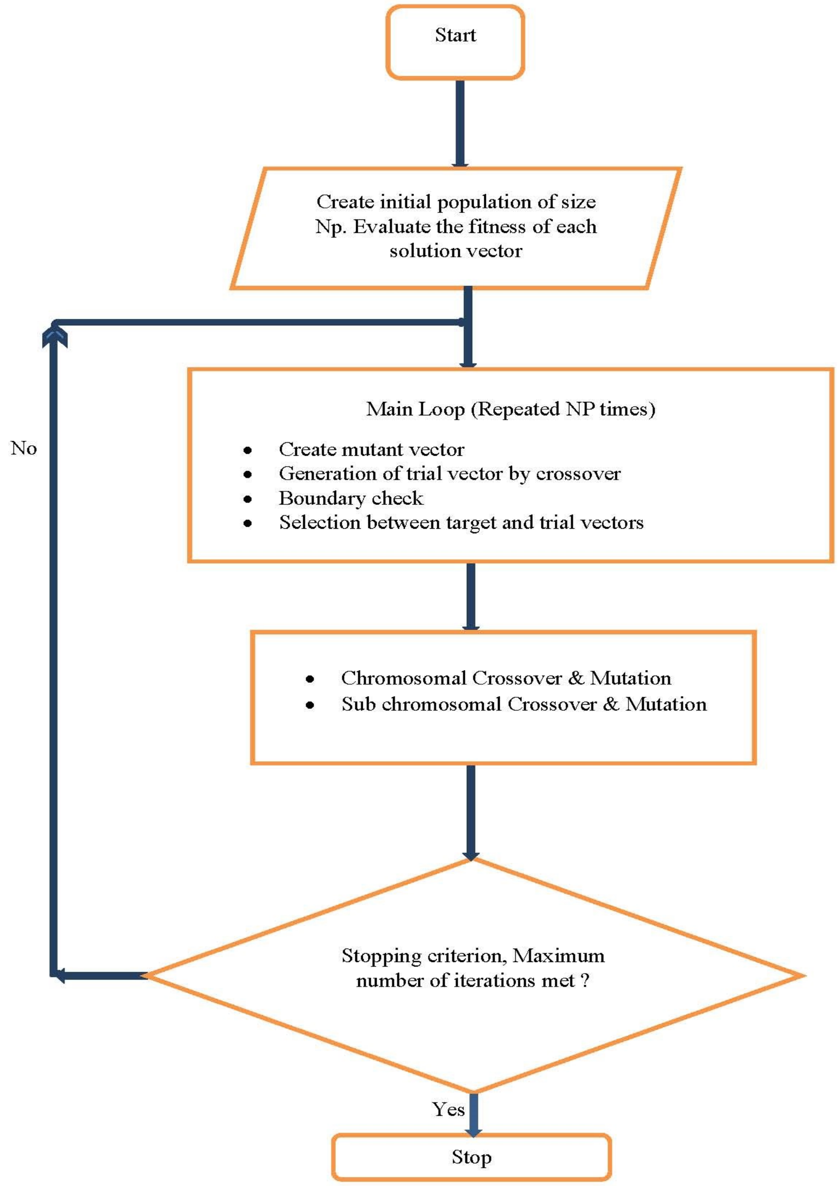

Fig:2 Flow chart for the proposed hybrid Differential Evolution (HDE) algorithm

For implementation of Hybrid Differential Evolution (HDE), Job set 7 and Layout 3 are considered as an example. HDE computes the vector differences between randomly chosen population members and receptor editing for different jobs and the sequences are obtained based on the mutation and crossover.

The HDE is explained in the following steps for the job set 7:

Step 1: Considering the job set

Job set: 7							
Layout: 3			No of jobs: 8		No of operations: 19		
Job 1	Job 2	Job 3	Job 4	Job 5	Job 6	Job 7	Job 8
M1-M4	M2-M4	M2-M4	M3-M4	M1-M3	M2-M3-M4	M1-M2-M3	M1-M2-M4
1 – 2	3 - 4	5 - 6	7 - 8	9 - 10	11 -12 -13	14 -15 -16	17 -18 -19

In DE for the operation in a job set numbers are assigned serially.

Step 2: Generating the Population size (double the number of operations) randomly by using precedence relation i.e., operation of the same job set must be in increasing order but anywhere in the sequence. These are presented in Table.1 and the steps shown in the Fig:1 are implemented to identify the maximum operational completion time (makespan) for each sequence.

Table .1: Generated population size for the HDE

S.No	Sequence	Makespan
1	9-5-11-14-17-7-3-1-12-15-10-6-4-18-2-8-16-19-13	110
2	11-7-3-9-1-17-5-14-10-15-8-2-6-18-12-4-16-19-13	112
3	17-7-5-9-3-1-11-14-2-4-12-8-6-10-18-15-19-16-13	116
4	14-7-9-17-3-5-1-11-10-6-15-12-18-4-8-2-19-13-16	116
5	7-1-17-5-11-14-3-9-18-6-15-2-12-4-10-8-16-19-13	116
6	17-9-14-7-11-5-3-1-8-15-18-10-4-12-2-6-16-13-19	119
7	11-7-1-14-3-17-9-5-12-18-10-15-8-2-4-6-13-19-16	121
8	14-3-5-9-7-11-1-17-2-10-6-8-18-4-15-12-19-13-16	121
9	17-7-14-1-9-3-11-5-2-4-10-18-6-12-15-8-13-19-16	121
10	3-17-14-7-1-5-9-11-6-2-15-12-10-4-8-18-13-19-16	121
11	14-11-17-5-7-3-9-1-10-4-2-12-6-15-8-18-19-16-13	123
12	5-17-11-1-3-9-7-14-10-18-15-8-12-2-4-6-19-13-16	123
13	3-1-7-5-17-9-11-14-4-10-12-2-6-18-8-15-16-13-19	124
14	3-1-14-5-9-17-7-11-15-8-12-10-6-18-4-2-16-13-19	125
15	11-7-14-5-1-17-9-3-10-4-6-8-15-2-12-18-13-16-19	125
16	11-7-3-1-9-14-17-5-15-2-12-8-4-6-18-10-13-16-19	125
17	9-14-7-5-17-3-11-1-8-15-12-6-4-18-2-10-16-13-19	125
18	5-1-14-3-9-7-17-11-15-8-10-18-2-6-4-12-16-19-13	126
19	17-11-14-9-1-5-3-7-8-10-4-15-12-18-6-2-16-19-13	126
20	11-1-17-5-9-7-14-3-8-4-18-15-12-2-10-6-16-19-13	126
21	3-7-11-5-14-9-1-17-6-8-10-15-12-4-18-2-13-16-19	127
22	11-14-5-1-9-7-17-3-2-4-15-8-12-6-10-18-19-16-13	127
23	9-3-1-17-11-5-14-7-15-8-4-12-6-2-10-18-13-19-16	127
24	11-9-1-14-7-5-17-3-15-4-6-10-8-2-12-18-19-13-16	127
25	11-17-5-9-3-1-14-7-8-15-12-6-4-2-10-18-16-13-19	127
26	1-7-11-9-17-5-14-3-2-4-10-12-6-18-15-8-16-13-19	129
27	9-17-3-11-14-1-5-7-10-4-18-8-15-6-12-2-16-13-19	129
28	11-17-9-1-14-7-5-3-18-15-6-10-2-8-4-12-19-16-13	130
29	17-1-11-9-14-5-7-3-12-10-4-2-8-6-18-15-19-16-13	130
30	9-7-11-5-1-3-17-14-6-8-18-4-15-10-2-12-19-16-13	130
31	11-5-7-1-3-9-17-14-8-4-6-18-2-10-15-12-19-13-16	130
32	5-1-9-14-11-3-7-17-6-18-2-10-4-12-15-8-16-19-13	130
33	11-5-1-7-14-9-3-17-6-8-15-18-10-12-2-4-19-16-13	130
34	9-3-14-5-11-17-1-7-15-4-2-18-6-12-10-8-16-13-19	130
35	11-3-9-1-14-17-7-5-8-4-6-15-18-12-2-10-16-19-13	130
36	9-1-7-17-3-14-11-5-6-10-2-15-18-12-4-8-13-19-16	134
37	14-1-5-7-9-17-11-3-10-4-12-18-2-8-6-15-19-13-16	135
38	5-14-9-7-17-1-11-3-12-2-4-8-18-15-10-6-19-13-16	138

From the above Table it can be interpreted that in 1st sequence, number ‘9’ represents 1st operation on the job no 5 and similarly number ‘5’ represents the 1st operation on job no 3. Similarly number ‘19’ represents 3rd operation on job no 8 and so on.

Step 3: After all the sequences of the initial population have been evaluated, the best among them is taken. In this case the best among the initial population is
X_{best} = 9-5-11-14-17-7-3-1-12-15-10-6-4-18-2-8-16-19-13 --- 110

Step 4: Four vectors X_1, X_2 , X_3 & X_4 will be randomly selected in the population is added to a best vector to get the resultant vector known as mutant vector
(X_{new}), as $X_{new} = X_{best}+F_1(X_1-X_2) +F_2(X_3-X_4)$ - (1)
9-5-11-14-17-7-3-1-12-15-10-6-4-18-2-8-16-19-13 = X_1
11-7-3-9-1-17-5-14-10-15-8-2-6-18-12-4-16-19-13 = X_2
17-7-5-9-3-1-11-14-2-4-12-8-6-10-18-15-19-16-13 = X_3
14-7-9-17-3-5-1-11-10-6-15-12-18-4-8-2-19-13-16 = X_4
Subtracting and add these four vectors (absolute value is taken) and as suggested by Storn and Price [9] multiplying it with Factor F_1= 0.65 and F_2 = 0.85 and rounding off, we get
0.65{(9-5-11-14-17-7-3-1-12-15-10-6-4-18-2-8-16-19-13) – (11-7-3-9-1-17-5-14-10-15-8-2-6-18-12-4-16-19-13)}+0.85{(17-7-5-9-3-1-11-14-2-4-12-8-6-10-18-15-19-16-13)-(14-7-9-17-3-5-1-11-10-6-15-12-18-4-8-2-19-13-16)}
= 0.65(2-2-8-5-16-10-2-13-2-0-2-4-2-0-10-4-0-0-0)+0.85{(3-0-4-8-0-4-10-3-8-2-3-4-12-6-10-13-0-3-3)
= (1-1-5-3-10-7-1-8-1-0-1-3-1-0-7-3-0-0-0) + (3-0-3-7-0-3-9-3-7-2-3-3-10-5-9-11-0-3-3)
= 4-1-8-10-10-10-10-11-8-2-4-6-11-5-16-14-0-3-3
Adding this with the best vector
9-5-11-14-17-7-3-1-12-15-10-6-4-18-2-8-16-19-13
We get
13-6-19-24-27-17-13-12-20-17-14-12-15-23-18-22-16-22-16
Now converting the values above 19 (max value allowed to values within bounds) we get
13-6-19-5-8-17-13-12-1-17-14-12-15-4-18-3-16-3-16

Step 5: Do the crossover operation for mutant vector
Mutant vector crossed over randomly with another population member
9-3-14-5-11-17-1-7-15-4-2-18-6-12-10-8-16-13-19
Chromosomes before crossover:
13-6-19-5- 8-17- 13-12-1-17 |14-12-15- 4- 18- 3- 16- 3- 16
9 -3- 14-5-11-17-1-7-15 - 4 |2-18-6-12-10-8- 16-13-19
Chromosomes crossover
13-6-19-5- 8-17- 13-12-1-17 -2- 18- 6- 12-10- 8- 16-13-19
9-3-14-5-11-17-1 - 7-15- 4 -**14 -12 -15 - 4 -18- 3- 16- 3- 16**
After crossover with crossover factor of 0.5. we get the resulting vector as
13-6-19-5- 8-17- 13-12-1-17 -2- 18- 6- 12-10- 8- 16-13-19
Here it is observed that this vector doesn't contain all the operations and some operations are repeated. Hence the corrected repair function is used to avoid repetition and also used to include all the operations. So the resulting output after doing repair is
13-6-19-5- 8-17- 3-12-1- 4 -2- 18- 7- 9-10-11-16-14-15

Repair function:
Repair function is used to make sure the vector so generated using random numbers follows precedence requirement constraints of the operations. If the precedence is not followed, the repair function swaps values within the array.
7-3-14-11- 5-17- 1-9-12-8 -18- 15- 4- 6-10- 2- 13-16-19
Step 5: After getting the final sequence from each iteration crossover and mutation concepts are implemented which are hired from sheep flock heredity algorithm.

Step 6: Receptor editing:
The process of removing the worst makespan value chromosomes from the population and replacing them with randomly generated chromosomes is called receptor editing. After this process a new population will be emerge this new population will become the input to the next iteration. This process continous until the termination criterion is reached.

Step 7: Termination criterion:
The above discussed procedure is repeated until the termination criteria is reached. In the present work repeating the procedure for more number of generations is considered as termination criterion.

Step 8: The best sequence and its related makespan obtained after completion of 1000 iterations is presented in Table .2.

Table.2: Operations schedule through HDE (for Problem set 7 and layout 3)

Operation Number	Machine Number	Vehicle Number	Travel Time	Job Reach	Job Ready	Make Span
5	2	1	0	4	4	13
7	3	2	0	10	10	26
3	2	1	28	32	32	43
14	1	1	14	16	16	26
6	4	1	18	26	26	33
11	2	2	14	18	18	31
4	4	1	4	12	12	21
9	1	2	28	30	30	39
12	3	1	32	38	38	57
17	1	1	42	44	44	55
10	3	2	39	47	57	75
1	1	2	51	53	55	61
2	4	1	44	54	54	60
15	2	2	53	55	55	64
18	2	1	58	60	64	73
8	4	2	61	63	63	70
13	4	1	66	68	70	76
16	3	2	69	75	75	88
19	4	1	74	82	82	90

Table 2 shows operation scheduling of through hybrid differential evolution algorithm for job set 7 layout 3. From the table it is interpreted that operation 5 on machine 2 is completed by 13 min hence 3^{rd} operation will start after completion of 5^{th} operation on machine 2. In case of job set 7 and layout 3 operation 7 on machine 3 is completed by 26 min hence 12^{th} operation on machine 3 will start after completion of 7^{th} operation on machine 2. Similarly, no operation on the particular machine will start until the operation on the machine is completed. From the vehicle heuristic algorithm for first two operations AGVs are selected randomly in case of third operation AGV '1' is selected basing on the availability of AGV with minimum travel time this constraint will be taking care in the algorithm, for job set 7 and layout 3 the operational completion time (makespan) is 90.

VIII. RESULTS AND DISCUSSION

Computations for makespans for different combinations of job sets and layouts for hybrid differential evolution algorithm, Priority rules (FCFS, SPT, LPT, Nageswararao et al. 2017), Heuristic (NEH, Prakash babu et al, 2018, FUZZY, P. B. Kanakavalli et al, 2018) with t/p > 0.25 are presented in Table 3. A code is used to designate the example problems which are given in the first column. The digits that follow 1.1 indicate the job set and the layout. In t/p ratio < 0.25 table another digit is appended to the code. Here- having a 0 or 1 as the last digit implies that the process times are doubled or tripled- respectively- where in both cases travel times are halved.

Table .3: Comparison of make span values (for t/p > 0.25)

Job. No	t/p	FCFS	SPT	LPT	NEH	FUZZY	**HDE**
1.1	0.59	173	193	177	165	208	96
2.1	0.61	158	158	177	169	170	98
3.1	0.59	202	224	198	195	211	109
4.1	0.91	263	267	264	260	268	116
5.1	0.85	148	164	148	147	174	89
6.1	0.78	231	240	227	225	233	113
7.1	0.78	195	210	201	173	196	121
8.1	0.58	261	261	266	261	261	150
9.1	0.61	270	277	268	259	273	116
10.1	0.55	308	308	310	305	315	167
1.2	0.47	143	173	165	147	188	82
2.2	0.49	124	124	130	116	127	76
3.2	0.47	162	188	160	154	178	83
4.2	0.73	217	223	224	215	232	90
5.2	0.68	118	144	131	117	156	73
6.2	0.54	180	169	165	158	175	90
7.2	0.62	149	160	149	136	139	85
8.2	0.46	181	181	198	181	181	131
9.2	0.49	250	249	244	205	249	104
10.2	0.44	290	288	287	274	274	149
1.3	0.52	145	175	167	145	190	84
2.3	0.54	130	130	136	122	133	82
3.3	0.51	160	190	162	158	176	86
4.3	0.8	233	237	230	226	234	96
5.3	0.74	120	146	133	117	156	76
6.3	0.54	182	171	167	160	177	92
7.3	0.68	155	166	151	138	141	90
8.3	0.5	183	183	200	183	183	133
9.3	0.53	252	251	246	207	251	105
10.3	0.49	293	294	293	280	280	129
1.4	0.74	189	207	189	189	228	104
2.4	0.77	174	174	174	169	190	112
3.4	0.74	220	250	212	213	225	113
4.4	1.14	301	301	298	298	294	128
5.4	1.06	171	189	171	171	193	97
6.4	0.78	249	252	237	234	243	119
7.4	0.97	217	242	151	192	232	135
8.4	0.72	285	285	200	285	285	152
9.4	0.76	292	311	290	285	295	125
10.4	0.69	350	350	345	345	353	161

The optimal sequence of machines and AGVs are determined by using FCFS-SPT- LPT-NEH-FUZZY and HDE for t/p >0.25 are shown in Table.3. From Table 3 it can be observed that, out of 40 problems, 40 problems give better results using HDE when compared with all other five algorithms .Computations for completion time for different combinations of job sets and layouts for four metaheuristic and one hybrid metaheuristic algorithms with t/p < 0.25 are done and tabulated in Table 4.

Table 4.Comparison of make span values (for t/p < 0.25)

Job.No	t/p	FCFS	SPT	LPT	NEH	FUZZY	**HDE**
1.10	0.15	207	248	252	207	278	126
2.10	0.15	217	217	225	185	208	131
3.10	0.15	257	327	282	255	300	143
4.10	0.15	303	328	317	277	352	123
5.10	0.21	152	190	187	154	225	102
6.10	0.16	304	281	297	272	294	146
7.10	0.19	231	240	264	213	235	137
8.10	0.14	338	338	347	332	338	247
9.10	0.15	390	367	359	324	382	182
10.10	0.14	452	429	444	398	393	218
1.20	0.12	194	238	246	197	268	123
2.20	0.12	194	194	206	167	187	128
3.20	0.12	241	311	270	241	285	139
4.20	0.12	285	312	298	248	340	116
5.20	0.17	142	180	184	143	217	100
6.20	0.12	292	260	284	251	277	141
7.20	0.15	212	218	249	188	210	136
8.20	0.11	306	319	334	306	306	244
9.20	0.12	380	355	347	309	372	179
10.20	0.11	445	423	439	388	384	212
1.30	0.13	195	239	247	196	169	122
2.30	0.13	197	197	209	170	190	129
3.30	0.13	240	312	271	240	284	138
4.30	0.13	292	317	301	255	339	117
5.30	0.18	141	181	183	143	216	99
6.30	0.24	296	261	285	252	278	141
7.30	0.17	215	221	250	191	213	137
8.30	0.13	307	320	335	307	307	245
9.30	0.13	381	356	348	310	373	180
10.30	0.12	448	426	442	391	387	191
1.40	0.18	213	255	254	213	288	124
2.41	0.13	307	307	319	267	293	191
3.40	0.18	261	330	282	258	305	143
3.41	0.12	370	476	411	310	435	209
4.41	0.19	434	471	451	393	504	177
5.41	0.18	218	269	270	222	321	148
6.40	0.19	310	288	299	275	303	151
7.40	0.24	239	251	270	221	246	137
7.41	0.16	329	344	385	224	332	203
8.40	0.18	343	343	349	339	343	248
9.40	0.19	396	379	370	325	388	182
10.40	0.17	466	445	455	415	408	214

The optimal sequence of machines and AGVs are determined by using FCFS-SPT- LPT- NEH-FUZZY and HDE for t/p < 0.25 are shown in Table 4. From Table 4 it can be observed that out of 42 problems, 42 problems give better results using HDE when compared with all other five algorithms.

IX. CONCLUSION

Flexible Manufacturing system is considered as better choice to confront the difficulties of global competition. But for successful implementation efficient scheduling is essential. Scheduling of an FMS is a very difficult problem because of other consideration like material handling. In this work an endeavor has been made to tackle the problem of scheduling both the machines and AGVs simultaneously by a hybrid metaheuristic algorithm. The following conclusions are drawn from this work. Execution of the proposed Hybrid Metaheuristic Algorithm is assessed by considering 82 benchmark problems comprising of various jobsets and layout configurations. From the results it is observed that the proposed hybrid Differential Evolution (HDE) algorithm yielded improved results in all the 82 problems when compared with the other algorithms.

X. SCOPE OF FUTURE WORK

In the present work a hybrid metaheuristic is proposed to solve simultaneous scheduling of problems in FMS. There is scope for further research work in the following aspects: In FMS jobs enter with different priorities and the problem can be made dynamic in nature. When required sequence needs to reschedule. The simultaneous scheduling problem can be extended further by including AS/RS system. Real time issues like traffic jamming- without buffer space and machine breakdowns can also be considered.

XI.REFERENCES

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