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Simultaneous Scheduling of Machines and AGVs in FMS Through Hybrid JAYA Algorithm

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Abstract*: High amount of flexibility and quick response times have become essential features of modern manufacturing systems where customers are demanding a variety of products with reduced product life cycles. Flexible manufacturing system (FMS) is the right choice to achieve these challenging tasks. The performance of FMS is dependent on the selection of scheduling policy of the manufacturing system. In Traditional scheduling problems machines are as considered alone. But material handling equipment's are also valuable resources in FMS. The scheduling of AGVs is needed to be optimized and harmonized with machine operations. Scheduling in FMS is a well-known NP-hard problem due to considerations of material handling and machine scheduling. Many researchers addressed machine and AGVs individually. In this work an attempt is made to schedule both the machines and AGVs simultaneously. For solving these problems- a new hybrid metaheuristic JAYA algorithm (HJAYA) is proposed.

Keywords : AGVs, FMS, Metaheuristic algorithms, NP-hard problems,Operational Completion Time (makespan)

I. INTRODUCTION

A Flexible Manufacturing System (FMS) is a highly automated manufacturing system well suited for the simultaneous production of a wide variety of part types in low to mid volume quantities at a low cost while maintaining a high quality of the finished products. FMS executed number of benefits in terms of reducing cost- increased utilization of machine- condensed work-in –process levels- etc. However- there are a number of problems faced during the life cycle of an FMS and these functions are classified into: design- planning- scheduling- and controlling. In particular- the scheduling task and control problem during the manufacturing operation are of importance owing to the dynamic nature of the FMS in respect of flexible parts- tools- assignments. In FMS scheduling- decisions that need to be made include not only sequencing of jobs on machines but also the routing of the jobs through the system.

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Apart from the machines- other resources in the system like Automated Guided Vehicle (AGV) and Automated Storage/Retrieval System (AS/RS) must be considered. The AGVs effectiveness depends on vehicle management system.

II. LITERATURE REVIEW

A. Simultaneous scheduling in FMS

In simultaneous scheduling- the real time as well as the off-line scheduling is taken into account. Bilge and Ulusoy [1] exploited the interactions between the machine and AGVs scheduling simultaneously. The material transfer between machines is done by a number of identical AGVs which are not allowed to return to the load/unload station after each delivery. Abdelmaguid et al.[2] suggested a hybrid GA for the problem of simultaneous scheduling of machines and AGVs in FMS with minimizing the makespan. The algorithm is applied to a set of 82 test problems- which was constructed by other researchers- and the comparison of the results indicates the superior performance with the developed coding. Reddy and Rao [3] studied the simultaneous scheduling problem with makespan- mean flow time and mean tardiness as an criterion. The proposed hybrid GA for FMS scheduling problems yielded better results when compared to other algorithms. Gnanavelbabu et al. [4] examined the scheduling of machines and AGVs simultaneously in FMS using differential evaluation with makespan minimization. The algorithm is tested by using test problems proposed by various researchers and the makespan obtained by the algorithm is compared with that obtained by other researchers are analyzed. Anandaraman et al. [5] presented a solution for the simultaneous scheduling problem by evolutionary approach in FMS with vehicles and robots with the objectives to minimize the makespan- mean flow time and mean tardiness. The scheduling optimization is carried out using metaheuristic algorithm. The algorithms are applied for test problems taken from the literature and the results obtained using the two algorithms are compared. Nouri et al. [6] introduced the clustered holonic multiagent model using metaheuristic for simultaneous scheduling of machines and transport robot in FMS. Computational results are presented using three sets of benchmark instances in the literature. New upper bounds are found- showing the effectiveness of the presented approach. Md Kamal et al. [7]

Flexible Job Shop Scheduling Problem (FJSSP) is an extension of the classical Job Shop Scheduling Problem (JSSP). Keeping in view this aspect- this article presents a comprehensive literature review of the FJSSPs solved using the GA. The survey is further extended by the inclusion of the hybrid GA (HGA). Nageswararao et al [8]

III. SIMULTANEOUS SCHEDULING PROBLEMS IN FMS

A. Problem structure

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

B. Objective function

Operation completion time = Oij = Ti j+ Pij

T_{ij} = Traveling time for j^{th} operation and i^{th} job

P_{ij} = operation processing time

C. Optimization parameters considered

Population Size = Double the no of operations

Iterations completed = 1000

D. Vehicle scheduling methodology

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. To obtain the makespan value for a given sequence of operations the following procedural steps are implemented.

Step 1: To Consider the machine number (M.No) of the given sequence for the job.

Step 2: To Select the AGV

Step 3: To identify the vehicle previous location (VPL)- previous operation machine number (POMN)- vehicle ready time (VRT) and previous operation completion time (POCT)

Step 4: To calculate vehicle empty trip time (VET) using

VET= VRT+VPL to POMN.

Step 5: Finding out the maximum from POCT and VET.

Step 6: Obtaining the total travel time of vehicle (TT) using

TT=VET+ POMN to M.No.

Step 7: To know the machine readiness time (MRT).

Step 8: To Identify the maximum of TT and MRT.

Step 9: Maximum time (from step 8) is added to process time to get the operational completion time.

Step 10: Repeated the steps from 2 to 9 for all other operations.

Step 11: To Identify the maximum operational completion time- which represents the possible completion time (makespan) of given job set.

IV. JAYA ALGORITHM

Jaya Algorithm was developed by Venkatarao et al (2016). The algorithm always tries to get closer to success (i.e. reaching the best solution) and tries to avoid failure (i.e. moving away from the worst solution)

The steps involved in JAYA are given below:

Step 1: Select the job set

Step 2: Generate random sequences as per the population size

Step 3: Identify the X_{best} and X_{worst} from the population

Step 4: Modify the sequences (X'_j) based on equation

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

Step 5: Identify the tendency of solution to move closer to the best solution

Step 6: Identify the tendency of solution to avoid the worst solution

Step 7: Solution is accepted if it gives better function value

Step 8: After getting better X'_j for all sequences, these all X'_j values goes to next iteration.

Step 9: Before going to next iteration implement receptor editing to remove worst solutions

Step 10: Finally report the optimum solution

A. Hybrid Algorithm

Since mixing of any two algorithms yields superior results, JAYA is amalgamated with Sheep Flock Heredity Algorithm.

B. Sheep Flock Heredity Algorithm

Sheep Flock Heredity Algorithm (SFHA) was developed by Hyunchul Kim (2001).This algorithm is based on the genetic inheritance.

The steps involved in SFHA are given below:

Step 1: To generate Initial population randomly

Step 2: For each chromosome, to evaluate the desired optimization fitness function.

Step 3: To do the sub chromosome level crossover and mutation

Step 4: After selecting the best chromosome from the population to do the chromosome level crossover and mutation.

Step 5: To calculate the fitness function for each chromosome in the population. Then to do the sorting function.

Step 6: After sorting the strings, to do the editing of the chromosomes in the population after the mutation process.

Step 7: After editing the chromosomes in the population the new population has to undergo next iteration until termination criterion is reached.

C. Hybrid JAYA Algorithm

Step 1: To consider the job set

Step 2: For the job set to implement JAYA as explained in art. 4 to get the sequence of operation.

Step 3: After getting the sequence of operation for each iteration, crossover and mutation concepts are to be implemented.

D. Algorithm to Optimal Scheduling Problem

For implementation of HJAYA, Job set 8 and Layout 4 are considered as an example.The data related to Jobset 8 is given in Table I. HJAYA computes difference between best candidate and worst candidate in the entire candidate solutions and the sequence is obtained based on mutation

The HJAYA is explained in the following steps for job set 8:

Step 1: Considering the job set

In HJAYA algorithm operations in a job set numbers are assigned serially.

Step 2: Generate random sequences as per population size, which are presented in Table II. The makespan for each sequence is calculated by implementing the steps discussed in article III section D and the maximum operational completion time (makespan) for each sequence is identified.

From the above table it can be interpreted that in 1st sequence, number '13' represents 1st operation on the job no 5 and similarly number '1' represents the 1st operation on job no 1. Similarly number '20' represents 4th operation on job no 6 and so on.

Step 3: Identify the X_{best} and X_{worst} from the population

X_{best} =

13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16 = 201

X_{worst} =

4-10-13-17-7-1-8-5-11-2-14-18-3-6-9-12-15-19-16-20 = 230

Step 4: Modify the sequences (X'_j) based on equation

$X'j,k,i=Xj,k,i+r1,j,i(Xj,best,i-|Xj,k,i|)-r2,j,i(Xj,worst,i-|Xj,k,i|)$

From the Table II the sequences are X_1 to X_{40} for example consider X_1 as X_j

X'j = 13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16 + {r_1[(13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16)-(13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16)] – r_2 [(4-10-13-17-7-1-8-5-11-2-14-18-3-6-9-12-15-19-16-20)-(13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16)]}

Subtracting these (Xbest - |Xj|) and (Xworst- |Xj|) (absolute value is taken) and multiplying it with random number r_1=0.85, r_2=0.65

X'j = 13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16 + {*0.85[0] – 0.65*[(4-10-13-17-7-1-8-5-11-2-14-18-3-6-9-12-15-19-16-20)-(13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16)]}

X'j = 13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16 + {*0.85[0] – 0.65*[(9-9-9-10-3-16-6-0-3-6-3-0-0-13-3-0-6-4-4-4]}

X'j = 13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16 + {6-6-6-7-2-10-4-0-2-4-2-0-0-8-2-0-4-3-3-3}

X'j = 13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16 + {6-6-6-7-2-10-4-0-2-4-2-0-0-8-2-0-4-3-3-3}

X'j = 19-7-10-14-12-27-6-5-16-12-13-18-3-27-8-12-13-18-23-19

Now converting the values above 20 (max value allowed to values within bounds) we get

X'j = 19-7-10-14-12-7-6-5-16-12-13-18-3-7-8-12-13-18-3-19

Here it is observed that this sequence 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 output of this function is

X'j = 19-7-10-14-12-1-6-5-16-2-13-18-3-4-8-9-11-15-17-20

This sequence is corrected by the repair function-I for precedence requirements and the output is

10-4-17-7-18-5-8-1-13-14-11-15-19-2-9-12-16-6-20-3 – Makespan- 182

If the makespan value of the new sequence is smaller than that of the original sequence, then the new one is stored in place of the original one. In case where the algorithm could not find a better sequence then it stores the original sequence.

Step 5: The above procedure has been applied for all 40 sequences and minimum make span values are found after 20 runs.

Step 6: After getting the final sequence from each iteration crossover and mutation concepts are utilized which were hired from sheep flock heredity algorithm as explained in detail in article IV section B.

Step 7: Receptor editing:

The editing of the chromosomes in the population after the cross over operation is known as receptor editing. In this process a number of worst makespan value chromosomes are eliminated from the population and randomly generated chromosomes are added in those places. After editing the chromosomes in the population, the new population has gone to next iteration until termination criterion is reached.

Step 8: Termination criterion:

The process of selection, crossover, mutation and receptor editing are repeated till the termination criterion is satisfied.

A number of termination criteria are available in the literature like, repeating the procedure for number of generations, running the algorithm for a fixed duration of time, and stopping the simulation when there is no improvement in fitness for the last "g" generations. In this work the first criterion viz., repeating the procedure for number of generations is taken as the termination criterion.

Step 9: The evaluated values of different parameters in arriving at the makespan after 1000 iterations for the best sequence is presented in Table III.

Table III shows operation scheduling of through Hybrid JAYA algorithm for job set 8 layout 4 is shown. From the table it is observed that operation 13 on machine 1 is completed by 14 min hence 17th operation will start after completion of 13th operation on machine 1. In case of job set 8 and layout 4 operation 4 on machine 2 is completed by 20 min hence 1st operation on machine 2 will start after completion of 4th 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 8 and layout 4 the operational completion time (makespan) is 195.

Table-I: Data related to Job Set 8

Job set: 8					
Layout: 4		No of jobs: 6		No of operations: 20	
Job 1	Job 2	Job 3	Job 4	Job 5	Job 6
M2-M3-M4	M2-M3-M4	M2-M3-M4	M2-M3-M4	M1-M2-M3-M4	M1-M2-M3-M4
1 - 2 -3	4 – 5 - 6	7 -8 -9	10 -11 -12	13 -14 -15 -16	17 -18 -19 -20

Table -II: Generated population size for the H JAYA

S.No	Sequence	Makespan
1	13-1-4-7-10-17-2-5-14-8-11-18-3-19-6-12-9-15-20-16	201
2	1-4-10-13-7-17-5-8-11-14-18-2-9-12-6-15-3-19-16-20	201
3	1-13-4-10-17-7-2-8-5-11-18-14-3-6-15-9-12-19-16-20	201
4	13-1-4-7-10-17-2-5-8-14-18-11-3-6-12-15-19-9-16-20	201
5	4-1-10-13-17-7-2-8-5-11-14-18-3-6-9-12-15-19-16-20	206
6	1-17-4-7-10-13-2-8-5-18-11-14-3-9-6-12-15-19-16-20	206
7	17-1-7-10-13-4-2-5-14-8-11-18-6-3-9-12-15-19-16-20	206
8	1-7-10-13-17-4-2-5-11-8-14-18-6-15-9-12-3-19-16-20	207
9	1-7-10-13-17-4-2-14-11-8-5-18-15-3-6-9-12-19-16-20	207
10	17-1-4-7-10-13-2-5-11-14-8-18-3-9-12-15-19-6-16-20	207
11	1-4-10-7-17-13-2-5-8-11-14-18-6-15-3-9-12-19-16-20	207
12	10-1-4-7-13-17-18-2-5-8-11-14-15-3-9-12-6-19-16-20	207
13	7-1-10-4-13-17-2-8-11-18-5-14-9-12-15-3-19-6-16-20	207
14	4-7-17-10-13-1-18-5-8-11-14-2-6-3-9-12-15-19-16-20	207
15	1-4-10-7-13-17-2-5-8-11-14-18-3-6-12-15-19-9-16-20	207
16	1-7-4-13-10-17-2-8-11-14-5-18-3-6-19-9-12-15-20-16	207
17	4-10-13-1-7-17-2-5-8-11-14-18-19-3-6-9-12-15-16-20	210
18	1-4-17-7-10-13-8-5-11-2-14-18-9-15-3-6-12-19-20-16	210
19	1-4-17-7-10-13-2-5-18-8-11-14-6-3-19-9-12-15-16-20	210
20	1-4-13-7-10-17-2-5-8-11-14-18-3-19-6-9-12-15-16-20	210
21	1-17-7-10-13-4-8-2-5-11-14-18-3-12-19-6-15-9-16-20	210
22	4-1-7-10-13-17-2-5-8-18-11-14-3-9-12-15-19-6-16-20	212
23	1-7-4-10-17-13-2-14-5-8-11-18-3-6-9-12-15-19-16-20	212
24	4-10-7-1-13-17-2-5-8-11-18-14-3-9-6-12-15-19-16-20	212
25	1-4-10-7-13-17-2-5-8-11-14-18-3-6-9-12-15-19-16-20	212
26	1-10-4-7-13-17-5-2-11-8-18-14-3-6-9-12-15-19-16-20	212
27	7-1-4-10-13-17-2-5-8-11-14-18-6-15-12-3-9-19-16-20	213
28	4-7-10-13-17-1-8-2-11-18-14-5-3-6-19-12-9-15-16-20	214
29	4-1-7-10-13-17-5-8-2-11-14-18-3-15-12-9-6-19-16-20	215
30	1-17-4-10-13-7-2-8-11-14-5-18-3-6-9-12-19-15-16-20	216
31	1-10-4-7-13-17-2-8-5-11-14-18-3-15-9-6-12-19-20-16	216
32	17-1-4-10-7-13-5-8-2-14-11-18-12-15-9-3-19-6-16-20	218
33	1-4-13-7-10-17-2-5-14-11-8-18-9-3-6-19-12-15-16-20	218
34	1-2-3-4-13-6-7-11-8-9-14-10-12-16-19-17-15-18-20-5	219
35	1-4-7-10-13-17-2-5-8-11-14-18-6-12-9-19-15-3-16-20	221
36	13-7-17-1-10-2-8-14-4-3-9-15-5-6-11-12-18-16-19-20	222
37	7-1-4-10-13-17-11-5-18-14-8-2-3-6-9-12-15-19-16-20	224
38	1-4-7-10-13-17-2-8-14-18-11-5-3-6-12-9-15-19-16-20	224
39	10-1-4-7-13-17-2-11-8-5-14-18-3-6-9-12-15-19-16-20	224
40	4-10-13-17-7-1-8-5-11-2-14-18-3-6-9-12-15-19-16-20	230

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Table-III : Operations schedule through HJAYA (for Problem set 8and layout 4)

Operation Number	Machine Number	Vehicle Number	Travel Time	Job Reach	Job Ready	Make Span
13	1	1	0	4	4	14
4	2	2	0	8	8	20
17	1	1	22	26	26	36
1	2	2	28	36	36	48
7	2	1	44	52	52	64
10	2	2	56	64	64	76
2	3	1	52	60	60	81
14	2	1	68	72	76	90
18	2	2	78	82	90	104
5	3	1	72	80	81	102
8	3	2	82	90	102	123
11	3	1	86	94	123	144
15	3	2	96	104	144	162
3	4	1	94	100	100	111
6	4	2	104	110	111	122
12	4	1	144	150	150	161
19	3	2	122	130	162	180
9	4	2	130	136	161	172
16	4	2	162	168	172	181
20	4	1	180	186	186	195

Table-IV: Comparison of make span values (for t/p > 0.25)

Job. No	t/p	FCFS	SPT	LPT	NEH	FUZZY	HJAYA
1.1	0.59	173	193	177	165	208	96
2.1	0.61	158	158	177	169	170	113
3.1	0.59	202	224	198	195	211	120
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	132
7.1	0.78	195	210	201	173	196	132
8.1	0.58	261	261	266	261	261	175
9.1	0.61	270	277	268	259	273	117
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	86
3.2	0.47	162	188	160	154	178	96
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	108
7.2	0.62	149	160	149	136	139	92
8.2	0.46	181	181	198	181	181	159
9.2	0.49	250	249	244	205	249	104
10.2	0.44	290	288	287	274	274	150
1.3	0.52	145	175	167	145	190	84
2.3	0.54	130	130	136	122	133	100
3.3	0.51	160	190	162	158	176	102
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	116
7.3	0.68	155	166	151	138	141	104
8.3	0.5	183	183	200	183	183	169
9.3	0.53	252	251	246	207	251	108
10.3	0.49	293	294	293	280	280	154
1.4	0.74	189	207	189	189	228	104
2.4	0.77	174	174	174	169	190	124
3.4	0.74	220	250	212	213	225	130

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	140
7.4	0.97	217	242	151	192	232	154
8.4	0.72	285	285	200	285	285	195
9.4	0.76	292	311	290	285	295	123
10.4	0.69	350	350	345	345	353	178

Table – V : Comparison of make span values (for t/p < 0.25)

Job.No	t/p	FCFS	SPT	LPT	NEH	FUZZY	HJAYA
1.10	0.15	207	248	252	207	278	126
2.10	0.15	217	217	225	185	208	148
3.10	0.15	257	327	282	255	300	162
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	192
7.10	0.19	231	240	264	213	235	137
8.10	0.14	338	338	347	332	338	292
9.10	0.15	390	367	359	324	382	182
10.10	0.14	452	429	444	398	393	262
1.20	0.12	194	238	246	197	268	123
2.20	0.12	194	194	206	167	187	143
3.20	0.12	241	311	270	241	285	159
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	187
7.20	0.15	212	218	249	188	210	136
8.20	0.11	306	319	334	306	306	287
9.20	0.12	380	355	347	309	372	179
10.20	0.11	445	423	439	388	384	259
1.30	0.13	195	239	247	196	169	122
2.30	0.13	197	197	209	170	190	146
3.30	0.13	240	312	271	240	284	160
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	188
7.30	0.17	215	221	250	191	213	137
8.30	0.13	307	320	335	307	307	288
9.30	0.13	381	356	348	310	373	180
10.30	0.12	448	426	442	391	387	260
1.40	0.18	213	255	254	213	288	124
2.41	0.13	307	307	319	267	293	217
3.40	0.18	261	330	282	258	305	162
3.41	0.12	370	476	411	310	435	239
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	189
7.40	0.24	239	251	270	221	246	138
7.41	0.16	329	344	385	224	332	203
8.40	0.18	343	343	349	339	343	293
9.40	0.19	396	379	370	325	388	182
10.40	0.17	466	445	455	415	408	266

V. RESULT AND DISCUSSSION

Computations for completion time for different combinations of job sets and layouts for Hybrid JAYA 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 done and tabulated in IV. 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.

In the optimal sequence of machines and AGVs are determined by using FCFS-SPT- LPT-NEH-FUZZY and HJAYA for t/p > 0.25 are shown in Table IV. From Table IV it can be observed that, out of 40 problems, 40 problems give better results using HJAYA when compared with all other five algorithms (100%).Computations for completion time for different combinations of job sets and layouts for Hybrid JAYA 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 done and tabulated in Table V.

In the optimal sequence of machines and AGVs are determined by using FCFS-SPT- LPT- NEH-FUZZY and HJAYA for t/p < 0.25 are shown in Table V. From Table V it can be observed that out of 42 problems, 42 problems give better results using HJAYA when compared with all other five algorithms (100%).

VI. CONCLUSION

Flexible Manufacturing system is considered as better option to face the challenges of global competition. But for successful implementation efficient scheduling is essential. Scheduling of an FMS is a very difficult problem because of other considerations like material handling. In this work an attempt has been made to solve the problem of scheduling both the machines and AGVs simultaneously by hybrid metaheuristic algorithm the following conclusions are drawn from this work. Performances of Hybrid Metaheuristic Algorithm are evaluated by considering 82 benchmark problems consisting of different job sets and layout configurations. From the comparison of these results Hybrid JAYA algorithm yielded improved results in 82 problems.

VII. SCOPE OF FUTURE WORK

In this research work simulating metaheuristic Algorithms to solve simultaneous scheduling problems in FMS. There is scope for further research work in the following aspects: In FMS jobs are entered 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- machine breakdown can also be considered.

REFERENCES

1. Bilge, U., & Ulusoy, G. (1995). A time window approach to simultaneous scheduling of machines and material handling system in an FMS. Journal of Operations Research, 43, 1058-1070.
2. Abdelmaguid, T. F., Nasef, A. O., Kamal, B. A., & Hassan, M. F. (2004). A hybrid GA / heuristic approach to the simultaneous scheduling of machines and automated guided vehicles. International Journal of Production Research, 42, 267-281.
3. Reddy, B. S. P., & Rao, C. S. P. (2006). A hybrid multi-objective GA for simultaneous scheduling of machines and AGVs in FMS. International Journal of Advanced Manufacturing Technology, 31, 602-613.
4. Babu, A.G., Jerald, J., Haq, N., Muthu Luxmi, V., & Vigneswaralu, T.P. (2010). Scheduling of machines and automated guided vehicles in FMS using differential evolution. Int. J. Prod. Res, iFirst, 1-17.
5. Anandaraman, C., Vikram, A., Sankar, M., & Natarajan, R. (2012). Evolutionary approaches for scheduling a flexible manufacturing system with automated guided vehicles and robots. International Journal of Industrial Engineering Computations, 3, 627-648.
6. Nouri, H. E., Driss, O.B., & Ghédira, K. (2016). Simultaneous scheduling of machines and transport robots in flexible job shop environment using hybrid metaheuristics based on clustered holonic multiagent model. Computers, 488-501.
7. Amjad, K.M. et al. (2018). Recent research trends in genetic algorithm based flexible job shop scheduling problems. Mathematical Problems in Engineering, 1–32.
8. Lundy, M., & Mees, A. (1986). Convergence of an annealing algorithm. Math. Program, 34:111-124.
9. Rao, R.V. (2016) Jaya: A simple and new optimization algorithm for solving constrained and unconstrained optimization problems. Int. J. Ind. Eng. Comput. 7, 19–34.
10. Nageswararao, M., Narayanarao, K., & Rangajanardhana, G. (2017). Integrated Scheduling of Machines and AGVs in FMS by Using Dispatching Rules. Journal of Production Engineering, 20(1), 75-84.
11. Prakash babu, K., Vijaya Babu, V., & Nageswara Rao, M. (2018). Fuzzy heuristic algorithm for simultaneous scheduling problems in flexible manufacturing system. Management Science Letters, 8(12), 1319–1330.
12. Prakash babu, K., Vijaya Babu,V., & Nageswara Rao, M. (2018). Implementation of heuristic algorithms to synchronized planning of machines and AGVs in FMS. Management Science Letters, 8(6), 543–554.
13. Hyunchul, K., and Byungchul, A. (2001) .A new evolutionary algorithm based on sheep flocks heredity model, In: Pacific Rim Conference on Communications, Computers and Signal Processing, 2, 514–517.

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