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A Simulation Based Approach for Studying the Effect of Buffers on the Performance of an FMS

L. Siva Rama Krishna[1], T.S.Satya Saketh [2], M.V.Satish Kumar[3]
[1](Dept. of Mechanical Engineering, Univ. College of Engg., Osmania University, Hyderabad, India-500007.)
[2](Department of Mechanical Engineering, Univ.College of Engg, Osmania University, India-500007)
[3](Department of Mechanical Engineering, KITS, Huzurabad, India)

ABSTRACT: *Scheduling of an FMS is a complex combinational optimization problem. Material handling is an important component of FMS and hence its scheduling is to be integrated with that of the machines. In this paper a simulation based approach for studying the effect of buffers on performance of an FMS with minimizing makespan as an objective is studied. The simulation is carried out using a discrete event simulation software i.e. Flexsim. The paper addresses the simultaneous scheduling of both machine and material handling system in an FMS environment. For this a benchmark problem with different job sets and different layouts is considered for the same.*

KEYWORDS : *Flexible Manufacturing System, Simultaneous Scheduling, Discrete Event Simulation Software, Buffer Storage, Make Span.*

I. INTRODUCTION

Since all the process parameters play a significant role in quality and quantity based output of an FMS environment, it is of paramount importance to adopt appropriate improvements while solving scheduling problems of an FMS environment. Monitoring and controlling different process parameters at different levels of abstraction are the most important aspect of analyzing an FMS. The advances in technology introduce us to various scientific approaches in solving the problem evading the traditional practices like mathematical modeling and genetic algorithms. However Discrete Event Simulation is a revolution in the field of analysis and it proves worthy while solving scheduling problems. Both scheduling of machines & scheduling of material handling devices play a decisive role in planning an FMS layout. While solving for Simultaneous scheduling of both machines and material handling devices Discrete event simulation software comes handy. These softwares provide detailed and meticulous explanation in unfolding the viabilities of the process parameters involved. Various Discrete Event Simulation softwares available in the market are Flexsim, Arena, Pro-Model .

A discrete event simulation software which models the operation of a system as a discrete sequence of events in time. Flexsim Simulation software is very well suited package for scheduling of an FMS . Realistic graphic interface, comprehensive performance reports and minimum processing time makes Flexsim a credible tool. Also a custom code/logic can be incorporated into the software while solving complex problems. In this paper the authors have made an attempt in studying the effect of Buffers on average stay time of jobs on machines and total makespan estimated on two different layouts for seven different job sets.

II. LITERATURE REVIEW

Umit Bilge and Gunduz Ulusoy [1] considered a Multiple Integer programming for solving scheduling problem of both the machines and material handling devices. They are one of the few researchers that included both material handling devices and machine scheduling. Muhammad and Tomohiro Murata [2] made use of particle swarm algorithm for vehicle scheduling and minimization of make span. Krishnan T. Karthikeyan, T. R. Chinnusamy, A. Murugesan [3] employed a dynamic coding for scheduling of an FMS. Subbaiah and Nageswara Rao [4] developed a scheduling formula using sheep flock algorithm. B. S. P. Reddy and C. S. P. Rao [5] proposed a multi objective genetic algorithm to address combination of machine and vehicle scheduling.

III. PROBLEM STATEMENT

The objective of this paper is to study the effect of buffers in the production line. A benchmark problem [1] with different job sets and different layouts is considered for the same. A problem with seven different job sets is selected and an effort has been made to simulate the job sets on two different layouts. It is aimed to schedule both the machines and material handling devices simultaneously in an FMS environment. A discrete event simulation software Flexsim has been chosen for simulation. The objective criteria is to minimize the total make span and also ensure that the machine utilization in improved.

Firstly the layouts are simulated as given in the problem statement. Total makespan for each job set on both the layouts is obtained and the result is compared with the results obtained when the layouts are modeled with buffer storage at each machine. Further the results obtained when simulated with buffers are compared with results obtained from benchmark problem.

The data for job sets used in solving the problem are given in Table 1.

Table 1: Data for the Job Sets used [1]

Job Set 1 Job 1: M1(8), M2(16), M4(12) Job 2: M1(20), M3(10),M2(18) Job 3: M3(12),,M4(8),M1(15) Job 4: M4(14), M2(18) Job 5: M3(10),M1(15)	**Job Set 2** Job 1: M1(10),M4(18) Job 2: M2(10),M4(18) Job 3: M1(10), M3(20) Job 4: M2(10),M3(15),M4(12) Job 5: M1(10),M2(15), M4(12) Job6: M1(10),M2(15), M4(12)
Job Set 3 Job 1: M1(10),M3(15) Job 2: M2(18), M4(15) Job 3: M1(20),M2(10) Job 4: M3(15),M4(10) Job 5: M1(8), M2(10),M3(15),M4(17) Job 6: M2(10),M3(15),M4(8),M1(15)	**Job Set 4** Job 1: M1(6),M3(12),M4(9) Job 2: M1(18),M3(6),M2(15) Job 3: M3(9),M4(3),M1(12) Job 4: M4(6), M2(15) Job 5: M3(3), M1(9)
Job Set 5 Job 1: M1(19),M2(11),M4(7) Job 2: M1(19),M2(20),M4(13) Job 3: M2(14), M3(20),M4(9) Job 4: M2(14), M3(20),M4(9) Job 5: M1(11),M3(18),M4(8) Job 6: M1(10),M3(12),M4(10)	**Job Set 6** Job 1: M1(6), M4(6) Job 2: M2(11),M4(9) Job 3: M2(9),M4(7) Job 4: M3(16), M4(7) Job 5: M1(9),M3(18) Job 6: M2(13),M3(19),M4(6) Job7 : M1(10),M2(9),M3(13) Job 8: M1(11),M2(9),M3(8)
Job Set 7 Job 1: M2(12),M3(21),M4(11) Job 2: M2(12),M3(21),M4(11) Job 3: M2(12),M3(21),M4(11) Job 4: M2(12),M3(21),M4(11) Job 5: M1(10),M2(14),M3(18),M4(9) Job 6: M1(10),M2(14),M3(18),M4(9)	

Figure 1 shows Layout 1 which is a loop layout. It consists of one Load/Unload station and 4 work centers which are located at assigned places. The layout has a unidirectional flow of jobs.

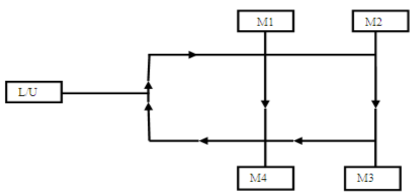


Figure 1: Layout 1 [1]

Figure 2 shows Layout 2, which is a ladder layout. It consists of one Load/Unload station and 4 work centers which are located at assigned places. The layout has a unidirectional flow of jobs.

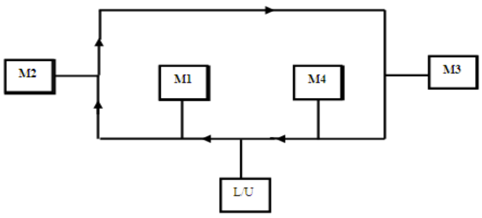


Figure 2 : Layout 2 [1]

Table 2 and 3 illustrates the travel time matrix for layout 1 and layout 2 respectively.

Table 2: Travel Time Data for Layout 1 [1]

	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

Table 3: Travel Time Data for Layout 2 [1]

	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

IV. RESEARCH METHODOLOGY

Flexsim simulation software has been chosen to study the effect of buffers in an FMS layout. Flexsim is an effective tool in solving complex scheduling problems. Also accurate results are obtained with minimum execution time when compared to hybrid algorithms. Real time scheduling situations can be incorporated into simulation with the help of simple coding. Detailed results are obtained with reference to all the required graphs and other statistical data. Various steps involved in solving the problem that has been described above are, designing the layout so as to further simulate the given job sets, scheduling of machines as per the requirement of the job set, recording of all the required process parameters, evaluation of the results and statistical data that has been obtained to study the effect of buffers .The layouts are modeled on the simulation software, which includes all the necessary entities and other simulation parameters. The modeling of layouts is done with and without buffers. An input buffer and an output buffer are created at each machine. The layouts modeled with and without employing buffer storage are shown in Figures 3 (a) and 3 (b) respectively.

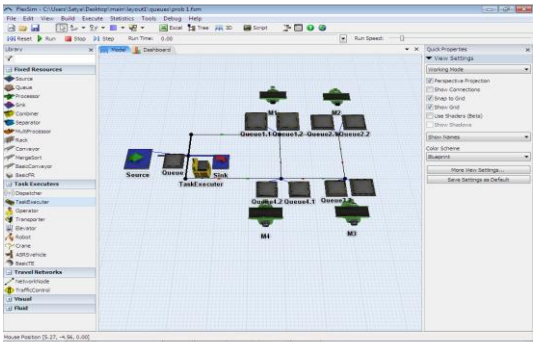


Figure 3 (a): Design of Layout1 in Flexsim with Buffer Storage.

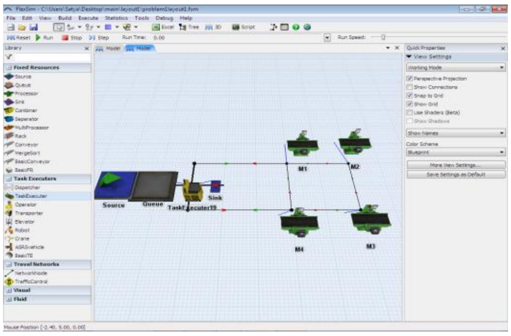


Figure 3 (b): Design of Layout 1 in Flexsim without Buffer storage

Once the layout design is done, the flow path of each job in a particular job is incorporated into the layout as per the schedule data given. This is done by connecting the machine and Load/Unload station as per the job set. Figure 4 shows the connections that are made within the layout.

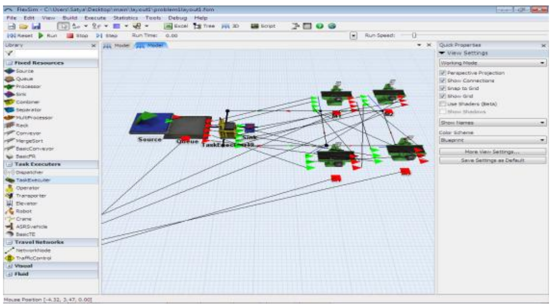


Figure 4: Connection with in the layout 1 for flow of jobs

Once the connections are made, recording of statistical data of various process parameters of the simulation are turned on. Required data is recorded and statistics are plotted accordingly. Similar methodology was adopted for modelling layout 2 and the corresponding results were presented in the next section.

V. RESULTS AND DISCUSSIONS

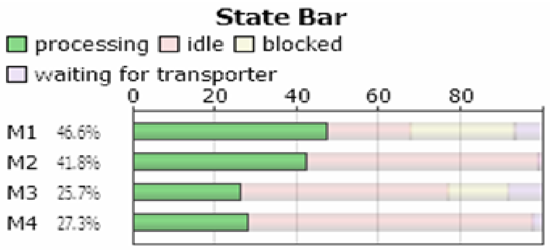
Table 4 illustrates the total make span of different job sets when simulated on both the layouts using Flexsim. It also gives a detailed comparison of results when Buffer storage is used.

Table 4: Comparison of Total Make Span on layout 1 and layout 2 when solved with & without Buffer storage

Jobset	Total Make Span Units Without Buffer Storage.		Total Make Span Units with Buffer Storage.	
	Layout 1	Layout 2	Layout 1	Layout 2
Job Set 1	124.50	122.84	100.88	119.2
Job Set 2	147.00	150.4	122.72	119.59
Job Set 3	144.77	158.80	114.02	110.12
Job Set 4	93.92	101.36	76	99.09
Job Set 5	189.34	189.59	120.48	137.79
Job Set 6	142.86	139.6	99.78	129.25
Job Set 7	205.96	277.5	170.01	230.9

It has been observed that there is significant change in the total make span when the problem was solved with inclusion of buffer storage. It has also been observed that the machine utilization was improved and blockage of machine because of non availability of material handling device was reduced. Figure 5 and 6 gives an elaborated statistical data pertaining to status of machines state bar for job set 1 on layout 1, both when buffers are used and when they are not. It can be clearly observed from the state bar that the blockage time and time spent in waiting for material handling device was reduced.

Statistical understanding of the effect of buffers on the performance of the FMS can be obtained from the following graph representation where data pertaining to Jobset 1 on layout 1 is provided. Similar results have been obtained for all the other jobset when simulated on layout 2.



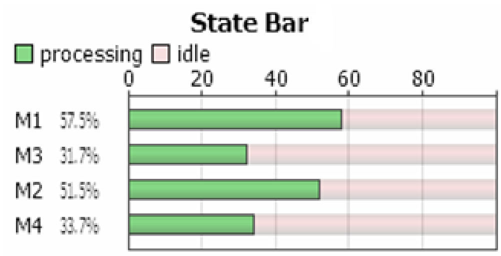
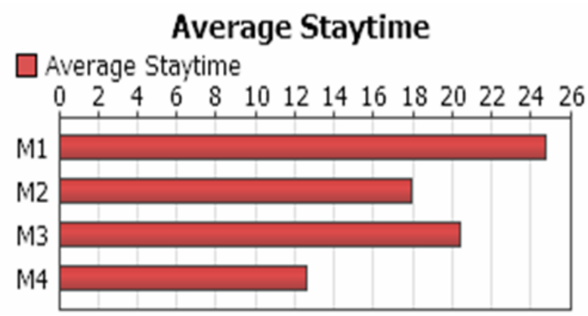


Figure 5: Machine Status for Job Set 1 on layout 1 without Buffers

Figure 6: Machine Status for Job Set 1 on layout 1 with Buffers.

Also the average stay time of jobs on a particular machine has drastically come down, which reduces work-in-process time of a particular machine. Figure 7 (a) and (b) gives a clear understanding of the average stay time of jobs on each machine. Usage of Buffers in the layout reduces the time which a particular job spends on the machine waiting for material handling devices after the completion machining process.



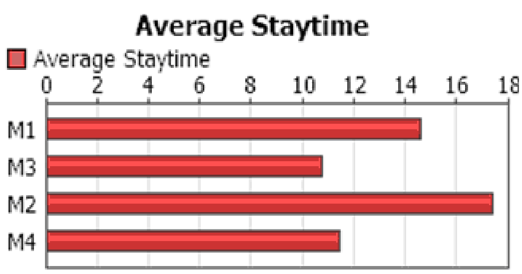


Figure7 (a): Average stay time of jobs for Jobset 1 on layout 1 when simulated without Buffer

Figure 7 (b): Average stay time of jobs for Job Set 1 on layout 1when simulated with Buffer

It has also been observed that the decrease in average stay time of the job at various machines has been compensated with the input buffer and output buffer that have been employed. Figure 8 gives statistical data of the average stay time of different jobs at the buffers of the different machines.

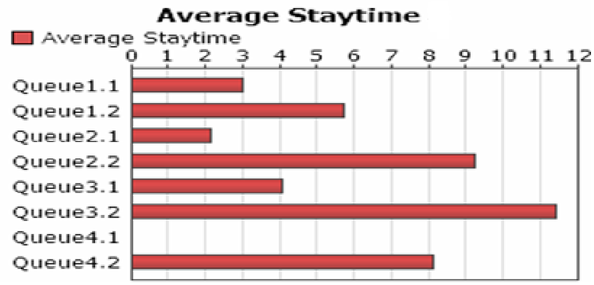


Figure 8: Show the distribution of average stay time of jobs at Input and Output buffers of each machine for JobSet 1 on layout 1.

Table 5 gives a comparison of make span of different job sets when simulated on Flexsim simulation software and the results that are recorded in the standard benchmark problem.

Table 5: Comparison of total make span units obtained from Flexsim with that of Standard Bench Mark problem

Job Set	Total Make Span units as recorded in standard benchmark problem without buffer		Total Make Span units obtained in Flexsim using buffer	
	Layout 1	Layout 2	Layout 1	Layout 2
Job Set 1	123	122	100.88	119.2
Job Set 2	143	146	122.72	119.59
Job Set 3	148	149	114.02	110.12
Job Set 4	100	99	76	99.09
Job Set 5	185	186	120.48	137.79
Job Set 6	136	137	99.78	129.25
Job Set 7	287	288	170.01	230.9

VI. CONCLUSIONS

The purpose of this study is to introduce Buffer Storage in scheduling problem of an FMS layout, which had a relatively positive impact in minimizing the total make span of a job set . The simulation for the give problem statement was done in two ways. Firstly the layouts were simulated without any buffers. The results obtained are compared with those obtained when the layout is simulated with buffer storage at each of the work centers. The results discussed above signifies the importance of Buffer in minimizing the makespan. On layout 1 a maximum of 57.1% minimization of makespan was found for Job Set 5. On layout 2 a maximum of 44% minimization of makespan was fount for Jobset 3. An average of 33.42 % minimization of makespan was obtained from layout 1 for all the job sets, where as for layout 2 average minimization of make span obtained was 17.8%.

From the above results is can be observed that Flexsim as a Discrete Event Simulation software has better potential in exploring the vivid behaviors of various properties in a scheduling problem in an FMS layout. The software simultaneously simulates the complete problem which includes both machine and material handling. Real time situation can be simulated and also being able to solve Dynamic scheduling problem proves capabilities of the software. High statistical accuracy makes it an adequate tool in the field of engineering.

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