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Application of Simulation Model for Distributed Scheduling Problems in FMS

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***Abstract*—The main objective of this paper is to study the Distributed Scheduling (DS) problems in Flexible Manufacturing System (FMS) environment using simulation model. This FMS is assumed to be single factory and multi factory which are analyzed by production capacity, throughput, utilization and work-in-process (WIP) by considering scheduling rules. The rules which are includes Largest processing time (LPT), shortest processing time (SPT), first come first serve (FCFS) and last come first serve (LCFS). Finally these rules are compared with each other and concluded that which rule is better than others with respect to performances in the view of single factory and multi factory. Further the author has suggested future research works too.**

***Index Terms*—Distributed Scheduling, FMS, Simulation, Performance measures.**

I. INTRODUCTION

Recently, many companies have changed their production from traditional single-factory to multi-factory, by building new factory, merging, or through factory acquisition to increase their international competitiveness. These factories may be geographically distributed in different locations, which allow them to be closer to their customers, to comply with the local laws, to focus on a few product types, to produce and market their products more effectively, and to be responsive to market changes more quickly It enhances the utilization of manpower, factories, machines, and raw materials. In addition to companies can achieve better quality, lower production and distribution cost, and reduce the risk of uncertainties. Production scheduling problems are in the level of operations. When a set of demands is actually received and allocated to a factory, production schedule will be generated. This is called single-factory production scheduling problems. Scheduling problems have attracted many researchers since the last three decades. Scheduling in multi-factory network is different from that in single-factory because there is a choice of factories to allocate the jobs. When a set of demands are input to the multi-factory network, different job allocation solutions will result in a different scheduling, operating cost, makespan, etc. James. R.P [1] et.al have considered general flexible manufacturing/assembly/disassembly systems with special features like i) there are several-types, each with given processing time requirements at a specified sequence of machines; ii) each part-type needs to be produced at a pre specified rate; etc. They exhibited a class of scheduling policies implementable in real time in a distributed way at the various machines, which ensure that the cumulative production of each part type trails the desired production by no more than a constant. The buffers of all the machines are guaranteed to be bounded, and the system can thus operate with finite buffer capacities. James.R. P [2] et.al have presented a class of Generalized Round-Robin scheduling policies for which the buffer level trajectory of each part-type converges to a steady state level. Furthermore, for all small initial conditions, they shown that these policies can be Pareto-efficient with respect to the buffer sizes required. Using the bounds for the single machine case, they analyzed performance of regulated systems implementing Generalized Round-Robin scheduling policies .Neil.A [3] et.al have studied Heterarchical manufacturing systems with highly-distributed, real-time control of arrival times of parts exhibit high levels of robustness and adaptability to changes in machine availability, part mix, processing times, and due dates. A general approach is presented for modeling these systems. Examples of multiple-machine and multiple-processing-step systems are presented, illustrating their behavior and closed-form solutions obtained of discontinuous differential equations that represent their dynamics. D. Trentesaux [4] et.al have aimed this paper is to point out some of the abilities of Distributed Artificial Intelligence in the domain of scheduling, control and design support of FMS. A distributed management system is proposed, based on Distributed Problem Solving. In future works, to design a Distributed Decision Support System for integrated scheduling, control and design support of production systems. Felix T.S.Chan [5] et.al have proposed an adaptive genetic algorithm for distributed scheduling problems in multi-factory and multi-product environment. A new crossover mechanism named dominated gene crossover will be introduced to enhance the performance of genetic search, and eliminate the problem of determining optimal crossover rate. A number of experiments have been carried out. The results indicate that significant improvement could be obtained by the proposed algorithm. Chiung Moona [6] et.al have proposed an advanced process planning and scheduling model for the multi-plant. The objective of the model is to decide the schedules for minimizing makespan and operation sequences with machine selections considering precedence constraints, flexible sequences, and alternative machines. The problem is formulated as a mathematical model, and an evolutionary algorithm is developed to solve the model. Numerous experiments are carried out to demonstrate the efficiency of the proposed approach. Felix T.S.Chan [7] et.al have studied the influence of machine maintenance to distributed scheduling problems. This paper designed a hypothetical distributed scheduling model with three different problem sizes to demonstrate the significance of simultaneously solving machine maintenance problem with distributed scheduling problem. They applied Genetic Algorithm with Dominant Genes methodology to solve the model. Several optimization approaches, including

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separating and integrating the two problems, are tested and compared. The results show the merit of integration. Felix T.S.Chan [8] et.al have proposed a genetic algorithm with dominant genes (GADG) approach to deal with distributed FMS scheduling problems subject to machine maintenance constraint. The optimization performance of the proposed GADG will be compared with other existing approaches, such as simple genetic algorithms to demonstrate its reliability. The significance and benefits of considering maintenance in distributed scheduling will also be demonstrated by simulation runs on a sample problem. Esther Alvarez [9] has discussed some specific characteristics of the planning and scheduling problem in the extended enterprise including an analysis of a case study, and reviews the available state-of-the-art research studies in this field. Most studies suggest that integrated approaches can have a significant impact on the system performance, in terms of lower production costs, and less inventory levels. Chun Wang [10] et.al have presented a distributed scheduling algorithm for reactive maintenance of complex systems. The proposed algorithm uses an iterative bidding procedure to assign operations of maintenance jobs to engineers with partially overlapped skill sets. The effectiveness of this proposed algorithm is demonstrated through a computational case study. Prototype implementation and applications to real world domains are discussed. Mehdi Yadollahi [11] et.al has proposed a memetic algorithm for distributed FMS scheduling which considers maintenance problem. The objective of this algorithm is to create a time-cost trade off which is being brought up for the first time. The experimental results show that the optimization performance of this proposed algorithm is 8.85% better than SMGA and also 10.99% better than GADG algorithm.

II. PROBLEM SPECIFICATION AND SIMULATION MODEL

In general DS problem, when the network receives a number of jobs, it has to determine how to allocate them to the suitable factory and generate the corresponding production schedule(s). Each factory has number of machines and can produce all product types with different efficiency. Each job has number of operations, and each operation can be performed on more than one suitable machine (but not all) with different processing time. So, in this paper A single factory and multi factory of FMS have been considered. Table 1 shows a single factory scheduling problem with alternative production routing obtain from Felix.T.S.Chan [8]. It is consists of 5-jobs, 3-machines with corresponding processing time and each job requires 4-operations to be performed for its completion. Each job has to be visit machines based on the routing defined by applying the scheduling priority rules. The process times for each individual operation are defined at each machine. The outputs from the machines are collected at the sink after all operations are over. Similarly Table 2 shows the problem parameters with processing time of operation on different machines taken from Felix.T.S.Chan [8]. It has multi factory (Factory 1 of MF and Factory 2 of MF) which consists of 10-jobs, 6-machines and 2-factories. Each factory consists of 5 jobs and 3-machines with corresponding processing time and each job requires 4-operations to be performed for its completion. The manufacturing systems evaluated through production capacity, throughput, utilization, and WIP by applying various scheduling rules such as LPT, SPT, FCFS, and LCFS.

TABLE I
SINGLE FACTORY SCHEDULING PROBLEM

J 1 O.	m/c no	P T	J 2 O	m/c no	P T	J 3 O	m/c no	P T	J 4 O	m/c no	P T	J 5 O	m/c no	P T
1	1	7	1	1	8	1	1	10	1	2	9	1	1	10
1	3	4	1	2	12	1	2	15	1	3	5	1	3	15
2	2	3	2	3	4	1	3	8	2	1	6	2	2	7
3	1	3	3	1	7	2	2	2	2	3	2	2	3	14
3	3	6	3	2	14	2	3	6	3	2	7	3	1	5
4	1	2	4	1	8	3	1	2	3	3	12	3	2	8

PT: Processing Time, m/c no: Machine number, J 1 O: Job 1 operation, J 2 O: Job 2 operation etc..

TABLE II
MULTI FACTORY SCHEDULING PROBLEM

J 1 O	m/c no	P T	J 2 O	m/c no	P T	J 3 O.	m/c no	P T	J 4 O	m/c no	P T	J 5 O	m/c no	P T
1	1	7	1	1	8	1	1	10	1	2	9	1	1	10
1	3	4	1	2	12	1	2	15	1	3	5	1	3	15
2	2	3	2	3	4	1	3	8	2	1	6	2	2	7
3	1	3	3	1	7	2	2	2	2	3	2	2	3	14
3	3	6	3	2	14	2	3	6	3	2	7	3	1	5
4	1	2	4	1	8	3	1	2	3	3	12	3	2	8
4	2	4	4	3	4	3	3	4	4	1	9	4	1	4
1	1	7	1	1	8	1	1	10	1	2	9	1	1	10
1	3	4	1	2	12	1	2	15	1	3	5	1	3	15
2	2	3	2	3	4	1	3	8	2	1	6	2	2	7
3	1	3	3	1	7	2	2	2	2	3	2	2	3	14
3	3	6	3	2	14	2	3	6	3	2	7	3	1	5
4	1	2	4	1	8	3	1	2	3	3	12	3	2	8
4	2	4	4	3	4	3	3	4	4	1	9	4	1	4

PT: Processing Time, m/c no: Machine number, J 1 O: Job 1 operation, J 2 O: Job 2 operation etc

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The single factory and multi factory distributed scheduling (DS) problems have been modeled using Flexsim simulation software [12] which is shown in Figures 2 and 3 respectively. Finally the entire FMS is simulated with 200000 time units which includes warm-up period of 20000 time units with 10 replications.

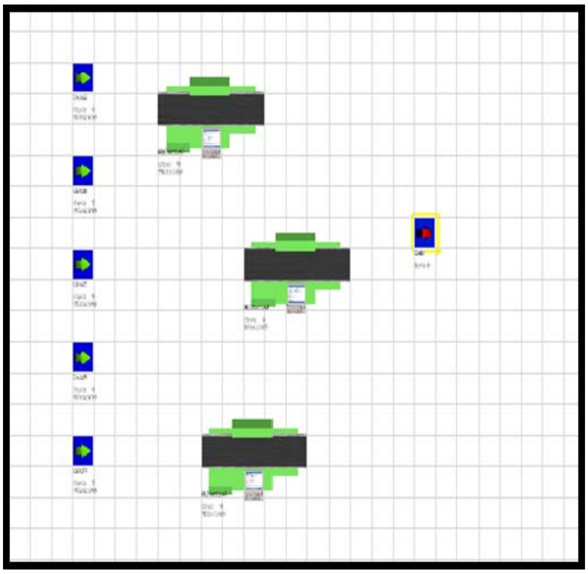

Fig. 1. Single factory model of Flexsim

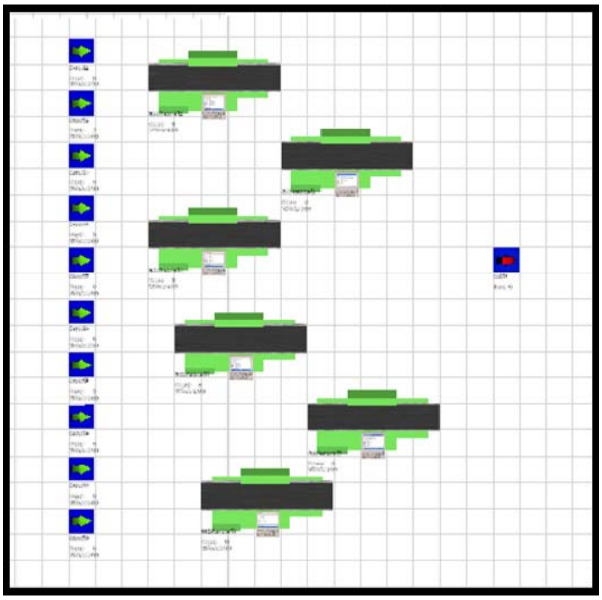

Fig. 2.Multi factory model of Flexsim

Assumptions

1). Each product type can be produced in any of these factories in a different production sequence and operation time.
2). All the operations of each job have to be completed in the same factory. (i.e. factory switching is not allowed)
3).Each machine can handle only one operation at a time.
4).There are no precedence constraints among operations of different jobs.
5).Operation cannot be interrupted. Each operation can only start upon the completion of its preceding operation.

III. RESULTS AND DISCUSSIONS

The results of the simulation were compared and presented in the Tables 3,4,5 and 6.The corresponding bar charts were also plotted and presented the Figures 3,4,5 and 6 respectively. From the Simulation experiments it is indicated that, the performance measures like production capacity, throughput utilization, and WIP have affected by different scheduling rules. These performances measures are discussed thoroughly one by one as follows

It is observed that, SPT rule shows better than all other rules in the case of production capacity. In view of LPT rule, single factory scheduling is better than multi factory scheduling. Production capacity is decreasing by 21.2% in multi factory scheduling when compared with single factory scheduling. Similarly multi factory scheduling shows better than single factory scheduling. Production capacity is 10.9% higher in multi factory scheduling than single factory scheduling. Where as FCFS rule multi factory scheduling is better than single factory scheduling and the production capacity increasing by 9.9% when compared with single factory scheduling. In LCFS rule multi factory scheduling is better than single factory scheduling by 14.8%

TABLE III
OUTPUT VALUES OF PRODUCTION CAPACITY

	Single factory	Factory 1 of MF	Factory 2 of MF
LPT	22500	17717	20455
SPT	22277	21635	24725
FCFS	18442	20270	16791
LCFS	20833	23936	17578

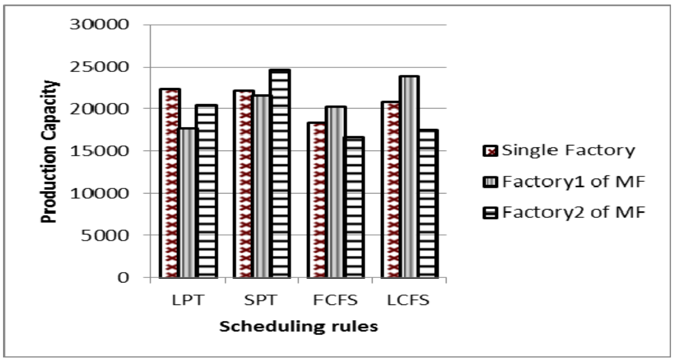

Fig. 3. Effect of Production capacity with scheduling rules

It has been observed that, Maximum throughput is obtained from multi factory scheduling by applying FCFS rule. Throughput is increased by 40.2% in multi factory scheduling than single factory scheduling with respect to LPT rule. Further throughput is increased by 3.1% in multi factory scheduling than single factory scheduling in the view of SPT rule. Finally throughput is increased by 18.2% in multi factory scheduling than single factory scheduling in FCFS rule. Throughput is decreased by 6.7% in multi factory scheduling when compared with single factory scheduling in LCFS rule.

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TABLE IV
OUTPUT VALUES OF THROUGHPUT

	Single factory	Factory 1 of MF	Factory 2 of MF
LPT	2703	3605	3791
SPT	2550	2631	2581
FCFS	3814	4511	3287
LCFS	4012	2826	3743

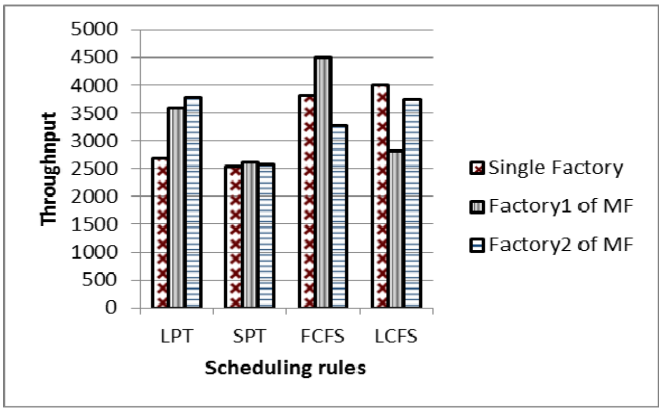

Fig. 4. Effect of throughput with scheduling rules

It has been seen that, Maximum utilization obtained from multi factory scheduling by applying LCFS rule. Utilization increased by 12.5% in multi factory scheduling than single factory scheduling in LPT rule. In SPT rule utilization decreased by 38.6% in multi factory scheduling. Utilization decreased by 3.73% in multi factory scheduling than single factory scheduling in FCFS rule. In LCFS rule also utilization decreased by 52.5% in multi factory scheduling.

TABLE V
OUTPUT VALUES OF UTILIZATION

	Single factory	Factory 1 of MF	Factory 2 of MF
LPT	37.06	41.7	36.15
SPT	34.34	24.09	21.07
FCFS	48.2	38.4	46.4
LCFS	57.7	27.4	37.3

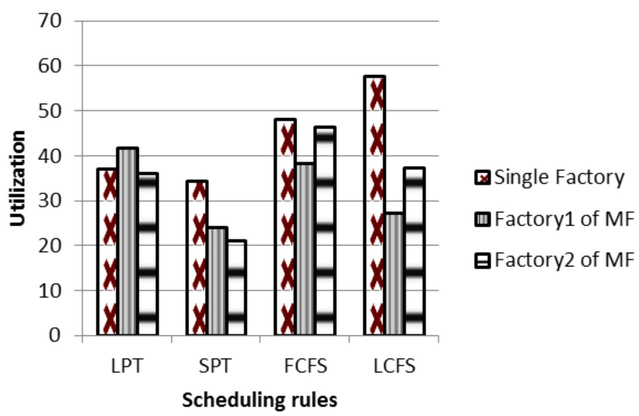

Fig. 5 . Effect of utilization with scheduling rules

It is observed that, Work-in-process (WIP) is low in multi factory scheduling in SPT rule. In LPT rule WIP increased by 13.5% from single factory scheduling to multi factory scheduling. In SPT rule WIP reduced by 38.8% in multi factory scheduling. In FCFS rule WIP reduced by 4.8% in multi factory scheduling. In LCFS rule WIP reduced by 35.8% in multi factory scheduling.

TABLE VI
OUTPUT VALUES OF WIP

	Single factory	Factory 1 of MF	Factory 2 of MF
LPT	111	126	111
SPT	103	72	63
FCFS	145	114	138
LCFS	173	81	111

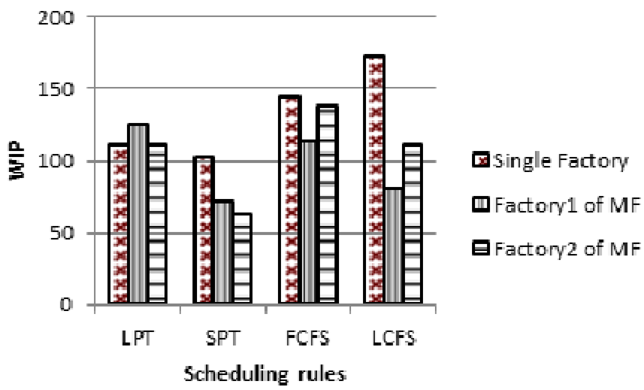

Fig. 6 . Effect of WIP with scheduling rules

IV. CONCLUSIONS

In this paper an attempt have been made to compare single factory and multi factory in FMS with respect to scheduling rules using Flexsim as a simulation software. The author has drawn conclusion that, multi factory scheduling is better than single factory scheduling in many aspects. SPT scheduling rule shows better than the other scheduling rules in the view of production capacity. Maximum throughput is obtained in multi factory by applying FCFS rule. Maximum utilization is observed in multi factory by applying LCFS rule. Similarly WIP shows minimum in multi factory by using SPT rule. So it nut shell the multi factory scheduling is better than the single factory scheduling by obtaining maximum production capacity, maximum throughput, maximum utilization and minimum WIP. In future this problem can be extend by considering flexible job shop scheduling, breakdown analysis, cost analysis, more scheduling rules, validate with soft computing tools.

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