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Performance Evaluation of Flexible Manufacturing Systems: A Case Study

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--ABSTRACT--
Modern Manufacturing industry is fast becoming technologically complex. Integration of computers in manufacturing industry has transformed it and modern manufacturing systems like Flexible Manufacturing Systems (FMS) are emerging. The term (FMS) usually refers to a set of processing workstations (e.g. CNC machines), inter-connected by an automatic material handling and storage system and where a distributing computer system controls the process. FMS is called 'flexible' because of its ability to process a range of different parts at different work-stations simultaneously, along with different styles and production quantities can be adjusted to the change in demands. Simulation is a popular approach to study the performance of FMS. In this study, a simulation model of the case study FMS has been developed by using a software tool "Arena for studying three selected performance measures namely WIP (Work in Process), Cycle Time (CT) and Throughput Rate (Th) of the system. From simulation model, the values of WIP, CT and Th were found to be 4.2937 Jobs, 33.4176 minutes and 5 Jobs respectively

KEYWORDS: Flexible Manufacturing Systems, Performance measures, Arena Simulation

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I. INTRODUCTION

Modern Manufacturing industry is fast becoming technologically complex. Integration of computers in manufacturing industry has transformed it and modern manufacturing systems like Flexible Manufacturing Systems (FMS) are emerging. The term (FMS) usually refers to a set of processing workstations (e.g. CNC machines), inter-connected by an automatic material handling and storage system and where a distributing computer system controls the process. FMS is called 'flexible' because of its ability to process a range of different parts at different work-stations simultaneously, along with different styles and production quantities can be adjusted to the change in demands. (Groover MP, 2014) Although a number of benefits are claimed to have been realised by FMS, yet successful implementation of FMS is not without problems. FMS implementation problems are related to their design, planning,

scheduling, and control issues. It is, however, desirable to evaluate the performance of FMS.Simulation is a popular approach to study the performance of FMS. Computer simulation is the imitation of a dynamic system using a computer model to analyse, evaluate and improve system performance (Law A, M. 2008). Several studies have been conducted for simulation-based analysis of FMS. (Abdulziz M et al, 2012) (Kashif M et al, 2017). For reliable and valid performance analysis of FMS, it is, however, necessary that simulation models must be validated by real life cases. In this research, a simulation model of the case study FMS has been developed by using a software tool "Arena by Rockwell Automation (Law A, Kelton D, 2000). Three performance measures of the system were selected. The selected performance measures were WIP (Work in Process), Cycle Time (CT) and Throughput Rate (Th). The values of these measures were obtained from Arena model and were validated by comparing with empirical results. The subsequent sections detail an over view of FMS, objectives of research, research methodology and conclusion.

II. FLEXIBLE MANUFACTURING SYSTEMS (FMS)

An Overview: Flexible manufacturing system consists of computer numerical controlled machines that perform various operations on group of parts. Moreover, the system is provided with an automatic material handling system. CNC work stations and material handling systems are controlled by a central computer. FMS are highly complex automated system as shown in figure 1.1 (Abdulziz M et al, 2012)

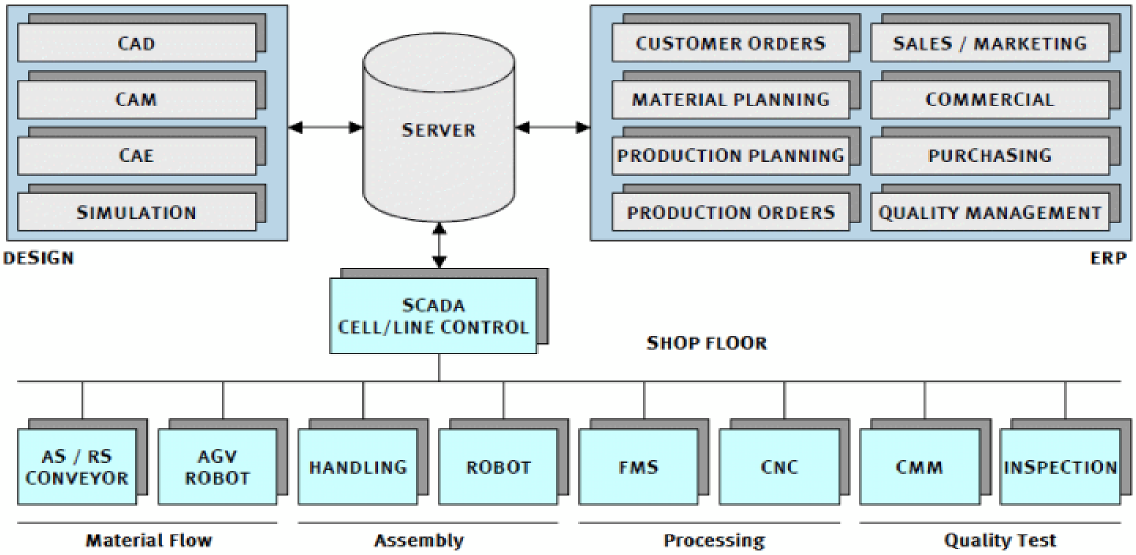

Fig. 1 Modular flexible manufacturing system block diagram

"FMS automatically transfers pallets between work stations, storage system and loading and unloading system. The core of FMS is s sophisticated control software that can schedule production, manage and transfer programs and run unmanned production" (Hermaste et al, 2014) In FMS multiple part types can be loaded on to the system simultaneously because machines have the prior information about tooling and processing information to work on any part. Parts can arrive at individual machines in any sequence by reading a code on the part.

Performance measures of FMS: Flexibility in manufacturing system is generally expected to improve its performance. The claimed benefits of FMS include better machine utilization, reduced manufacturing cycle times, greater labour productivity, lower inventory requirements, greater responsiveness to changes, less labour requirements (Kashif M et al, 2017). The claimed benefits of FMS can be justified by evaluating their performance. Although manufacturing systems can be analyzed for various performance measures, however, work in process (WIP), Manufacturing Cycle Time (CT) and Throughput rate are often considered their key performance indicators (Askin R. and Standidge C. 1993)**.** These three key performance measures are considered in this study.

III. LITERATURE REVIEW

(Kashif M et al, 2017) in their study identified common performance measures for FMS. These Machine utilization and manufacturing cycle time. They evaluated the performance of FMS by using IDEF modelling language and simulation techniques. In another study, (Abdulziz M et al, 2012) used Petri net and bottleneck analysis techniques for performance measures for FMS. They evaluated the utilization and overall productivity of a FMS. (Fei Xiong and Jin Yao, 2014) measured the cycle time and throughput rate of a FMS using simulation approach. They developed a Heuristic Algorithm to find the throughput rate as a function of WIP level.

Many researchers have used Arena for simulation-based performance analysis of FMS. (Adriana F. et al 2017) proposed an approach for estimating operational parameters of a FMS. They developed an Arena model to test their proposed approach. They demonstrated through simulation how machine utilization can be improved in case of FMS. Kumar G. and Bisoniya T.S, 2015) developed an Arena model for analyzing scheduling problems of FMS. They used genetic algorithm to optimize scheduling of FMS. (M. Arshad and Milana, 2016) proposed a simulation model for evaluating scheduling rules for FMS. Using different layout configurations, they concluded that FMS layouts have marginal effect on performance measures of FMS. (Ainaz Ebrahimi et al, 2015) used a Network Analysis approach for determining the optimal performance of FMS. They analyzed an existing system and suggested the measures for optimization of the performance based upon combined network analysis and simulation approach. (Pandey R and Singh A, 2016) evaluated the utilization eff AVGs in FMS environment. They developed and simulated an Arena model of job shop manufacturing.

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Problem Statement and Objectives: In flexible manufacturing systems each machine cell can perform many different operations under various operational conditions. Analyzing the performance of machine cells under different operational conditions is key to the optimization of flexible manufacturing systems. In this research a case study FMS will be analyzed for three performance measures namely throughput rate, cycle time and work in progress (WIP).

Followings are the objectives of the study.

1. To study performance measures of FMSs
2. To build simulation model of the FMS under study
3. Validation of Simulation model

IV. CASE STUDY

Description of the FMS under study: The FMS modelled in this study is installed at department of Industrial Engineering and Management in Mehran University of Engineering & Technology, Jamshoro. Sindh, Pakistan. The system model is BenchMill 6100 and manufacturer is Intelitek, a USA based company. The system is a versatile PC-based benchtop CNC machining center that enables to deliver robust instruction in computer numerical control and advanced manufacturing. (Manufacturer's Description, web source).

Figure 2: A complete view of the system

Simulation Model : Simulation model was developed in software tool, Arena. The system is modelled as serial system of three interconnected working stations i.e. A loading Robot CNC Milling Machine and an Unloading Robot. Figure 3 shows the Arena modules for system components

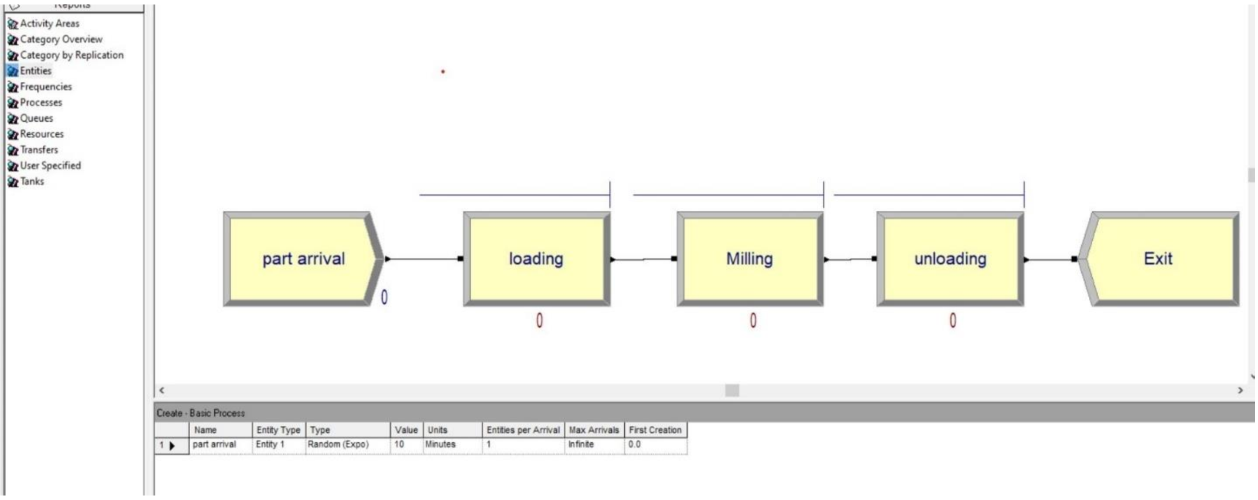

Figure 3: Arena modules for system components

Mean arrival rates and mean serve rates used for various workstation are given in the table below.

work station	**Mean Arrival Rate (λ)**	**Mean Service Time (μ)**
Loading Robot	5	3
CNC Milling	3	10
Unloading Robot	10	5

Table 1: Input Parameters of the Simulation Model

The model was run for a single simulation replication with a length of four runs. Figure 4 shows the simulation run setup for the model.

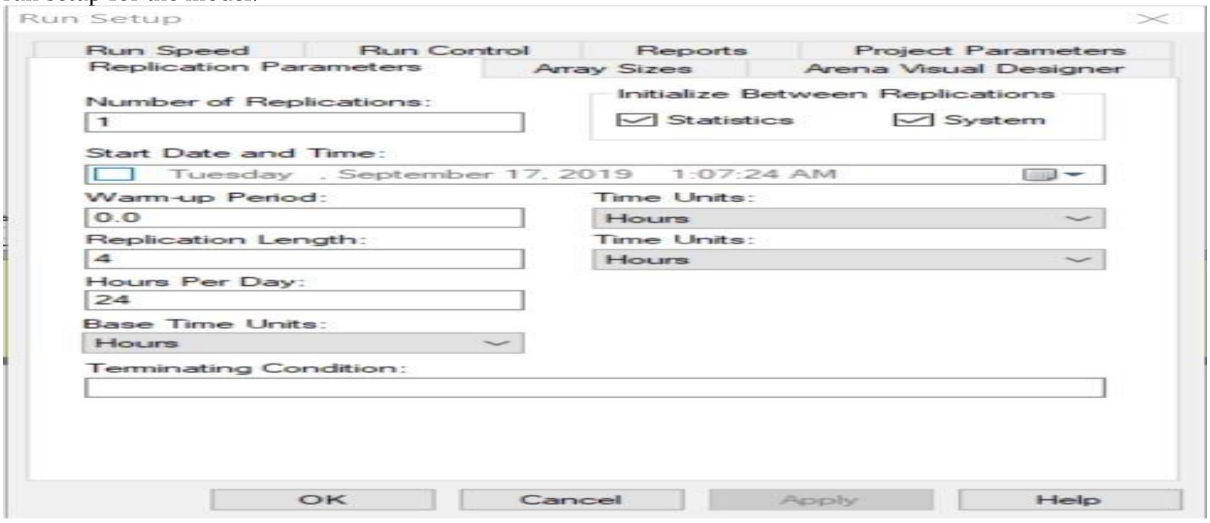

Figure 4: Simulation run setup for the model

Figure 5 shows the simulated queue of the entities.

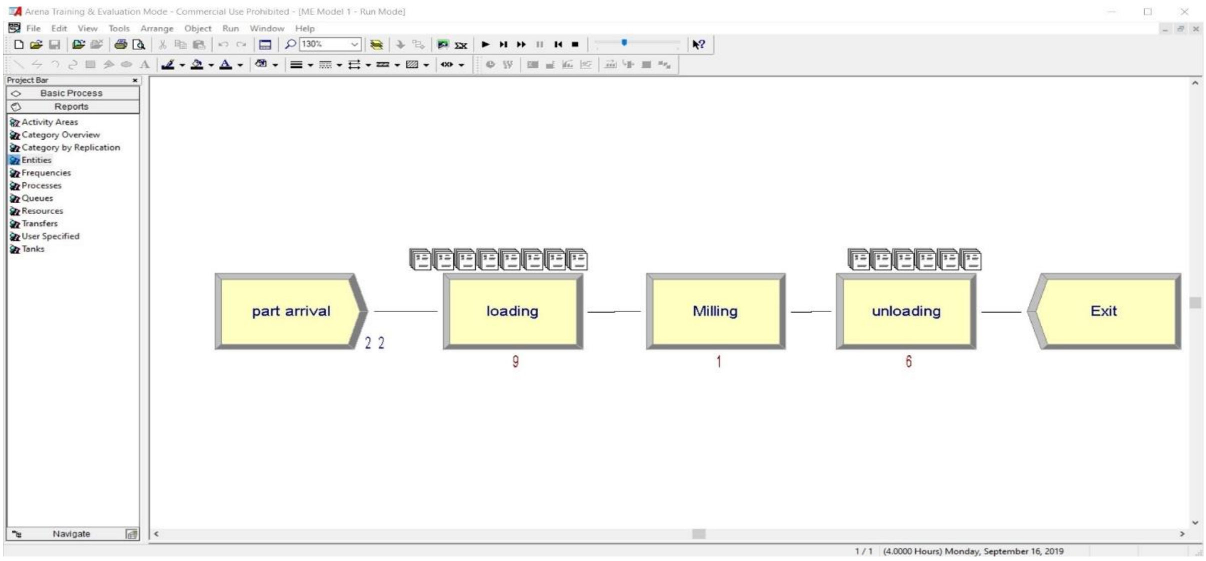

Figure 5: Simulated queue of the entities

Simulation results are shown in the table below

WIP	**Cycle Time**	**Throughput (Th)**
4.2937 Jobs	**33.4176 Minuets**	**5 Jobs**

Table 4.: Results of the simulation model

V. CONCLUSION

Results: Various performance measure for FMS were studied in literature and three measures were selected i.e. WIP, Cycle Time and Throughput. A simulation model of the system was developed using software tool, Arena and the values of WIP, Cycle Time and Throughput were calculated based upon simulation. The simulation results were compared with empirically observed results. The comparative results are given in the table 5

Parameter	Empirical Results	Simulation Results	% Difference
WIP	5 Jobs	4.2937 Jobs	0.70 (41 %)
Cycle Time	33.624 Minutes	33.4176 Minutes	0.2064 (0.61%)
Throughput	5	5	No difference

Table 5: Emrical and Simulation Results of the model

It can be seen that there is narrow difference between the empirical and simulation results of WIP and Cycle Time and no difference in Throughput. For WIP the difference is 0.7 which is of the range 14 %. For Cycle Time the difference is still narrow i.e. 0.2064 which is in the range of just 0.61 %. Similarly, for throughput there is no difference. Hence both the empirical and simulation results are consistent with each other. Moreover, at given rate of arrival of jobs and processing times, throughput rate is 5 jobs per hour.

From these findings following conclusions can be drawn:

1. High is the ratio of arrival to processing time, better would be the throughput rate of the system.
2. It implies that conveyer and loading robot should be regularly maintained for maintaining the arrival to processing ratio of loading robot.
3. Mechanism of tool shift for the system should be regularly maintained for keeping the arrival to processing ratio constant.

Future Work : From the present findings, this work can be advanced along the following directions.

- Besides three key performance indicators of FMS selected in this study, other performance measures such as server utilization can be found.
- The Model can be tested with more arrival rates and service rates and for various probability distributions.

Agent base simulation approach can be tested. A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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