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IMPLEMENTATION OF FMS SIMULATION IN A VIRTUAL ENVIRONMENT

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ABSTRACT

Flexible manufacturing system is a system that is able to respond to changed conditions. In general, this flexibility is practiced in many industries. This present study explores the FMS in a virtual environment from the original real time data obtained from a selected industry. The discrete event simulation software arena is used to simulate the production data to obtain the practical approach of FMS in real time environment. The first category is the so called machine flexibility which enables to make various products by the given machinery. The second category is routing flexibility enabling to execute the same operation by various machines. Flexible manufacturing systems usually consist of three main parts: CNC machine tools, transport system and control system. The run results satisfy and match the real time results in a flexible manufacturing environment.
Key Words- Cell layout, FMS, CNC, and Arena

I. INTRODUCTION

The first applications of flexible manufacturing systems in early 1960's have introduced the philosophy of flexibility in manufacturing; the key term to attain a cost effective production, with emphasis on quality and customer oriented production with shorter product delivery times. The process of constructing an FMS is costly as it requires heavy capital investment in machinery and equipment. Because of that, the design of FMS's requires an intensive work on planning an efficient and effective system. Simulation shows up at this stage providing managers with a tool that helps to evaluate the results of different configurations of hardware and software for the production of a variety of available products [1]. Simulation helps find optimal solutions to a number of problems at both design and application stages serving to improve the "flexibility" of FMS's [2].

Although the application of simulation into FMS's is inevitable due to its benefits, it is not an easy one. The stages of modeling can be considered as art rather than science and therefore it is the task of researchers. However, the flexibility requirement of FMS necessitates the dissemination of every activity that concerns production throughout the levels of a company [3]. Due to this fact simulation models are in interaction with almost every level of employee starting from workers and craftsmen, up to higher levels in the management, either in terms of preparing models or evaluating results [4]. This problem of enterprises can be overcome through the use of custom interfaces and integration of simulation software with every day-use programs.

II. FLEXIBLE MANUFACTURING SYSTEMS

Increasing expectations of today's customers involving the quality and variety of produced goods are becoming more and more critical on the market. The fast changing tendencies on the market results in a shortened life cycle for products and a competitive market that forces the manufacturers to explore new markets to sell the goods [5]. The requirements of the market necessitate the introduction of changes in the organization of production processes, through the launch of automation, computer aided design and manufacturing works and management, and the development of modern multi-stand machining systems, such as Flexible Manufacturing Systems (FMS) [6].

FMS is defined as a computer-controlled configuration of semi-dependent workstations and material-handling systems designed to efficiently manufacture various part types with low to medium volume [7]. It is an integrated production system composed by a set of independent machining centers. An automatic part handling system interconnects the machining centers to a group of part-storage locations such as loading/unloading positions and input/output buffers. A central supervisor (the FMS control software) monitors and manages the whole system [8]. The work pieces in FMS are usually complex, and can require complicated manufacturing steps. Production of the various parts requires processing by different combinations of manufacturing, but FMS is versatile and can perform different operations on a variety of products. Often an FMS machine can perform many processing steps. Another approach finds the number of tools and then reduces that number by cost control methods. Standardization of tools, their kind and quantity, and specifications are a natural development of FMS [9].

III. PRODUCTION AND MANUFACTURING

One of the largest application areas for simulation modeling is that of manufacturing systems, with the first uses dating back to at least the early 1960's. Since then, it has been used effectively in the design and analysis of manufacturing systems. Law (1999) has identified specific issues that simulation is used to address in manufacturing [10]. The need for and the quantity of equipment and personnel such as number, type, and layout of machines for a particular objective, Requirements for transporters, conveyors, and other support equipment (e.g., pallets and fixtures), Location and size of inventory buffers, Evaluation of a change in product volume or mix, Evaluation of the effect of a new piece of equipment on an existing manufacturing system, Evaluation of capital investments, Labor-requirements planning, Number of shifts.

As seen from the above discussion, manufacturing and production offers a huge number of issues to deal with. The work of Williams (2002) is important as it presents the usefulness of simulation in studying the impacts of system failures and delays on the output and cycle time of finished parts [12]. Patel et al (2002) have used discrete event simulation for analyzing the issues of first time success rate, repair and service routing logic, process layout, operator staffing, capacity of testing equipment and random equipment breakdown in automobile manufacturing processes. They offer concepts and methods for discrete manufacturing processes especially for the Final

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Process System for optimizing resources and identifying constraint [13]. Altinkilic (2004) has presented a use of simulation to improve shop floor performance [14]. The performance of the existing system is evaluated by using ARENA®. Due to the motivation for redesigning the shop flow, manufacturing cells are performed and the performance of the new system is evaluated and compared with that of the current system. As a result, based on a simulation analysis, several recommendations are made to the management of the mentioned job shop production system.

IV. FMS SIMULATION

Simulation has found a great deal of concern in FMSs. Usually the need of simulation arises with the questions to be answered when planning an FMS. Some of these problems concern the design of the system, while others relate to its operation. It is important, especially when building simulation models of systems, to recognize that different types of problems necessitate different types of models. Consequently, a framework within which the various problems can be placed so that similar problems can be addressed with similar types of model is needed. One of the most appropriate in the present context is that by Van Looveren et al. (1986) who identify six problems and three levels of planning [15] such as Strategic Planning, Tactical Planning, and Operational Planning.

V. PROBLEM DEFINITIONS

In this present study, the computer simulation study performed in a pilot Flexible Manufacturing Cell to investigate the application of simulation into Flexible Manufacturing Systems is to be presented. The complete integration of the existing system with the developed simulation models is not currently realized however it is proposed as a future development. The concentration is devoted to the integration with auxiliary programs to ensure usability of the developed models by inexperienced users. The feasibility of integration at this stage is demonstrated by designing, developing, and implementing and showing that it can be customized to be used for

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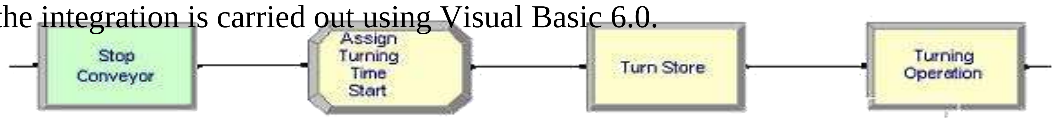
simulation in FMS. The simulation part is realized by using SIMAN and ARENA 7.0 and the integration is carried out using Visual Basic 6.0.



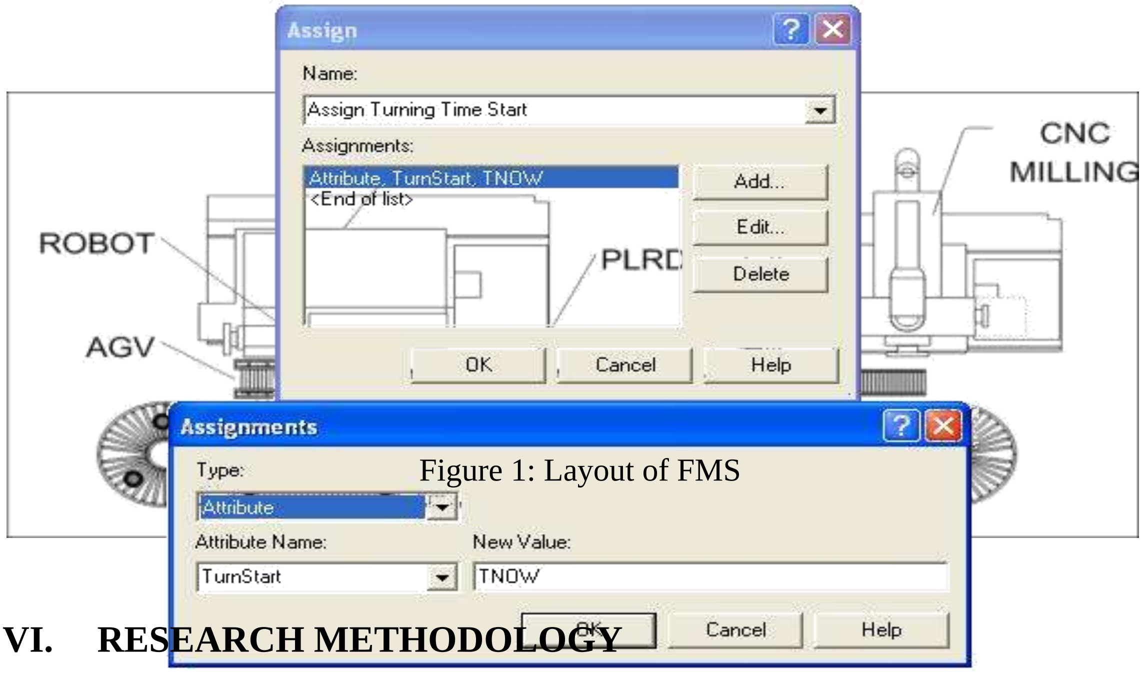


Figure 1: Layout of FMS

VI. RESEARCH METHODOLOGY

To achieve the set objectives for the present research work, a unique methodology based on the real time simulation with the help of real time data is being used. The system layouts are developed and defined critically on ARENA simulation software. Systems to be simulated are quite diverse in terms of size and complexity. However, regardless of how complex a discrete-event system may be, it is likely to contain some basic components that are also common to flexible manufacturing systems. The structural components of a discrete-event simulation include entities, activities and events, resources, global variables, a random number generator, a calendar, statistics collectors and animation [16]. These structural elements and their relations with flexible manufacturing systems are described in the following sections. The models generated throughout the study are used as examples to demonstrate the methods of application for modeling and simulation.

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Figure 2: Attribute assignments for statistical purposes

VII. SIMULATION STRUCTURE

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VIII. RUN RESULTS

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Test runs are made by using the specified parameters in the preceding section. Part process plans are used in the runs. The statistical results of the runs under 6 different scheduling algorithms are given on the following tables. Table 1 gives the average values for the selected performance measures. These values are taken from the Export Data Module's of the corresponding models.

Table 1: Average of performance measures

	FCS	**FCFS**	**EDD**	**SPT**	**LPT**	**PRI.**
(in minutes)			TALLY VARIABLES			
Lateness Value	66.261	48.517	34.492	36.571	56.545	39.800
Earliness Value	19.120	63.181	30.451	30.541	30.782	31.810
Turning Times	6.683	6.675	6.678	6.687	6.687	6.685
Milling Times	3.496	3.505	3.505	3.501	3.501	3.496
Machining Times	7.634	7.635	7.638	7.641	7.641	7.632
Time in System	102.830	56.814	57.897	57.094	75.363	63.518

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Total Makespan	1236.55	1159.46	1157.99	1151.01	1155.15	1151.95
	DISCRETE-CHANGE VARIABLES					
Milling Utilization	0.212	0.255	0.253	0.256	0.254	0.254
Turning Utilization	0.405	0.442	0.445	0.447	0.449	0.448
Conveyor Utilization	0.020	0.227	0.237	0.236	0.258	0.223
Robot Utilization	0.243	0.331	0.324	0.333	0.333	0.334
Number in AGV	7.323	0.903	0.871	0.825	2.086	1.570

In addition to the average values of the performance measures, some of the statistics are important from the point of number of occurrences such as the number of late parts and early parts. Each delivers different costs to production, although it is out of scope of this study.

Table 2: Number of occurrences for important performance measures

	FCS	**FCFS**	**EDD**	**SPT**	**LPT**	**PRI.**

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	TALLY VARIABLES					
Lateness Value	85	41	60	57	65	57
Earliness Value	15	59	40	43	35	43

Additionally, the numbers of schedules for the robot and the turning and milling machines is important. The scheduling of the components can incur fixed costs and from maintenance point of view they need to be traced. As the number of parts and their respective plans are same for all the scenarios these values are also the same for all runs.

Table 3 Number of schedules for hardware components

	Turning Machine	**Milling Machine**	**Robot.**
Number Scheduled	75	75	500

Some statistics are important considering the resulting maximum values. The maximum time parts spend in system and the maximum lateness values are important for tracing the system performance and the maximum number of parts on the AGV is important to define the incoming part capacity for the static buffer.

Table 4 Maximum values for important performance measures

	FCS	FCFS	EDD	SPT	LPT	PRI.
(in minutes)	TALLY VARIABLES					
Lateness Value	138.52	138.39	109.79	168.14	285.37	153.00
Time in System	154.28	163.71	170.12	225.33	297.06	246.53
	DISCRETE-CHANGE VARIABLES					
Number in AGV	12	6	6	5	10	13

When the tardiness values are concerned it is observed that the EDD principle provides the minimum average for lateness values, which is an expected result. The long waiting times in SPT and LPT algorithms increase the time in system values for specific part types, which in turn increases the lateness values. The "only one part in system" principle of FCS results in elevated values for all time dependent statistics except earliness values. The use of EDD does not guarantee the minimum number of tardy jobs. This fact is seen on Table 2 as the minimum number of tardy jobs is attained in the FCFS rule. This is not a surprising result as the due dates are dependent on the system entrance time.

Turning, milling and consequently the machining times are almost equal for all sample runs as the part numbers and types used in all the runs are the same. The importance of this statistics arises when the total manufacturing times are compared with make spans of the parts. In the best configuration that minimizes the time in system of the parts, FCFS rule, the average manufacturing time is about 14% of the average make span of the parts. In the most unfortunate case this value drops to about 7.5 %. The effect of this fact demonstrates itself through low utilizations of machines.

The utilization of turning and milling machines are about 45% and 25% respectively and do not differ in significant amounts from one scenario to another. This is also an expected result, as the scenarios directly affect the system entrance sequences for parts and there is no machine dependent sequencing. Another fact identified through these utilization and machining times' values is that the system is highly transportation and storage means dependent as most of the time parts spend in the system are due to waiting on the conveyor.

The number in AGV statistic is important to identify the AGV capacity. As expected, The FCS scenario results in the most number of both average and maximum parts on the AGV as only one part is accepted into the system. The LPT and priority scenarios also cause elevated number of parts waiting on AGV as less prior parts or, parts with short processing times are forced to stay on the AGV for long times. The maximum number of parts on AGV is also

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important as the capacity is directly dependent on this value. The SPT scenario results in the least number of both maximum and average entities on AGV.

It is obvious that the results obtained are production order dependent and are subject to change. Considering all those results, an objective function can be determined according to the requirements of the management of the FMS. Before realizing the production orders on the actual FMS, these orders can be processed on the models and according to the results of the runs a production scheme can be figured out.

IX. CONCLUSION AND FUTURE WORKS

This research on Computer Integrated Manufacturing is mainly focused on the implementation of a flexible, re-configurable simulation and modeling system. It focuses on realizing the modeling and simulation of Flexible Manufacturing Systems. The models developed throughout the study are used to come up with different scenarios of production and sample results and decisions about production issues that can be attained through the use of simulation are provided.

Simulation is expected to increase its strength and area of application through integration with other tools. These other tools will include spreadsheets, statistical analysis software, mathematical optimizers, programmable logic designers, robotic software, or process flow layout and analysis tools. With this motivation in mind, the scope of the work is extended to comprise the development of methods and applications to be used for linking a simulation package, ARENA®, to less advanced programs such as text editors and Microsoft Office® programs with the development of custom interfaces to provide a fast and effective decision support tool for every level of a company. This combination provides the users with a tool that is fast to use and easy to maintain for the assessment of performance measures for FMS.

The actual aim to be expected from a simulation study is its supplying a scientific basis for making decisions about the modeled system. As the final component of the study, sample simulation runs under different scenarios of production are presented. The preparation procedure of the runs and the interpretation of the results obtained through the developed software are important to provide an idea on the effective use of simulation in manufacturing systems.

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