A brief review of Flexible manufacturing system in terms of simulation approach

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Abstract:

The aim of this present paper is to brief review for a flexible manufacturing system (FMS) cell. Operational devices used in the manufacturing are elaborated including basic introduction of flexible manufacturing system and its advantages. The review focuses mainly on simulation methods carried out in different stages. Different important models used in flexibility are discussed in length. Applications and approaches used to solve the problems encountered in the FMS. The aim of paper is to explore the research gaps in flexibility and further the potential for future work. The paper concludes with the summary of review on flexible manufacturing system.

Key Words: *simulation, Operational Device, MES*

INTRODUCTION

Flexible Manufacturing System (FMS) is a group of several machines or process dedicated to produce a group of objects that common which the ability is flexible for a similar group objects in process, such as their operation, tolerance, and the capacity of the machine tool. It is called flexible because it has good flexibility in machine capability, these sequences or alternative in process, product, production, and its development. A flexible manufacturing system (FMS) is an automated manufacturing system consisting of a set of numerically con- trolled machines with automatic tool interchange capabilities, linked together by an automated material handling system [Guerrero, 1999]. Now a day and future challenges in industrial activity is the ability of speed and precision to produce a product and provide services in a wide range of demands which are always want to customize. This is often faced as an industrial problem, especially if associated with the price and speed to the marketing competition in terms of delivery, it should better than the competitor. So the total unit cost has to become lower, delivery time faster and the product life cycle shorter significantly. This problem is often solved with the building automation system to produce products with customized, but the process cost is near to mass production, of course the target speed and accuracy will remain achieved. One of the automation systems in the manufacturing sector is Flexible Manufacturing System (FMS) for complex components with diverse (multi) variations machining process. Many decisions for an FMS operation should be appropriately made to improve resource utilization [Stecke, 2001; Das, 2009]. Maimon and Gershwin [Maimon, 1988] pointed out that it is very important to determine the loading and routing plans before FMS scheduling is performed. A considerable body of research literature has accumulated on FMS area since the late 1970's when the first papers were published. A few surveys of the literature have also appeared (Buzacott and Yao 1986, Rachamadugu and Stecke 1989, Gupta *et al.* 1989).

Not much work has been done to develop analytical models that deal with the concepts of flexibility rigorously and of course, to determine the optimal levels of flexibility (Slack 1987). As a result, the measures proposed in the literature are naive and, at times, somewhat arbitrary. United States shown an astonishing lack in many cases, they perform worse than the conventional technology they replace. The technology itself is not to blame; it is the management that makes the difference" (Adler 1985). Baranson (1983) argues that the global view held by Japanese firms towards marketing and production explains why the managers there take a long-term and comprehensive view towards capital investments that considers not only cost savings in labor, material, and space, but more significantly the broader strategic implications of increased flexibility (to respond to changes in consumer demands and competitive threats) and versatility in designing and producing of products (De Meyer et al. 1989). Empirical evidence also supports the view that flexibility does not get its proper due at the time of decision making with regard to investment in manufacturing technology (Lim 1987; Krasa and Llerena 1987).

ADVANTAGES of FMS

There are many more advantages of FMS however; the main advantage of the flexible manufacturing system is its high flexibility in management of production facilities and resources (time, machines and their utilization, etc.). The largest application of these systems is in the area of small batch production where its efficiency is getting near to the mass production efficiency. Its disadvantage is the high implementation price. The most important feature of FMS is not its high degree of automation but its flexibility [Guerrero, 1999]. A variety of objectives have been considered in process planning problems such as machine workload balancing, minimization of part movements, cost optimization, minimization of total processing time, maximum resource utilization, etc. [Grieco, 2003; Chen, 2005]. There are various approaches to the term flexibility of manufacturing systems. The most frequent meaning of this term is described as follows:

- Possibility of production program change without any significant alteration of machinery (new NC program, eventual tool change),
- Speed of production program change from previous product line to new products,
- Possibility to change production program at level of individual products.

OPERATIONAL DEVICES FOR FMS

A flexible manufacturing system (FMS) is a group of numerically controlled machine tools, interconnected by a central control system. The various machining cells are interconnected, via loading and unloading stations, by an automated transport system. Operational flexibility is enhanced by the ability to execute all manufacturing tasks on numerous product designs in small quantities and with faster delivery. It has been described as an automated job shop and as a miniature automated factory. Simply stated, it is an automated production system that produces one or more families of parts in a flexible manner. Today, this prospect of automation and flexibility presents the possibility of producing nonstandard parts to create a competitive advantage. The concept of flexible manufacturing systems evolved during the 1960s when robots, programmable controllers, and computerized numerical controls brought a controlled environment to the factory floor in the form of numerically controlled and direct numerically controlled machines.

For the most part, FMS is limited to firms involved in small batch production or job shop environments. Normally, small batch producers have two kinds of equipment from which to choose: dedicated machinery or un-automated, general purpose tools. Dedicated machinery results in cost savings but lacks flexibility. General purpose machines such as lathes, milling machines, or drill presses are all costly, and may not reach full capacity. Flexible manufacturing systems provide the small batch manufacturer with another option one that can make small batch manufacturing just as efficient and productive as mass production. Flexible manufacturing system with robot operation for environment of drawing-free production (therein after only FMS) will be represented by the model CIM (Computer Integrated Manufacturing) in conditions of UVSM MTF. It is a systemic approach to planning, management and production itself. The target is to gain experience in these fields at the level of a manufacturing system as a unit (Erika, 2010 & Marcela, 2009). In practice, these experiences, if accepted, can considerably increase competitiveness of industrial companies. Such a competitiveness increase will result from higher efficiency in planning, management and production. Higher efficiency will be seen in shorter production time, higher utilization of machines and tools, higher production flexibility what all together means production cost saving.

Production flexibility increase and cost reduction is strongly influenced by strict observance of applied data structures in communication between individual workplaces in the whole production chain from designing individual components via designing a product, and production preparation up to programming individual manufacturing and handling devices and finally the production itself. The whole FMS (all manufacturing and handling devices) must therefore contain a communication structure based on modern industrial standard that is compatible also with other industrial facilities to enable trouble free data transfer. One of marginal conditions for definition of FMS characteristics is the ability to cooperate with CAD system CATIA available in our institute. In addition, this system will also have to cooperate with other CAD software systems. This cooperation is extremely important in a term of final project objective: drawing-free production. The block diagram of such a modular system is in the Fig.1. The principal philosophy of the system is based on theoretical knowledge and practical experience in the area of production planning, management and implementation of small batch and piece manufacturers. At present, these production areas are the ones with the most dynamic development.

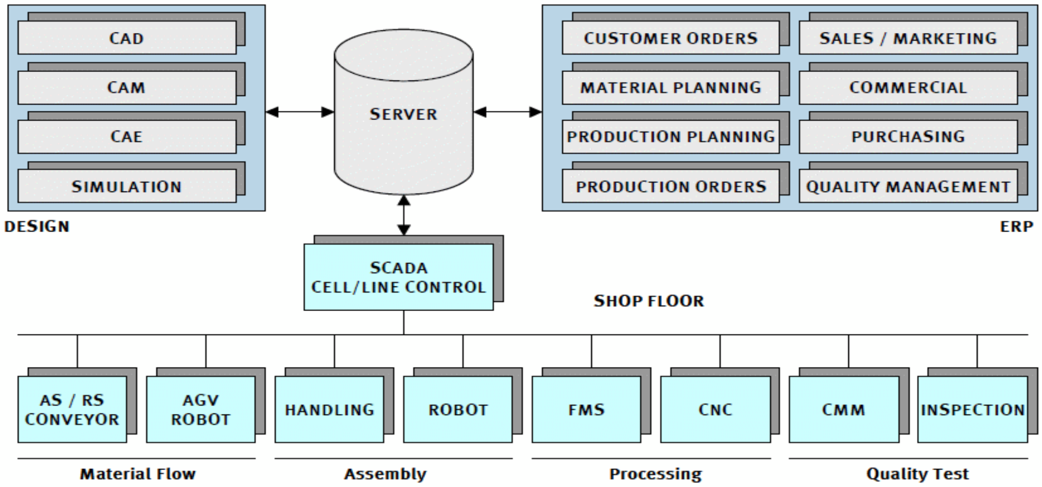

Figure 1: Modular flexible manufacturing system block diagram

MODELS FOR FMS

Petri net (PN) theory [Peterson, 1981] provides one of the most popular formal specification languages for concurrent systems, have been utilized in engineering fields and theoretical computer science by both practitioners and theoreticians. Petri nets have an enormous expressive power making them capable and suitable to model a rich variety of dynamic asynchronous concurrent systems. Operating systems, computer architecture, software engineering, semantics of programming languages, communication protocols, complexity theory, neural networks and artificial intelligence, modern control theory and automation, automated manufacturing systems, and PLC (Programmable Logic Circuit) design are good examples of the application areas of Petri net theory [Murata, 1989]. Further Margulis (1970) two main processes are introduced. One of these processes imitates symbiotic evolution, which would contribute to the maintenance of diverse solutions, while the other process uses the concept of end symbiotic evolution to promote the convergence to the Pareto optimal solutions.

SIMULATION IN MANUFACTURING

"Simulation is the imitation of the operation of a real-world process or system over time. Simulation involves the generation of an artificial history of the system, and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system that is represented [Bank, 2000]. In the mid-1940s, simulation makes a significant leap with the contribution of Tochter and Owen develop the General Simulation Program in 1960, which is the first general purpose simulator to simulate an industrial plant that consists of a set of machines, each cycling through states as busy, idle , unavailable and tailed [Nance, 1993]. Simulation models are categorized based on three basic dimensions: 1) timing of change, 2) randomness and 3) data organization. Based on whether the simulation depends on the time factor or not, it can be classified into static and dynamic. A static simulation is independent of time while dynamic simulation evolves over time. Dynamic simulation can be further categorized to continuous and discrete. In discrete simulation, changes occur at discrete points in time while in continuous, the variable of time is continuous. In addition, discrete simulation is divided to time-stepped and event driven. Time-stepped consists of regular time intervals and alterations take place after the passing of a specific amount of time. On the other hand, in event-driven simulation, updates are linked to scheduled events and time intervals are irregular. As far as the dimension randomness is concerned simulation can be deterministic or stochastic. Deterministic means that the repetition of the same simulation will result to the same output, whereas, stochastic simulation means that the repetition of the same simulation will not always produce the same output. Last but not least, simulation is classified to grid-based and mesh-free according to data organization. Grid-based means that data are associated with discrete cells at specific locations in a grid and updates take place to each cell according to its previous state and those of its neighbours. On the other hand, mesh free relates with data of individual particles and updates look at each pair of particles [Ronne, 1986 & Sulistio, 2012]. An integrated system, of part modeling, nesting, process was planning, NC programming and simulation and reporting for sheet metal combination processing functions has been applied in several sheet-metal manufacturing plants [Pan, 2009]. In order to deal with the problem of independence in risk assessment, an approach using Coloured Petri Nets is developed and applied to model risk factors in ERP systems [Aloini, 2012]. The need for a quality manufacturing system solution is a driving factor creating the demand for MES

(Manufacturing Execution System). The functions of MES are consistent with the goals of TQM (Total Quality Management) applied to industrial manufacturing companies [Deuel, 1995]. Facility layout planning (FLP) refers to the design of the allocation plans of the machines/equipment in a manufacturing shop-floor [Jiang, 2013]. SCADA (*Supervisory Control and Data Acquisition)* systems are applied worldwide in critical infrastructures, ranging from power generation, over public transport to industrial manufacturing systems [Eusgeld, 2011]. A supply chain is the value-adding chain of processes from the initial raw materials to the ultimate consumption of the finished product spanning across multiple supplier-customer links [Dugal, 1994]. A modern manufacturing network is composed of cooperating OEM plants, suppliers and dealers that produce and deliver final products to the market [Mourtzis, 2013]. Original Equipment Manufacturers (OEMs) operate in highly competitive, volatile markets, with fluctuating demand, increasing labour costs in developing countries, and new environmental regulation [Simchi, 2010]. Efficient simulation-model generation will allow the user to simplify and accelerate the process of producing correct and credible simulation models [Lee, 2012].

APPROACH FOR SOLVING FMS PROBLEM

It is recognized that the algorithm is a promising approach to solving complex, dynamic, and integrated problems [Kim, 2005].

Mathematical programming approach: In this approach, the previous researchers have cast the problem into an optimization model. Buzacott and Yao (1986) present a comprehensive review of the analytical models developed for the design and control of FMS up until 1984. They strongly advocate the analytical methods as giving better insight into the system performance than the simulation models. Lashkari *et al.* (1987) developed a formulation of the loading problem. Their formulation considered refactoring and limited tool availability. Besides this problem, they place an upper bound on the number of tools that may be assigned.

Operating an FMS is an activity with multiple criteria. Some authors have brought in these criteria in their modelling. Lee and Jung (1989) formulate a part selection and allocation problem using goal programming. Kumar *et al.* (1990) present a multi-criteria approach to the loading and grouping problems in a FMS. Their approach aims to provide a large number of feasible solutions (and objectives) for the choice of the decision maker. To counter the mathematical difficulties with optimization, use of heuristics has been actively investigated. These heuristics may take the usual form of dispatching rules or they may be more complicated. Extensive study of dispatching rules has been carried out in the general job shop context (Conway 1965; Conway 1965b; Gere 1966; Panwalker and Iskander 1982). Mukhopadhyay *et al.* (1991) have developed an integrated heuristic approach to tool allocation, parts scheduling, pallets scheduling, machine scheduling, and AGV scheduling. Priority rules and the analytical hierarchy process (Saaty 1980) are used to make a series of operating decisions. Gershwin *et al.* (1986) present a control theoretic perspective on the production control aspects of FMS. Kimemia and Gershwin (1983) presented a closed loop hierarchical formulation of the FMS scheduling problem. Akella *et al.* (1984) describe the performance of a simulated model of an actual facility using this hierarchical policy. Han and McGinnis (1989) present a discrete time control method for a FMS cell. Their objective is to minimize the stock-out cost under time-varying demand from downstream cells. A single-stage cell with one or more workstations working in parallel is considered.

Recently some authors have presented discrete event simulation as a scheduling tool. Basically, simulation is proposed as a tool to evaluate the dispatching rules. This is not an entirely new approach: the study by Conway (1965) was based on simulation. Ishi and Talavage (1991) propose a time-series based algorithm for determining the length of the simulation window. This is done on the basis of the system state which is evaluated by a measure similar to the utilization of the FMS. Strategies are proposed to select a dispatching rule avoiding the problem of censored data with arbitrary simulation windows. Improvements in performance measures of up to 16.5% are reported. Artificial intelligence (AI) appears to be particularly suited to solving operation problems of FMS because AI was developed to solve similar problems involving a large search space and where human expertise can find reasonable solutions pretty fast. Steffen (1986) has presented a survey of AI based scheduling systems.

CONCLUSIONS

Many more research has been made in the scheduling and flexibility of manufacturing system. The exhaustive literature of FMS indicates that ever it has ample room for further research. There is now a mature literature using different methodological approaches. Simulation in FMS has drawn attention of global manufacturing industries. Further, Discrete-event simulation is another area which has the potential to make major contributions to FMS operation. Future work needs to be done in investigating the use of the methodologies in the practical arena, in making the control systems more user-friendly, and in developing more comprehensive control systems. FMS is different things to different researchers. Quite often only the alternate operations aspect is emphasized. It is time to move on to further developing comprehensive control schemes which take care of the complex interaction of the multiple resources in an FMS: transporters, CNC machines, robots, tools, fixtures, pallets. This could be done using hierarchical schemes.

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