REVIEW OF DIFFERENT PLANNING, DESIGN AND OPERATIONAL ISSUES OF FLEXIBLE MANUFACTURING SYSTEM

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Abstract: Flexible manufacturing systems (FMS) are distinguished by the use of computer control in place of the hard automation usually found in transfer lines. Due to the use of computer control, planning, design and operation of FMS has become more difficult and these factors require more attention for the successful implementation of FMS. The main objective of this paper is to review the major issues related to the planning, design and operation of FMS. The key issues of each factor planning, design and operation are discussed in detail.

Keywords: FMS, design, planning, operation, scheduling, routing.

1. INTRODUCTION

The unique characteristic that distinguishes FMS from other factory automation technologies is the ability to achieve flexible automation i.e., the capacity to efficiently produce a great variety of part types in variable quantities [1]. FMS differs from the conventional systems in terms of flexibility in the flow of materials from one tool to another and performing the operations as per the required sequence [2]. Each part can follow a variable route through the system. Flexibility is enabled in FMS by flexible and alternative production routes. Such alternative routes are made possible by different (or redundant) equipment types capable of performing the same operation or by different manufacturing processes that can be used to achieve the same final result [3]. In a nut shell, flexibility in material handling, in combination with multipurpose tools, makes it possible for a flexible manufacturing system to process a great diversity of parts [4].

However, managing the production of an FMS is more difficult than managing production lines or job shops because the additional flexibility-related degrees of freedom greatly increase the scope of decision variables [1]. Production planning and scheduling models arising in automated manufacturing environments exhibit several features not encountered in models developed for traditional production systems [5]. For instance, models of automated facilities typically include tooling constraints which reflect the possibility for a machine to use different tools in order to perform successive operations, within limits imposed by the size of the tool magazine. Also, these models often account for the existence of flexible material handling systems whose activities must be synchronized with the machining operations in order to optimize system utilization.

Numerous authors have discussed various issues regarding the planning, design and operation of FMS. The research problems raised by the adoption could be broadly classified into two problem areas: design problems and operation problems [6]. Adoption and implementation of FMS involves huge capital investment. Therefore it is important that the installation of this manufacturing system is preceded by thorough planning and proper design and the operation is characterised by good management of all resources. At the design stage, one is interested in specifying the system so that the desired performance goals are achieved. The operation problems are aimed at making decisions related to the planning, scheduling, and control of a given FMS. Nagarjuna et al., [1] broadly classifies the decisions involved in the management of an FMS as pre- and post-release decisions. FMS planning problem that deals with pre-arrangement of jobs and tools, before it begins to process, falls under pre-release decisions, whereas FMS scheduling problem, which considers the sequencing and routing of jobs at the time the system is in operation falls under post-release decisions. The different issues concerning the FMS are classified by Stecke [7] into three different categories as, (i) the design issues, (ii) the planning issues, (iii) the operational issues. These are discussed in the following sub-sections.

2. LITERATURE REVIEW

2.1 FMS Design Issues

After the initial planning decisions, the design issues are addressed. The major design issues include (Groover, 2008):

- Types of workstations
- Process routing variations and the FMS Layout
- Material handling system design
- Work-in-process and buffer capacity

- Number and types of tools
- Number and types of pallets and fixtures

As per the planned part types the number, types and position of the workstations including the processing workstations, load/unload stations, assembly, inspection, cleaning stations etc. are decided. As per the planning decision of how flexible the system is to be, the amount of automation into the system is decided. The layout of these workstations directly affects the amount of flexibility achieved by specifying the process and part routings, so the FMS layout design is made depending on the type of control strategies required. According to the chosen layout the primary and the secondary MHS are designed. Much considerations are involved in the design of the MHSs as they have a direct impact on the product lead time.

Further the level of WIP also affects the utilization and efficiency of FMS, so proper planning must be involved to determine the permissible WIP in the system. The buffer capacity has to be determined. Based on the turret capacity of the workstation and the processing requirements of the workparts the determination of the requirement of the number and types of cutting tools is done. Number of pallets and fixtures specifies the maximum number of parts that will be in the system. Too few pallets and fixtures lead to system under utilization and increases the waiting time, where as too many will cause system congestion and is an unnecessary expanse. Parts that differ too much in configuration and size also require different fixturing. So the optimum number of pallets and fixtures are to be decided as per the system requirements.

2.2 FMS Planning Issues

Pool et al., [8] defined planning as a sequence of actions that will transfer the initial world into one in which the goal description is true. FMS planning issues are those which have to be addressed before the FMS can begin to produce parts. At the planning stage, the various issues to be considered include [9]:

- Deciding the array of part types or families of parts.
- Processing requirements and selection of machine tools.
- Physical characteristics of the workparts
- Production Volume
- Number and type of flexibilities required

A family of parts to be processed in FMS is decided amongst all the parts being processes in the organization. This part type selection is made by considering the group technology philosophy or by any other similar technique. Part types which are compatible with each other may also be selected, in the sense that each type mainly utilizes different machine and so can be machined simultaneously and help attain a good overall system utilization. The due date criteria can also be considered for deciding the part types [7].

After, deciding the part types and noting their processing requirements, the selection of machine tools is done. The total processing requirements and total number of tool slots required from all machine types is also calculated. These machine and workstations are then grouped. These grouping are made with the help of total processing requirements, capacity available as per machine type and tool magazine. The physical characteristics of the work parts like the size, weight and the production volume are also the major planning issues as they influence the type of machine tools and the material handling equipments [9].

The specific types of the different flexibilities required or desired from the system are also planned at this stage. The amount of each flexibility is also determined. Browne et al. [10] defined and described eight types of flexibilities that all FMSs theoretically can have. Buzacott [11] begins to quantify some of these flexibilities. It is both expensive and difficult to have all the flexibilities in all the systems. All FMSs actually have varying amounts of these. So, in the planning stage it is to be defined what are the specific flexibilities the system is going to inherent and in what amount, so that the system may be designed and controlled accordingly. The availability of funds, space, technology and skilled labour are also the issues which are to be considered during the planning phase.

2.3 FMS Operational Issues

The operational issues in FMS are concerned with the strategies for running the FMS. These are the real time problems arising out of the changing customer orders, time of arrival of the order and the different processing requirements of the workparts. The operational issues are addressed after the FMS is installed to optimize the existing resources to meet the production requirements and achieve operational objectives. The main operational issues that must be handled regularly during the running of the FMS are [9]:

- Machine Loading
- Scheduling and dispatching

- Part routing
- Part grouping
- Tool management
- Pallet and fixture allocation

Loading involves the decision about the assignment of work to different machine tools in the manufacturing system for the purpose of machining [12].

A loading problem can be defined as, ‘‘given a set of parts to be produced, set of tools that are needed for processing the parts on a set of machines, and using a set of resources such as material handling systems, pallets and fixtures, how should the parts be assigned and tools allocated so that some measure of productivity is optimized’’ [13]. Different components of FMS put different constraints in making a loading plan. These include, variety of machine tools, control system, cutting tools and tool magazine capacity, etc.

Scheduling is the allocation of resources over time to perform tasks [14]. The purpose of scheduling is to determine when to process which job and by which resources so that the production constraints are satisfied and the production objectives are met [15]. In view of the scheduling theory, a general FMS may be considered to be job shop with parallel machines and additional limited resources [12]. The development of effective and efficient FMS scheduling strategies remains an important and active research area. Scheduling in for a FMS is more difficult than in a conventional manufacturing environment. This is primarily due to versatile machines, which are capable of performing many different operations resulting in many alternative routes for part types, and also due to the systems' capacity for simultaneous part processing.

Part routing, grouping, tool, pallet and fixture allocations are the other operational issues which are to be considered. For part routing and grouping the various possibilities in the system are to be considered and the routes followed by other parts are also present a constraint. The different activities concerned with the allocation and the usage of the cutting tools come under the tool management [16].

Ever since the first article written by Stecke and Solberg [17] on the production planning problem of FMS has been published, a lot of research has been devoted in this area by various researchers. There are thousands of research articles on FMS loading and scheduling problems proposed by different authors at different times. The pioneering work by Steke [18, 7, 17], described the FMS planning problem into five sub problems i.e. (i) part selection, (ii) resource allocation, (iii) machine grouping, (iv) production ratio determination and (v) loading. Liu and Maccarthy [19] have identified and discussed five major factors influencing the FMS operational problems such as (i) system types such as a single flexible machine (SFM), a flexible manufacturing cell (FMC), a multi- machine flexible manufacturing system (MMFMS) and a multi-cell flexible manufacturing system (MCFMS), (ii) capacity constraints, (iii) job characteristics, (iv) production management environment and (v) scheduling criteria.

Based on the methodology followed, FMS operations literature could be classified in the following ways:

- Mathematical programming approach
- Multi-criteria decision making approach
- Heuristics oriented approach
- Control theoretic approach
- Simulation based approach
- Artificial intelligence (AI) based approach

There is also some cross fertilization among these approaches. For example, some AI based approaches use simulation to generate or evaluate schedules. In mathematical programming approach, the researchers have cast the problem into an optimization model. Due to the computational complexity of the problem, optimization techniques such as integer programming and mixed integer programming are not practical. Simulation and despatching heuristics are the two most commonly used solution methods for scheduling problems of reasonable sizes.

The first mathematical formulation for FMS-loading problem was given by Stecke [18]. The grouping and loading were formulated as non-linear 0–1 mixed integer programs. A heuristic model based on multi-stage programming approach was proposed by Nagarjuna et al., [1] to solve machine loading problem in random FMS. Kumar et al., [13], studied the simple genetic algorithm and proposed a new methodology, constraint-based genetic algorithm (CBGA) to handle a complex variety of variables and constraints in a typical FMS-loading problem. Roh and Kim [20] proposed a loading and scheduling model based on due- date with an automatic tool transporter. The model focused on the problems of part loading, tool loading, and part sequencing with the objective of minimizing the total tardiness. Chan and Swarnkar, [21] presented a fuzzy goal programming approach for the machine tool selection and operation allocation problem of FMS. Tiwari and Vidyarthi [22] proposed GA-based heuristic for solving machine-loading problem in FMS with an objective of minimization of system unbalance and maximization of throughput. Li et al., [23] proposed a mega-trend-diffusion technique to estimate the domain range of a small data set and produce artificial samples for training the modified back propagation neural network (BPNN). A simple FMS simulation model was constructed, it consisted of a load/unload station, three automatic guided vehicles (AGVs), four CNC machines, and four pairs of input/output buffers (IB/OB) for each CNC machine. A computer simulation model was proposed by Chan [24], in order to evaluate some control rules on the performance of flexible manufacturing system. Three control rules: dynamic alternative routings, planned alternative routings, and no alternative routings, were proposed to control the selection of alternative routing for each part. Chan et al., [25] presented a simulation model of a flexible manufacturing system (FMS) which subjected to minimization three performance criteria simultaneously such as mean flow time (MFT), mean tardiness (MT), and mean earliness (MR). The FMS included five general-purpose machine workstations and one loading/unloading station.

A look at these available models indicates that these models solve the following problems:

- Selection problems
- Loading problems
- Work in process problems
- Part scheduling and allocation problems
- Dispatching problems
- Layout problems and
- Costing & investment problems

3. CONCLUSION

Various issues regarding the planning, design and operation of FMS are discussed. Through the exhaustive literature survey it is found that deciding the array of part types or families of parts, processing requirements and selection of machine tools, physical characteristics of the work parts, production volume and number and type of flexibilities required are the five major planning issues of FMS. There are six major design issues are discovered which are types of workstations, process routing variations and the FMS Layout, material handling system design, work-in-process and buffer capacity, number and types of tools, number and types of pallets and fixtures. The main operational issues that must be handled regularly during the running of the FMS are machine loading, scheduling and dispatching, part routing, part grouping, tool management, and pallet and fixture allocation. These issues require proper attention for the successful implementation and the smooth running of FMS.

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