THE DESIGN AND OPERATION OF FMS

Flexible Manufacturing Systems

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Finally I would like to thank my darling wife, Márti, and my lovely little son Gergely, for their patience during the eight months it took to write this book.

Foreword

The current aim of manufacturing engineering is to develop real FMS – Flexible Manufacturing Systems – as a positive step towards a fully automated factory. This direction, in which evolution is taking us, comprising flexible machining, assembly, product inspection and associated processes, will prove to be superior to conventional production systems.

Computer integrated manufacturing is a powerful and possibly revolutionary technology. In fact, FMS will change our way of thinking. Old technologies are dismissed because a highly flexible system has to be designed with total manufacturing integration in mind. And, for the development or even the survival of a country, a clear understanding of the highly automated factory concept is crucial.

It is true that fully automated factories will not be widespread for the next ten years. However, once the results of experience have demonstrated its capability and reduced the apparent risk, the advantages should set the pace to flexible automation.

In general, the principles and attitudes to promote any industrial programme depend on economic, social and educational factors, and the acquisition of knowledge is crucial. At the beginning of a development, when little is known, progress is slow. As more information is acquired, however, advances are made at an increasing rate until engineering and scientific limits start to be important. As the technology starts to succeed, others come to see its potential and the driving force increases with wider knowledge and better performance.

The most important key to the flexible automation era is to educate new experts who know and clearly understand systems and manufacturing (not only machining) technology, having also strong capablities in systems and software engineering. FMS will stand or fall, according to the attitudes of the new generation of managers, designers, researchers, advisers and lecturers.

In all these aspects of promoting a new technology, Dr P Ránky's book is of extreme importance. It is full of valuable information and penetrating insights, giving a comprehensive exposé of FMS practice that demonstrates the state-of-the-art and the expected trends.

The role of technical and scientific literature is to spread new concepts, to explain new methods, to collect and discuss the experience of research laboratories and industry, to push new solutions, to propose systematic investigations, to collect knowledge for technology transfer and to train in their use.

The Design and Operation of FMS sets out to achieve all these aims, and I am sure that Dr Ránky's contribution is a first quality one.

I am glad to write this foreword for Dr Ránky's book, son of Professor M Ránky, an outstanding researcher and friend, because of my appreciation for the work he has put in on FMS.

Professor Dr-Ing G F Micheletti
Politecnico di Torino

Author's Preface

I have written this book for practising engineers, for students, lecturers, researchers and managers to help them analyse, design, implement and run FMS, the production technology of this century.

The first two chapters are introductory. Chapter One defines FMS as a generally applicable technology, not only for machining, but for a large variety of other processes, including robotised assembly, inspection, welding, painting, sheet metal fabrication, etc. It gives a worldwide overview introducing a number of current applications.

The second chapter introduces the 'system approach' to the analysis and design of FMS. It underlines the importance of proper project management and design procedures and is addressed mostly to FMS project managers and project engineers who would like to know more about FMS components and their relationship in an integrated system.

Hopefully most of my readers will realise that the third chapter is very important for the comprehension of the overall data processing system and the distributed data base processing in FMS. Engineers working in this field must be able to use computers and software systems such as data bases and computer networks in their everyday work. My intention was to explain this area using the 'engineer's language', as far as possible.

FMS projects often fail because, otherwise experienced, mechanical, production and electronic system designers do not understand the data processing people properly. Thus, in my view, both software specialists and production and design engineers should help each other to learn of each others disciplines and become, to some extent, software engineers. The growing importance of Artificial Intelligence techniques and expert systems in manufacturing technology also underlines this need.

The most important message of Chapter Four is that CAD systems are far from good yet and that there is still a lot to be done in integrating CAD and CAM (Computer Aided Design and Manufacture). The example shown represents machining, inspection and washing operations, but the concept could be applied to other processes.

Chapter Five explains in detail how a distributed FMS tool data base is designed and implemented. I hope this section will be of widespread use and that the structured tool description concept will be implemented both in industry and by students.

Chapter Six applies the same structured description method to fixtures and clamping devices as in Chapter Five. It also analyses the work mounting and pallet positioning errors and gives a calculation method for the pallet position and orientation error. This will be of use also to equipment designers and test engineers as well as being of interest to students.

The seventh chapter introduces industrial robots and their programming. The case studies are intended to be as simple as possible and, rather than teaching different robot programming languages, demonstrates the benefits of off-line structured robot languages and their use in man-machine communication. This chapter also summarises the most important aspects of Automated Guided Vehicles and computer controlled warehouses.

The following chapter summarises the contact and non-contact inspection principles and gives a case study on programming co-ordinate inspection machines.

The purpose of Chapter Nine is to give an overview of computer, machine tool and robot interfacing techniques using standard interfaces and to explain DNC (Direct Numerical Control) systems. Since it contains the full source code of a DNC download program, readers can easily implement their own DNC communication system.

Chapter Ten attempts to summarise simple project scheduling methods by giving examples of the CPM and PERT programs in the FMS Software Library. Dynamic scheduling methods, being of crucial importance in FMS, are also explained.

Chapter Eleven describes generally applicable computer programs solving individual tasks during FMS design, evaluation and optimisation.

Finally, Chapter Twelve introduces the most important social and human aspects of FMS, CAD/CAM and robotics, and gives advice on how to become an FMS engineer, a combination of mechanical, production, control and software engineering.

The FMS Software Library

The text is accompanied by a number of software packages integrated in the FMS Software Library, which the author has created to help FMS managers, designers, production engineers and software engineers. The programs may also be used by lecturers and students on courses in production engineering, robotics and FMS, as well as in research and development.

Each program can run on most micro- mini- and mainframe computers in the form of:

- a stand-alone turnkey package
- a procedure library
- a UCSD Pascal UNIT (allowing integration into user written packages)

The FMS Software Library is distributed, supported, maintained and available for purchase from:

Mentec International Limited,
SUIC Building, University of Salford,
Salford M5 4WT, UK
Telephone (061)736 8921 Telex 568680 (SULIB)

Contents

Chapter One

Introduction to Flexible Manufacturing Systems

A FLEXIBLE Manufacturing System (FMS) may be defined as a system dealing with high level distributed data processing and automated material flow using computer controlled machines, assembly cells, industrial robots, inspection machines and so on, together with computer integrated materials handling and storage systems.

Within the framework of this book, manufacturing is considered to be a system which integrates different processes and requires a properly defined input to create the expected output.

Input may be raw materials and/or data (e.g. CNC part programs) which have to be processed using various auxiliary components of the system, such as tools, fixtures and clamping devices, and sensors and their feedback data. The output may also be data and/or material which can be processed on further units (often called cells) of the manufacturing system.

FMS can also be thought of as a distributed management information system linking together intelligent subsystems (often known as nodes) of machining, welding, painting, flame cutting, sheet metal manufacturing, inspection, assembly etc., and materials handling and storage processes.

This modular systems approach to FMS, can be applied not only while designing and operating machining systems, but also in other computer integrated projects, where machines work under computer control in an integrated manner. Such applications include flexible assembly using industrial robots and other assembly devices.

1.1 What is an FMS?

When designing an FMS, the basic problem is to create the cells from which the system is to be constructed. FMS cells are complex for several reasons. They can have different physical characteristics to perform the required conversion on workparts or subassemblies. They can have a variety of interconnections with different materials handling systems (robots, Automated Guided Vehicles, conveyors, pallet loading and unloading carts, etc.), and they have to communicate with data processing networks for successful integration with the system.

A greatly simplified illustration of an FMS cell is given in Fig. 1.1. It shows only one cell with its input and output, indicating its basic functions. These are: to perform the conversion process; to allow buffer storage and/or holding of workpiece or workpieces; to provide the physical links to the materials handling systems in the 'outside world'; and to provide the data communication links to the control system. The physical links allow the transport of parts, tools, pallets, etc.

The data processing links enable communication with the data bases containing part programs, inspection programs, robot programs, machining data, real-time FMS control data, etc. They also enable the feedback of data to the upper level of the control hierarchy, thus providing the facility for further analysis of performance or for real-time fault recovery.

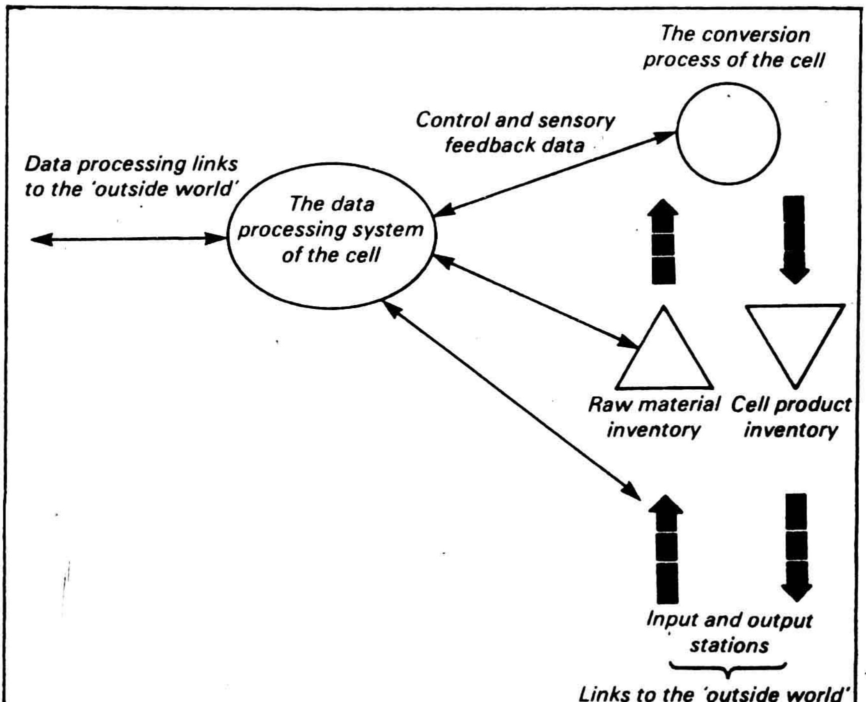

Fig. 1.1. The concept of the FMS cell with its data processing and materials handling links to the 'outside world'.

Part and tool transportation inside the cell can be performed by a variety of equipment, such as pallet changing devices, automated pallet storage devices, and part changing and tool changing manipulators. These devices are necessary for the stand-alone and often unmanned operation of the cell.

The main conversion process itself can be machining (e.g. turning, milling, boring, grinding, cutting, punching, etc.), chip removal (part washing and swarf retrieval), welding, painting, automated assembly, inspection, packaging, storage, etc.

The product of the cell usually leaves through a buffer store. The input and output buffer stores, as well as the materials handling system, can be the same transport device assuming that its capacity is large enough.

Logically each cell has to be handled separately in the process control system by providing an intelligent node of a distributed network.

The output of the cell is the product of that particular module of the FMS. It does not only consist of a finished, or semifinished part, but it also has to 'carry' data in computer readable format. This information will 'tell' the next cell what to do with the part, or generally how to process the output further, via the distributed communications network.

If, for example, the part went through a datum surfacing operation in one cell, then it could go to another cell for further machining or inspection operations. Both the part and the data in computer readable format (instructions on what further operations are required, in what order and on which surfaces) have to be transferred to the next cell. (The next cell does not necessarily mean physically the next station as in a rigid transfer system. It is rather the next cell as programmed for the required conversion process.)

1.2 How does FMS compare with conventional manufacturing systems regarding real-time materials handling and scheduling?

A typical flow-line manufacturing system can be characterised by a number of parts transferred in a unidirectional manner between different and/or similar work stations. The material flow in these systems is discrete and manually operated.

If the flow line uses automated materials handling between the processing stations, it is called a transfer system. Parts are generally machined and/or assembled on such systems in large batches (or lots), and the types of parts they can accommodate at the same time is very low, often only one, so they are inflexible.

Generally, FMS combines the benefits of a highly productive, but inflexible transfer line and a flexible, but inefficient, job shop, where each part has a predefined number of operations, of which one or more is performed at each machining or assembly station. The order in which these parts are manufactured is given by a list, or schedule. The schedule defines for a period of time which operations shall be performed, on which parts, by which machines.

The scheduling algorithm used in job shop systems is off-line because it is applied at the beginning of a scheduling period, and the results are valid for the entire shift, or longer. If an unexpected event happens, such as a tool break, machine tool or robot breakdown, because of the deterministic scheduling methods used, production is disrupted.

FMS needs to perform operations under the control of a dynamic scheduling system. This means that decisions concerning what workpiece is manufactured next on which cell, are made close to the end of the operation currently being performed by the particular cell. In other words, a complete FMS schedule is not made in advance because it must be capable of responding to real-time decisions.

FMS is more flexible than any of the systems mentioned above because there is practically no setup time wasted between different operations, and because the FMS cells are capable of performing many different operations in different orders.

1.3 The economic justification of FMS

Let us discuss briefly the basic reasons for designing and implementing FMS. At the present time systems worldwide have an exponential growth.

FMS provides the following benefits if designed and used successfully:

1) Greater productivity, which means a greater output and a lower unit cost, on 45%–85% smaller floor space.
2) Quality is improved because the product is more uniform and consistent.
3) The intelligent, self-correcting systems (i.e. machines equipped with sensory feedback systems) increase the overall reliability of production.
4) The expenses are smaller because the overall capital investment is 5%–10% lower, 45%–85% less machining facilities are required compared to conventional stand-alone CNC controlled machine tools, and also because the flexible materials handling and storage system provides an automated inventory system with considerably lower levels of stock and materials handling.
5) Parts can be randomly produced in batches of one or in reasonably high numbers and the lead time can be reduced by 50%–75%.
6) FMS is the only available manufacturing environment to date where the time spent on the machine tool can be as high as 90% and the time spent cutting can again be over 90%. Compare this to stand-alone NC machines, where the part, from stock to finished item, spends only 5% of its time on the machine tool, and where the actual productive work takes only 30% of this 5%. (See also Figs. 1.2 and 1.3)

The time resulting in useful work where stand-alone machines are used is, therefore, as little as 1%–1.5% of the time the part takes to be processed through the shop. [1.1]