Proceedings of the
4th International Conference on

Flexible Manufacturing Systems

Edited by R.Lindholm
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Edited by
R. Lindholm

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FOREWORD

FMS-4 Conference Chairman:

R. Lindholm

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FMS is a truly cross-disciplinary subject requiring skills and knowledge from several specialities to be merged together in order to make possible the development of a competitive manufacturing system.

FMS is an important technology for a country like Sweden with a small domestic market in the respect that the advantage of large scale production is reduced by this new technology. Swedish companies can become more competitive on the international market. The Swedish car manufacturers are good examples of this.

The state-of-the art of Flexible Manufacturing Systems is still dominated by a few forerunning companies but it is evident that the technology has now reached a state where it can be put to profitable use by a large number of companies. This is also reflected in the diffusion of the technology which is very rapid today.

In order to further this development it is in my opinion necessary to focus more on the skills and prerequisites required to design, introduce and operate FMS in 'ordinary' companies. One obstacle is the economic justification which must take into account far more than the labour saving effects in order to make the system pay-off. It is also important to find practical solutions to upgrading the operator-skills, developing new work forms and integrating the FMS into the company environment as a whole. Furthermore must wageforms, planning methods, methods for measuring results and local-area information be developed.

The development and experience of FMS in Sweden have to a large extent their roots in efforts to improve work environment and untie operators from machine paced work in order to utilize both capital equipment and human skills better. Due to this there are a large number of companies in Sweden with a very good basis to adopt the FMS technology and we already have many embryos to genuine FMS in operation in the form of partly or completely automated manufacturing cells. One more national strength is the recently signed 'Agreement on efficiency and participation' between the major labour market organizations SAF, LO and PTK. This agreement states shared values on adopting new technology to promote efficiency and participation and outlines ways to cooperate in the firms in practical and flexible ways giving the individual employee better opportunities to influence his working-conditions.

Sweden is for the first time host for the international conference of Flexible Manufacturing Systems – the fourth so far – and this is a great opportunity for us to share experiences in the FMS field with colleagues from other countries for mutual benefits.

Finally I would like to thank the programme committee for its valuable support in arranging the conference.

ROLF LINDHOLM.

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FMS – Research Viewpoint

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Abstract

After an initial hesitation flexible manufacturing systems have now begun to prove themselves as economical aids in solving demanding and variegated manufacturing problems, particularly in the increasingly important small and medium batch production area. Encouraged by the more than ten years of intensive research and various pilot projects in this field, the number of systems installed has recently grown in leaps and bounds.

Even now that the breakthrough in practice appears to have come about, however are still a large number of research tasks waiting to be dealt with. These include the solution to the problem of existing flexiblility bottlenecks, particularly with regard to machine periphery, and also the development of more efficient universal systems software for organizing and monitoring the increasingly complex machining and material flow functions.

In addition the horizontal and vertical integration of flexible manufacturing systems in the overall production process in a consistent manner, together with an increase in flexibility and productivity of parts manufacturing in other prior and subsequent areas, will also have to be looked into in greater detail in the future. Developments here are tending in the direction of uninterrupted connection of all operating areas with individual activities coordinated and monitored with the aid of a hierachically designed computer structure.

1 FMS - an integral part of a new production philosophy

The market for many industrial goods has now become a buyer's market and the profitability of a company is no longer determined by output or turnover alone. On the contrary survival for a lot of firms depends on reacting more flexibly and adapting more rapidly to customer requirements. "The customer is always right" and it is he rather than the manufacturer who determines the course of events. For industrial companies this means coming to terms with the idea of greater product and part diversification, higher quality demands and shorter product development and delivery periods. It also means that the prevailing idea of high productivity must be supplemented by that of greater flexibility. Industrial concerns will have to improve the service aspect of their operations and guarantee rapid order processing through flexible staffing and excess operating capacities. The constant struggle in production companies against product diversification only has limited prospects of success because the market is simply more powerful. We must therefore attempt to structure our products so as to be able to respond to the idea of product diversification in as economical way as possible.

One method of achieving this is the use of highly automated yet flexible systems for parts production. With the increasing use of such methods the entire philosophy of production is undergoing a change, marked by less division of tasks and more integration of functions and sections in flexible manufacturing systems (FMS), (Fig. 1)

2 FMS - experiencing a rapid growth in number of installations

No standard definitions exist currently for flexible manufacturing systems and as a result the numbers of such systems in operation in Germany and abroad differ considerably. If a flexible production system is defined as one in which the processing, material and information flow is flexibly automated to the extent that the different workpieces running through the system on the various paths are manufactured without manual intervention, the total number of FMS in the world can be put at about 230 /1/. Figure 2 shows a system in use in Japan and Figure 3 illustrates the most important characteristics of a flexible manufacturing system for gear boxes recently put into commission in South Germany. In view of the overall positive experiences with such systems to date annual growth rates in double figures can be expected both in Germany and abroad. Most medium-sized companies will be confronted sooner or later with FMS and it is likely the number of applications in future will be restricted less by the previous reluctance of users to accept flexible manufacturing systems than by the capacities of the manufacturer of such systems.

3 FMS will have to be applied also for production tasks beside machining

Based on the experience gained in the last few years in the planning and implementation of flexible manufacturing systems for machining of parts efforts are now being intensified to increase the profitability and reaction potential of further production spheres through the gradual introduction of flexibly automated processing and material flow system.

As a result of very recent development work, sheet metal parts manufacturers in particular have begun to make more extensive use of flexible manufacturing cells and systems, with the different machining processes, such as punching, nibbling and laser or plasma cutting, being integrated in the individual systems. Optimized production processes with short machining times but long retooling and non-productive times also need to be upgraded to reduce these uneconomical sectors by making use, for example, of workpiece and tool changing devices. Such facilities would have a greater rationalization effect than the further optimization of the process by reducing machining times even more. Good results can also be achieved in the transition from cutting in a type-specific complete cutting tool to the slower stamping/nibbling process with its very low workpiece-specific costs. Flexible sheet metalworking machines allowing complete processing of the workpiece on a single machine by suitably combining the various stages, such as stamping/nibbling and laser or plasma cutting, not only help to cut down non-productive times but also lead to a reduction in the amount storage and transport.

The high investment costs required for such systems can only be repaid in a reasonable period if the necessary degree of economic utilization is achieved through appropriate automation devices and corresponding organization. Developments here are tending towards completely automated systems in which the flexible loading, machining and unloading of differing workpieces is CNC controlled and monitored, (Fig. 4).

Figure 5 shows a production system for extremely diverse and small batch plane and two-dimensional sheet metal parts designed in collaboration with the Fraunhofer Institute for Production Engineering and Automation (IPA) in Stuttgart. In this system, apart from a newly developed flexible press system, laser processing stations both for cutting curved sheets and subsequent welding of thin-sided hollow parts were used for the first time /2/.

Developments similar to those used in the metalworking industry are also being initiated in the area of woodworking and plastics processing. Within these sectors, where large batch production has predominated in the past, changed market conditions and the need to respond to varied customer requirements without incurring too great an expense have made the introduction of flexible production structures and newly developed, easily adapted production and handling devices a necessity.

4 Central integration of processing functions

By integrating different production processes on a machine the time taken to complete production is reduced and the number of handling operations minimized. The complete machining of workpieces on machines capable of turning, milling, drilling and even precision machining in one clamping operation is likely to increase in significance. Productivity and flexibility can be improved at the same time through multi-station and multi-tool operation.

The same considerations apply to the use of industrial robots to carry out various different operations and to ensure maximum utilization even with small batches, e.g. when starting up a production process.

The integration of several machining processes by combining the appropriate modules (spindle and clamping units) with fixed basic modules (e.g. columns and guideways) was the main aim of a Japanese project for devising new basic ways and structures for machine tools and assembly devices /3/. Machine tools and assembly cells on the modular principle and the use of lasers in production for machining and chip breaking are just two of the most important areas under consideration. The machining processes can be combined almost at will in two production cells, (Fig. 6), each with three spindles and clamping units together with a driverless transport system for conveying the units for the automatic retooling process. By changing the module it is possible to change over automatically from prismatic to rotationally symmetrical parts.

Initial attempts at basically restructuring traditional types of machines and combining different and hitherto strictly separate machining operations in a single design are now also being made in Europe. Current development work is concentrated primarily on the complete machining of large and heavy workpieces with the aim, amongst other things, of minimizing clamping and retooling times with the aid of a special tool pallet system for turning, drilling, milling and grinding units.

In principle there are two discernible tendencies in machine tool structures:

- in the case of rigid mass production the machining functions are decentralized, i.e. the workpiece comes to the machining function (e.g. transfer line)
- in the case of flexible small batch production the machining functions are centrally integrated, i.e. the machining functions come to the workpiece (e.g. machining centre and lathe cell).

This means in the second instance that maximum technological efficiency in the individual machining functions might not be completely essential when it comes to optimizing the system as a whole.

5 Bottlenecks in flexibility will have to be overcome

If the most recent flexible manufacturing systems are looked at in greater detail a trend is discernible whereby the systems are no longer being bought as complete turnkey installations from a single supplier but are rather being built up gradually by the users on their own responsibility from single manufacturing cells. This procedure is made more difficult, however, by the fact that there are still no standardized material flow interfaces, particularly in the area of machine-oriented workpiece and tool preparation.

In defining uniform and manufacturer-independent standards for interfaces related to peripheral equipment, such as dimensions of pallet or exchange height of pallets, the application of universal means of conveyance should be realised independently of the degree of automation of the entire system. Flexibility of elements in direct contact with workpieces, such as handling grippers, clamping devices, or supporting elements to store workpieces in a magazine, cannot be increased at any rate, especially not at a reasonable cost. Therefore support to be put quickly into practice may, to a greater extent, be expected from elements to be rapidly exchanged or adapted and from a further reduction in the variety of workpieces by consequently forming families of parts.

With prismatic workpieces, with their well-known variety of dimensions and shapes, a main hindrance in flexibility and an enormous cost factor, are the clamping devices presently available. Only in a few cases was it so far possible to create a common interface at the workpiece, e. g. by casting an extending finger for clamping, which then, after the machining operation mostly had to be cut off. Adaptive systems are being developed with the ability to recognise the position of a workpiece only roughly positioned on the pallet, and to adjust the machining parameters accordingly. Reducing the manual effort required to load, adjust and clamp different workpieces with automatic clamping devices and handling equipment has also been realized in an experimental stage. However, automated and, at the same time flexible, clamping devices are not to be expected in the near future. These are, however, some developments which are concerned with the automated assembly of clamping devices in using modular fixture elements.

Time- and requirement-oriented provision of tools to the indicidual production devices continues to be a central problem in the operation of flexible manufacturing systems. In flexible manufacturing cells or systems, tools for drilling and milling of prismatic workpieces are usally buffered in magazines integrated into the machine. Small batch sizes, complex machining tasks and limited tool life call for a large number of different tools near the machine with the result that a considerable amount of capital is bound up in these voluminous magazines. Different solutions have recently been developed in machining centres for the automatic supply of tools at the right time, even during unattended operation, the majority of which aim at provide a complete that of new tools at the machine for each production order.

Transportation of tools from a central tool store and the exchange of tools can be successfully carried out by a mobile industrial robot, (Figure 7). This device, developed by the IPA with a grant form the Ministry of Research and Technology (BMFT) and with the cooperation of a major manufacturer of conveyance and handling devices, consists of an inductively guided vehicle and a pallet which the vehicle can automatically pick up and put down /4/. With the aid of this mobile industrial robot wear and also order-specific tools can be fitted directly in the tool magazine as required.

With the introduction of computer-aided production, recognition systems for automatic identification and classification of workpieces, workpiece carriers or tools is of increased significance, (Fig. 8). With the exception of a few Japanese systems in which workpieces or tools are identified once only at the start of the system and then organized directly by the computer according to the production sequence, the information in the large majority of production systems is organized for reasons of data security by object with the aid of automatic recognition systems /5/.

Simple mechanical coding systems such as cams are the most commonly used devices for workpiece, pallet or tool recognition as they are the most resistant to damage from chips, dirt or coolants. Their major limitation is the amount of information that can be coded. Because of the aggressive atmosphere in the factory all other coding systems, such as those based on magnetic or optical principles, have to be encapsulated to ensure that they are reliable and legible.

In order to be able to coordinate the increasingly complex workpiece, tool or jig flow, coding systems have to be developed which not only permit data to be stored and read reliable but also allow for modification in accordance with the production sequence.

6 Material flow must be consistent throughout

The horizontal integration of flexible manufacturing systems, i.e. the organization of the material flow between successive work stations, must be consistent throughout. The implication here is that to achieve an economical overall solution production and assembly cannot be treated as separate entities. Parts which can be manufactured economically but which cannot be transported without interruption to the assembly stations cause additional costs.

Efforts at making available suitable means of transport of the factory-proven European pallet type, (Fig. 9), must be intensified. With the development of modular magazine pallets whose insert modules can even be placed in the magazine frame with the aid of handling appliances the identity of transport, storage, in-feed and assembly units can be maintained without having to abandon existing and proven conveyors and accessories, (Fig. 10). With the aid of a process being developed by the Institute for Production Engineering and Automation (IPA) magazine frames, insert modules and carrier devices for workpieces, clamping elements and handling grippers can be planned, fitted and run through the production and assembly stations with maximum efficiency /6/.

7 FMS will have to be seamlessly integrated into the overall production process

The increased diversity of products and parts no longer permits economical production of "optimal batches". The capital tied up as a result of overfilled warehouses can account for as much as two-fifths of total assets in many mecanical engineering companies. The isolated optimization of individual targets such as low production costs, short run-through times or reduced stocks often leads to the production operation no longer being conceived or regarded as an overall system. Flexible manufacturing systems which have proved to be an effective aid in consolidating hitherto contradictory targets need to be integrated to a greater extent both horizontal and vertical in the production process. The full significance of this need for horizontal and vertical integration is not fully understood in many companies and for this reason users are often disappointed that large investments do not always bring about the desired structural change in the entire operation.

In this context, the importance and the continuing difficulties involved with computer-assisted information processing is often underestimated, both from the point of view of the communication between the individual components of a flexible manufacturing system and also the organizational integration of this production area in the overall structure.

Although a number of basic types of machinery and material flow devices can now be discerned in practice, there is still no standardized or transferable control software for organizing and monitoring the different machining and material flow tasks. In the case of small systems with machines from a single supplier various software modules already exist e.g. for DNC operation, tool organization or operating data registration, compiled in accordance with specific customer requirements. But for the majority of systems where a variety of machines, including older and less automated work stations, have to be integrated, time-consuming and cost-intensive development and adaption of the system software must still be carried out and this makes many potential users somewhat reluctant to introduce completely computerized production systems. This represents a considerable development area for university institutes and computer and software houses and high priority in the joint research work in the next few years will have to be given to

- the design of gradually extendable information systems in which independently running partial systems can be combined for user-specific operations and
- the definition of generally valid transferable control modules

with the aim of restricting cost-intensiv multiple development and adaptation work to a minimum. In this respect existing steps towards standardization, such as the Manufacturing Automation Protocol (MAP), designed by leading automobile and computer manufacturers in the USA for data transfer, should not be ignored /7/.

Parallel to the development of standardized FMS control software the integration of information flow functions in flexible manufacturing systems also deserves further attention. As with the use of CAD/CAM work stations in design and work preparation, information technology in flexible manufacturing systems should not remain separated and development and production times should be reduced to the economical minimum, (Fig. 11).

Succes can be achieved with partial solutions and the idea of proceeding in gradual individual steps - provided they are target-oriented - appears realistic because of the qualifications and risk situation. Future targets must, however, allow for the combination of individual measures and the connection of individual components into an overall CIM (Computer Integrated Manufacture) system. With the aid of this type of hierarchically structured computer and sofware system, the delvelopment of which is still in its infancy throughout the world, it should be possible in the future to coordinate all development, organization and control activities in the various company departments, such as purchasing, work preparation, manufacturing, assembly or marketing, and of upgrading the overall company operation.

With the use of a logically central data bank all data is registered once only while remaining up-to-date and reliably accessible to all those involved in the production process. This means that both decisions and production sequences can be introduced simultaneously and with common aims in the different technical and economical departments.

In the foreseeable future decision-making processes in computer-integrated manufacturing will remain in the hands of human operators. The computer can, however, help facilitate, assure and speed up this decision-making process and organize and monitor the execution.

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Figure 1 :

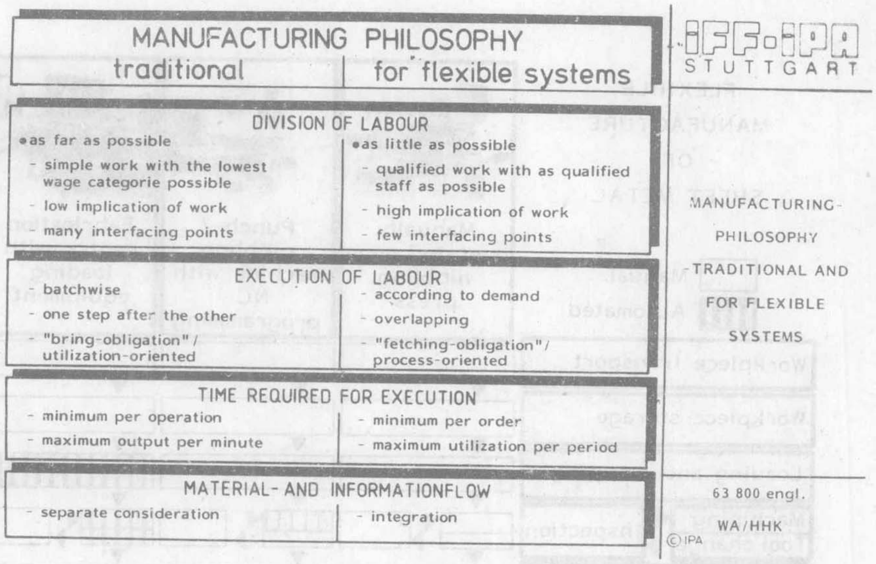

Figure 2 :

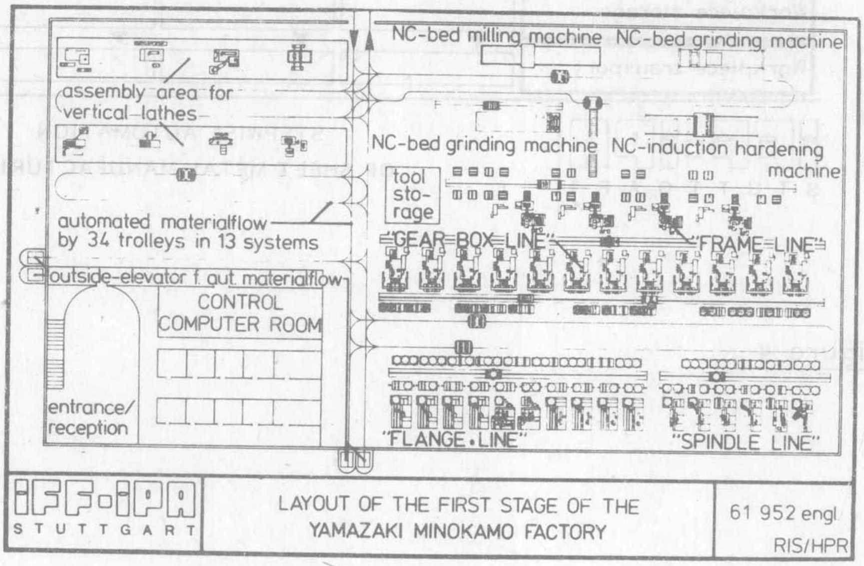

Figure 3 :