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CHANGES IN MANUFACTURING STRATEGIES……

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The factory of the future is going to take on the characteristics of a service company and thus calls for basic changes in production philosophy. The author points out that by division and simplification of labor an increase in productivity is limited because of structures with time-and cost-consuming interfaces. Markets and competition require new strategies and a rethinking in the conception of new production systems.

These representations are followed by theses and pictorial informations concerning the state of the art in flexible manufacturing and automation.

Key Words : Productivity, Flexible Manufacturing, Automation, Industrial Robot, Computer Integrated Manufacturing

1. INTRODUCTION

The development of industrial production can be described by three radical and far-reaching structural changes. The first change which started at the end of the 18th century was characterized by the replacement of human energy by machines. The era of power engineering had begun with the innovation of the steam engine.

The second big industrial evolution started at the ent of the 19th century. The use of electricity linked with inventions for its utilization - such as electric motors - resulted in a decentralization of driving energy. The basis for the mechanization of operations was thus established. This was the beginning of the era of mechanization.

Today we are in the era of automation, which started with the advent of electronic data processing around 1950. This third industrial development phase has been characterized above all by the drastic development of the information technology in recent years. It will have a decisive influence on the future of the factory and, thus, on the factory of the future.

Like the first and second phases of development, this phase, too, in which industrial production is now and will be in the future, will not be characterized by technological developments alone. Economic and social changes can be regarded, now as before, as decisive influencing factors, which will determine the kind and tempo of the changes coming up to us. Even with the technological feasibility given, these two factors will have a decisive influence on whether the factory of the future will be an unmanned factory and, thus, the Automatic Factory. It is more realistic that the factory of the near future will be the Automated Factory, apart from some exceptions, of course. An automated factory is a factory in which fewer people will be working with a higher output than today.

Since the experience made in production technology has shown that innovations take ten to twenty years until they will have fully penetrated all sectors, the development of the factory of the future is to be demonstrated by means of the trends that are clearly emerging already at the present time.

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2. THE FACTORY OF THE FUTURE-TODAY'S CHALLENGE TO ENTERPRISES

2.1 Major Influences and Trends

In all phases of their development the structural changes of industrial production have been influenced by various factors to a different degree. The influences coming from market and technology, society and law, and acting on the enterprises have been described in numerous publications and discussed at many national and international meetings.

The complexity of these influencing factors, their mutual interlacement, which is sometimes hard to demonstrate satisfactory, and the lack of knowledge regarding the relations between cause and effect, partly have led to controversial discussions on the factory of the future. These were intensified even more by the uncertainties associated with forecasts and by the different subject-specific aspects, which had an influence on the point of view from which these factors and their effects had been discussed.

It is often neglected in these discussions that the factory of the future is not the inevitable consequence of some laws of nature or a most due to the power of the word, as described by futurologists, but that it is man who conceives the elements of such a factory and decides on its deployment.

Despite these restraints and uncertainties it would be dangerous and wrong to ignore the emerging developments and the accompanying problems and to wait for a better secured data base regarding the decision on the measures to be taken now and the strategies to be developed now, as it is demonstrated by negative examples from different sectors in various countries.

Positive examples clearly demonstrate the efforts made by these enterprises in facing the challenges of the future, in order to be able to survive in competition.

Even if the factors influencing the enterprises are different from sector to sector and from country to country, so that both the effects of these factors on the enterprises and the measures to be taken for coping with the effects may be very different, it is, nevertheless, possible to give a summary of some general tendencies.

Nearly all industrial enterprises are finding themselves faced with increasingly keener national and international competition There are various causes for this. On the one hand, they can be traced back to saturated markets, cyclical influences, and a growing number of competitors within a market segment by diversification of the product programme of the respective enterprise, and the building up of excessive capacities, On the other hand, traditional buyer countries are facing enormous financial problems, so that no money is available for purchases, and the industrial nations of the west are forced to finance their exports themselves through their banks.

The growing competition and the necessity linked with it to comply with the specific customer requests to a still larger degree than in the past does not only lead to a considerable pressure on prices and, thus, to the necessity to cut costs by measures of different nature. To achieve this, automation is only one possibilty. At least to the same extent, the requirements made by the customer lead to an almost explosive increase in the variety of types, smaller lot sizes, short delivery periods, fluctuations in quantities, higher demands on the quality of the product and the quality of the after-sales service.

The market-oriented adaption of the product supply does not only lead to the factor that shorter deadlines will have to be economically controlled in all areas of an enterprise-in research and development, in design and production ; on the contrary, on the part of the technological development, this trend will be reinforced by shorter product life cycles, shorter intervals of product and process innovation and by the development in the field of microelectronics that can be outlined as dramatic.

Apart from these factors, the work design and work organization in the enterprises are influenced by outline conditions which can be derived e.g. from legislation, collective bargaining or standardization. The development of society in the form of higher educational levels or also of greater affluence lead to the desire for more attractive jobs and more flexible models of working hours. The growing environmental consciousness results in the demand to learn from the negative effects of the uncritical exploitation of the natural resources and, linked with it, a greater involvement of the aspects of environmental protection in the planning projects.

To survive in the competition by an as great as possible adaptation to the requirements of the market-this goal can only be achieved, if the production plant takes on the nature of a service business in that it has the adequate flexibility in all its areas. That is why the capability to adapt to the market (economy of scope) plays a much more important role than productivity alone (economy of scale). The traditional production philosophy is no longer suitable for this. A new production philosophy and, linked with it, the abandonment of old-established patterns of thinking is necessary (Fig. 1). Reorientation and adaption processes have become inevitable, so that it will be possible to improve the competitiveness of the enterprises. In this process, an increase in flexibility can only be one out of a number of goals. An improvement of the competitiveness will also mean higher productivity by cutting the total manufacturing costs on the one hand, and increasing the product value on the other (Suh, 1983). As analyses have shown, increases in productivity can be achieved most effectively by measures which include the following goals, in descending order (Suh, 1983) :

- ○ Increase in the value of the product
- ○ Reduction in the material costs
- ○ Lowering the information costs
- ○ Reduction in wage costs
- ○ Minimization of capital costs

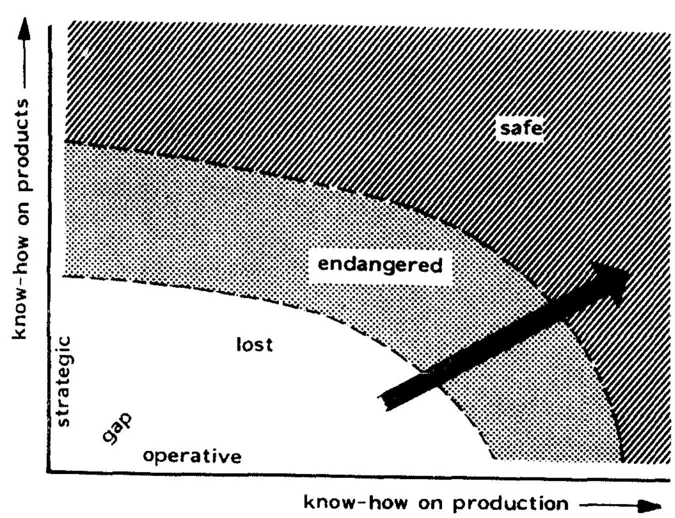
2.2 Success Based on Innovation

The innovation of products and processes is decisive for the success of enterprises, since these will then be able to obtain the greatest competitive advantage, if they manufacture innovative products as economically as possible. The latter, in turn, will often require the use of new production methods and also the use of new materials.

Therefore, it is the task of the enterprises to detect and eliminate the existing weakness in the field of product and process innovation (Fig. 2). This reduces two risks leading to a decrease of competitiveness: Strategically, regarding markets and products and operationally, regarding their manufactruing technology. This shows that, due to positional conditions, the metal-working industry will, in future, be competent in only those branches and market segments requiring great technical know-how and capability either for the product or for the manufacturing process.

MANUFACTURING PHILOSOPHY traditional	MANUFACTURING PHILOSOPHY for flexible systems
DIVISION OF LABOUR	
•as far as possible	•as little as possible
- simple work with the lowest wage categorie possible	- qualified work with as qualified staff as possible
- low implication of work	- high implication of work
- many interfacing points	- few interfacing points
EXECUTION OF LABOUR	
- batchwise	- according to demand
- one step after the other	- overlapping
- "bring-obligation"/ utilization-oriented	- "fetching-obligation"/ process-oriented
TIME REQUIRED FOR EXECUTION	
- minimum per operation .	- minimum per order
- maximum output per minute	- maximum utilization per period
MATERIAL- AND INFORMATIONFLOW	
- separate consideration	- integration

Fig. 1 Manufacturing philosophy traditional and for flexible systems



source: Prof. Schiele, KSB

Fig. 2 Competitiveness by know-how-intensive products and production

Which measures for the elimination of strategic gaps are particularly successful in individual cases certainly depends on the technological and market conditions of the particular industrial branch and cannot be answered in a general manner. Independent from the branch, however, the risk created for companies and employees by an operational gap must be apporached with the consistent utilization of the rationalization and automation reserves remaining available presently in production technology.

2.3 Information as a Factor of Production

In addition to the classic factors of production-land, labour and capital-information is gaining increasing importance as a further factor of production. The availability of data and its processing into information relevant to decision-making will more and become a factor deciding on market shares. Today's data processing is only conditionally suitable to cope with the tasks associated with this, since it is not yet information processing. In the majority of cases, data is only processed in machines today and only made into information material with great effort after it has been handed over to the user. Data always becomes information only through man, information that must be weighted, rated and processed. The catchword-information flooding of the enterprises-commonly used today is wrong. At the present time, there is a flood of data and at the same time a lack of information in the enterprises.

Three general demands for the future can be concluded from the above:

- The information necessary for the work and decision-making process will have to be selectively filtered out of the existing data and information flood and it will have to be available for decision-making in an improved condition.
- The concept of economy will have to be more in the foreground in the handling and processing of information in the future. Information will then turn form a cost factor to an income factor.
- The information problem will have to be understood as an all-embracing technical-organizational task.

To meet these essential demands, it is necessary that an organized information management should be built up.

2.4 Integration of the Islands of Automation

A wide variety of technical facilities for the automation of discrete manufacturing processes was developed over the past years and decades. With a few exeptions, these have been implemented in the form of island solutions. Today's challenge is to integrate these island solutions, both within the manufacturing components and between the manufacturing components. Furthermore, it is also necessary to establish a link between planning and implementation.

Provided that manufacturing, materials, and computer control equipment are integrated in a confined area of production, then this cell may be called an island of automation. There are relevant examples for this situation.

The decisive step towards the factory of the future is the interlinking of these islands of automation and the realization of a continual information and material flow for the entire business, both vertical and horizontal. Whether or not this step will be successful greatly depends on the necessity that the factory of the future should be regarded as an all-embra-cing system. It is necessary that this thinking in terms of a system and the necessity for integration should be considered in the development and realization of the components and, in this connection, particularly when designing the interfaces in the material and information flow.

3. ELEMENTS OF THE FACTORY OF THE FUTURE-CURRENT STATE AND TRENDS

3.1 Computer Integrated Manufacturing

Flexible automation and the integrated use of computers in all areas of the enterprises associated with production are the essential features characterizing the factory of the future. Therefore, Computer Integrated Manufacturing (CIM) is not only a catchword, it is a goal all future-oriented enterprises are striving for. Under an overall CIM concept-as shown in Fig. 3 (Waller, 1983)-the individual modules are currently being developed step-by-step and integrated.

In manufacturing to customers specifications, the design department has a decisive influence on the costs of the product and on the throughput time during the preparation of offers. To relieve the design engineers of repetitive tasks and to reduce design hours, CAD systems are increasingly used.

In the field of CAP, all data and documentation required for production are generated under computer assistance. The CAP systems include program packages for computer-assisted. preparation of work plans, for automatic generation of parts lists, assembly plans and inspection plans. All this is based on the information originating from the development and design engineering department and stored in a data base (Fig. 4).

The automatic generation of the NC programs to be used in machining and testing machines is gaining increasing importance. For this purpose, the geometrical and technological data normally used in CAD and CAP and stored in a shared data base are utilized, using standard programming languages. Functions of this kind enlarge the concept of CAD and mark the transition to integrated CAD/CAM systems.

Tasks of operative production control and process inspection are performed in the field of Computer Aided Manufacturing (CAM).

Due to the comprehensive calculations to be performed,

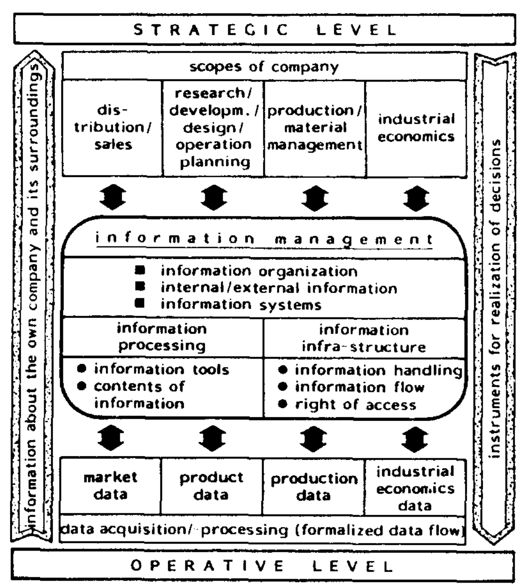


Fig. 3 Organized information management

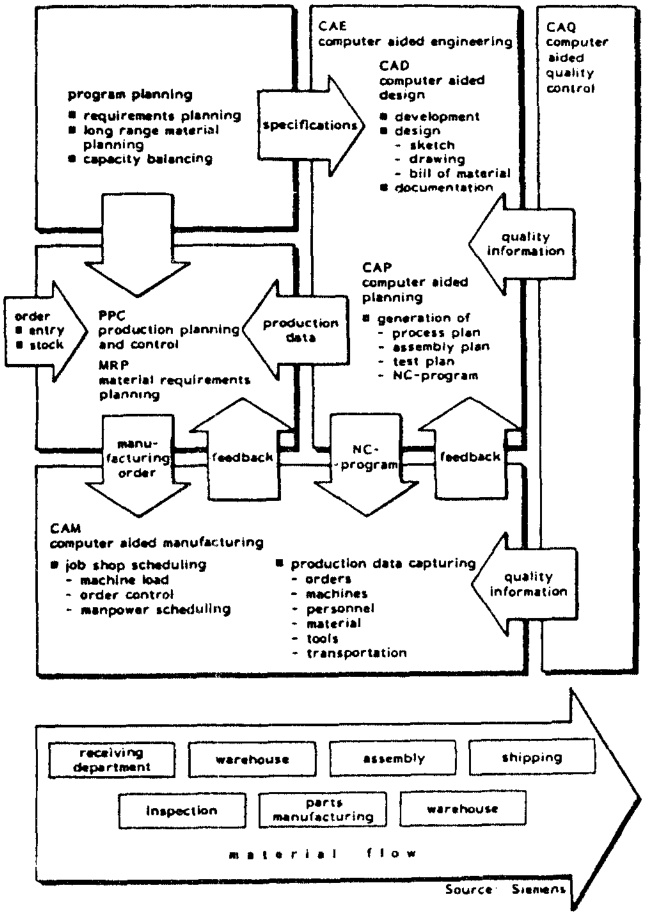


Fig. 4 CIM-computer integrated manufacturing

the large volumes of data to be managed, the frequent repetition of routine jobs and the heavily networked relations of information, the field of Production Planning and Control (PPC) has been a traditional EDP application in industrial organizations. The increasing attention to individual internal marginal conditions and the improved flexibility of standard software associated with it resulted in an unexpectedly sudden growth of the implementation of standard software systems.

The general development of Production Planning and Control Systems is characterized by two trends-the "push" approach and the "pull" method.

The "pull" method has become known here as the "KANBAN" system. This system is to achieve "production on call" on all production levels. The process is driven by the final stage of assembly, which passes a request tag for its immediate material requirements to the preceding stage. This approach is pursued in upstream direction up to the raw material level. The advantage of this method is the fact that there is no work-in-progress (WIP) inventory. The goal of the "reduction of current assets" is thus arrived at. The disadvantage is, however, that "KANBAN" calls for a constant demand on the part of the customers. Modifications of the "KANBAN" method are termed JIT (Just In Time) and OPT (Optimized Production Technology).

The "push" approach as implemented in systems of Manufacturing Resource Planning (MRP II) is based on the actual and future external demand. It goes beyond the previous approach of Manufacturing Planning (MPR) in that MPR II

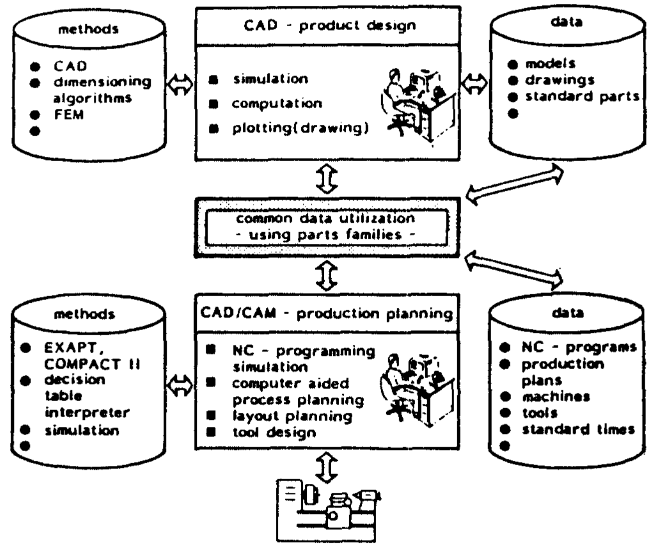


Fig. 5 Integrated system for product design and production planning

comprises a system for the integrated planning, control and inspection of material, machines, labour and funds covering all areas of an organization (Neunheuser, 1984). The advantage of an MRP system is its capability to quickly respond to customer requests. Linked with it, however, is the disadvantage of a large work-in-progress (WIP) inventory. Therefore, the further development of production planning and control systems will aim at combining the advantages of MRP-no order backlogs-with those of "KANBAN"-low WIP inventory.

The linking of the island solutions only indicated here into an integrated overall concept cannot be confined to the software alone. On the contrary, it is necessary to integrate the computers already available today and those to be installed in the future into a hardware hierarchy (Fig. 5).

3.2 Development in the Production of Parts

The development in the production of parts is above all characterized by technical and organizational measures aiming at both higher productivity and more flexibility.

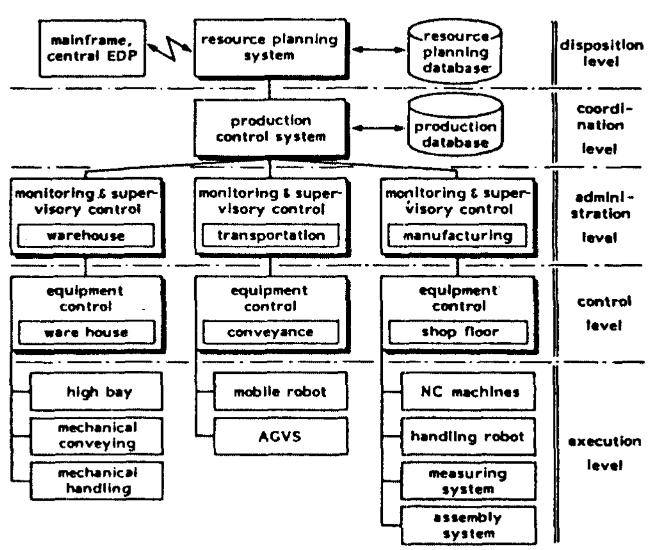


Fig. 6 Five-level hierarchy of computers

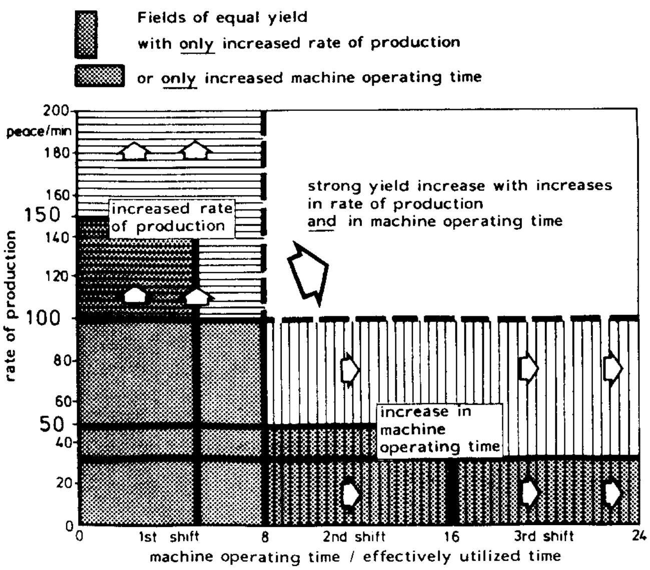


Fig. 7 Increased yield by increased rate of production and/or machine operation time

These initially include measures which permit a better utilization of fixed assets.

The available capacity field of a manufacturing plant (Fig. 6), which we have so far only utilized upwards in a vertical direction by inreasing the output time unit, is now to be stretched by temporal utilization, whereby we are attempting to operate the machine not only in groups of eight hours per working day, but for a much longer period. In the first step, automation for 35 minutes of operator free operation already brings about considerable gains in utilization.

Other measures aim at achieving a high degree of automation with increasing economy. Here, it is already possible to auto-mate the subfunctions shown in Fig. 7 with the facilities of the current state of the art.

In conventional, manually operated machines, the work is prepared, machined and prepared again to be transported onward-all manually. In the past the operation process was increasingly automated by controls. Today however, the work is prepared in a magazine by a transport system, partly already driverless. The machine operates alone, works off the order and magazines it for further transport. Flexible manufacturing systems are characterized by the fact that several such machines are interlinked in automated material flow and information flow-controlled by a computer. In the extreme case, the aim is that each workpiece in the magazine is different. This means that the manufacturing unit is able to produce overnight the parts required to assemble the product the next day and then to deliver it the day after. This results in a considerable decrease in the stock of half-finished and finished goods with a simultaneous, very high utilization.

A basic condition for the step-by-step increase in degree of automation is that the individual components are compatible among themselves as well as "upwardly" with regard to their material and information flow interfaces. The standardization followed thus far (although not closely enough) of solutions available on the market today for handling and linking facilities, as well as control systems, requires a greater cooperative effort between component manufacturers and research institutes.

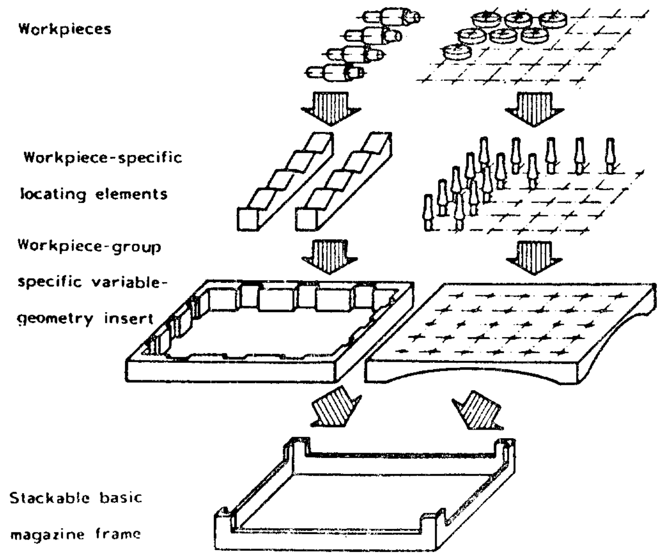


Fig. 8 Modular magazining system

Through an industry-wide standardization of, for example, purely operation-specific interfaces such as pallet dimensions or transfer heights, the application of universal transport systems and aids could be realized independently of the degree of automation for the entire system. A step in this direction is the concept developed by the Fraunhofer Institute for Production Technology and Automation in cooperation with various manufacturers of machine tools and automation facilities for an alterable magazine of modular construction in the conventional Europallet format for turned workpieces (Fig. 8). The goal of current development work is a modular magazine capable of receiving in order workpieces of various weights, sizes and process states, transporting the workpieces safely, and then placing them in the correct location for the handling facilities at the machine tools. Through standardization of the interfaces between machine and handling facilities, high compatibility of the solution developed should result.

3.3 Developments in Industrial Robotics

The areas of application of industrial robots in West Germany (Fig. 9) are primarily spot welding, painting and,

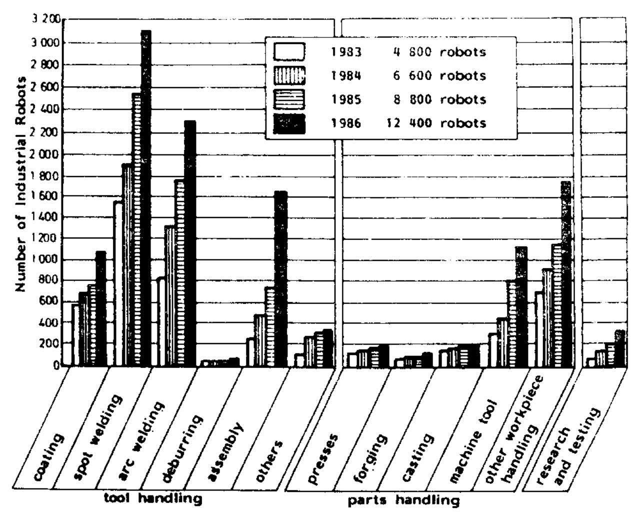


Fig. 9 Application fields for industrial robots in Germany

increasingly, seam welding as well as loading and unloading of machines. The highest growth rates have been predicted for industrial robots in assembly technology. Despite the strongest relative increase in industrial robots in assembly, one will still have to await further developments during the coming years. The problems in the area of assembly automation are only seldom due to the robot itself, the necessary peripherals posing the major obstacles.

In viewing future developments to be expected in the area of robotics, one can also see existing weak links:

○ Sensor technology will develop very rapidly and will enable robots to adapt with more "feeling" and "intelligence" to given tasks and to be able to work even within suboptimally-prepared environments. Thus the development work for problem-specific periphery is reduced.

○ The industrial robot-designed for flexibility and universal suitability-is developing more and more into a specialist (painting robot, welding robot, commissioning robot). This is due foremost to the special know-how inherent in the process and the periphery adapted to it.

○ The machine manufacturers have realized that automation in the proximity of their machines allow the achievement of considerably greater economies than the further optimization of the machines themselves. It has been seen that handling operations especially have drawn machine manufacturers' attention. The goal of this future development will be to offer the handling device as an accessory to the production facility.

○ In the intermediate term, the prices for industrial robots will not be influenced greatly. In order to be able to realize a greater number of industrial robot applications in the future, low-cost industrial robots are being developed.

○ In order to reduce the cycle time of handling procedures, lightweight robots must be developed. In order to achieve success in this area, developments in the supply sector must be awaited and at the same time, new directions must be taken in drive technology (power via shafts and motors containes in base).

○ Robots will be able to work in a larger workspace, i.e. they are becoming mobile. This can be realized, for example, with inductively-guided shop transport vehicles (Fig. 10), with warehouse stocking devices and additional industrial robot or with large gantry construction. Portable industrial robots will also be developed and applied, e.g. for welding in ship construction.

○ Programming of industrial robots will be made simpler through other programming techniques (CAD/CAM, speech input, higher programming languages, semiautomatic programming). Thereby the effort of program development will clearly decrease, allowing economical programming.

○ New industries and areas of application will open themselves to industrial robots, such as "clean room" technologies and manufacture of large parts (Fig. 11).

Fig. 10 Tool supply by a mobile industrial robot

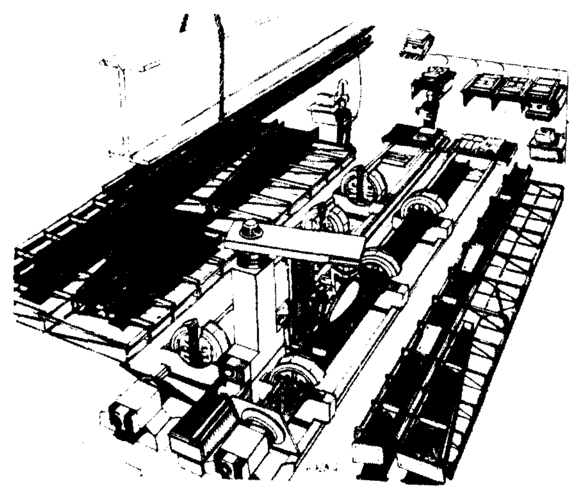


Fig. 11 Automated handling, tacking and welding of large Workpieces

3.4 Development in Assembly

In comparison with the production of parts, only a few flexibly automated systems have been realized so far in assembly. The potential for its application will, however, increase when more technical rules for assembly automation are formulated and followed (Fig. 12). Nevertheless, these can only be realized over a longer period of time, so that the prognoses regarding the development of assembly automation are vague.

Product design for assembly will gain importance, similar to that of part design for manufacture. Measures for assembly-suitable design of products are first to be consid-

TECHNICAL RULE	CONCLUSION
1. assembly necessitates system observation	overall consideration and inclusion in the automation of the fields: material preparation, handling, joining, adjusting, checking and packing
2. minimum no. of individual parts	integral construction
3. individual parts and sub-assemblies according to drawings	• adhering to size and shape tolerances • consideration of tolerance chains • reliable quality control • observation of availability of assembly plant
4. product structure from sub-assemblies	independent elements suitable for assembly and checking
5. collection of assembly procedures suitable for automation	• separation of automatic and manual assembly into fields • little pressure in assembly sequence
6. handling oriented individual parts	application of easily recognized ordering and positioning features
7. ordered magazining of individual parts and sub-assemblies	• separation of parts as late as possible in the manufacturing process (flow production) • magazining of indivdual parts and sub-assemblies • automatic or manual pre-ordering • manufacture at the assembly spot
8. straight-lined joining movements	sandwich construction
9. minimal flexibility demanded of gripper and devices	• formation of assembly families • formation of variants at the end of assembly • formation of assembly lots to reduce gripper and fixture changes

Fig. 12 Technical rules for assembly automation

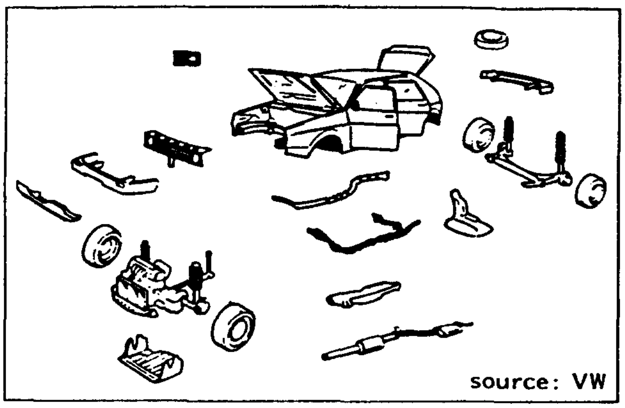


Fig. 13 Modular design of an automobile

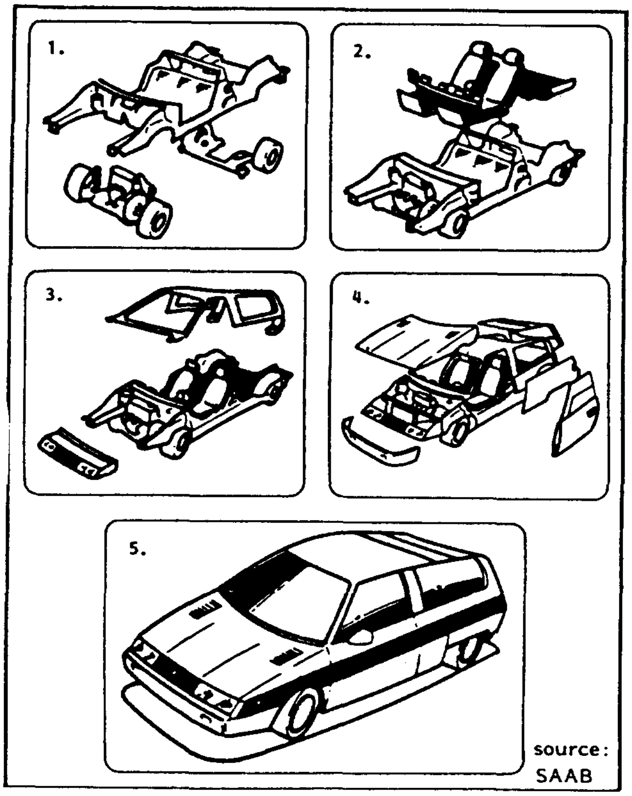


Fig. 14 Module concept for a final car assembly

ered in terms of parts handling and second with regard to joining of parts. Product design for ease of assembly leads to reduced effort in automation (or even allows automation in the first place) and reduces manual tasks necessary for assembly.

Design work with view to an easier assembly means that the design engineers do not only have to think in terms of "parts". Their future task will rather be to think increasingly in terms of "modules" of which a product is composed (Fig. 13 and 14.)

The spectrum of the future assembly will essentially be characterized as follows:

- o Labour-intensive assembly systems
- o "Hybrid" assembly systems with manual and automatic workstations
- o Flexibly automated assembly systems

4. SUMMARY

Despite all uncertainties inherent to a look at the future, the path to the factury of the future has been marked out. It is the goal of the individual measures to ensure that the factory of the future is an integrated system of people, equipment, materials, information and energy. The chances to achieve this goal lie above all in the developments in the field of information technology. To make use of these chances, reorientation and adaptation processes on the part of the staff on all hierarchy levels of the enterprises will be increasingly necessary. This also includes that the development of engineering and even less the application of it is left to the engineers alone, Ortega y Gasset put it like this: "In order to practise engineering, it is not enough to be an engineer". This contribution is also intended as an aid, in order to achieve this goal.

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