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MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

ROBOTS WITHIN A FLEXIBLE MANUFACTURING SYSTEM

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ABSTRACT

In recent years greater emphasis has been placed on keeping manufacturing costs down, profits levels up and staying ahead of competition. With labour and material cost at an all-time high more cost effective production solutions are being investigated by means of Flexible Manufacturing Systems (FMS).

The application of industrial robots to FMS and to production cells has, however, been rather limited. Proper use of robot within the frame work of a flexible manufacturing cells was up to now only made in relatively few applications. This is probably due to their relatively high cost, the need to distribute the cost between machines in the cell and the problem of balancing machining operations throughout the cell to maintain component flow.

However, we expect Flexible Manufacturing Systems and robot systems having less peripheral units by expanding robot variety from simple types to high performance types, development of better sensors and robot languages, higher performance robot controllers and cost reductions. Hence, this paper investigate the importance of applying robotic principles in support of improved flexible manufacturing systems, leading eventually to the factory of the future able to operate unmanned for substantial periods, especially at night.

INTRODUCTION

An industrial robots is a general-purpose, programmable machine possessing certain anthropomorphic characteristics[1] . It is most typically used for parts handling tasks but can also be used in conjunction with a variety of manufacturing processes. The robots can be programmed to carryout a sequence of mechanical movements. It will perform that sequence over and over again until reprogrammed to perform some other motion cycle.

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Robot is presently in its infancy as an industry. They are Computer Controlled devices that automatically perform a programmed sequence of operations. So far robots have primarily been used in welding and painting applications in automative assembly plants.

Several applications of industrial robots are Worldwide there are approximately 200 models of robots produced by nearly 100 manufacturers. The countries that are taking the lead in robot development and use seem to be Japan, the United States, the United Kingdom, and Italy, [2] . The beginnings of the robot in the USA can be traced to the inventor George Devol, who began patenting this industrial robot designs in the early 1950s. In 1958 to begin to fabricate several of the machines. Three prototypes were built in 1962, and by 1966, seventy robots had been built by manual methods. About 20,000 robots working in factories throughout the world, Fig.1 illustrates the distribution of the robots in the industrial countries. Figure 2, shows the distribution of robots for different jobs within the UK as of December 1981. An industrial robot is simply an aid to increased productivity like any other tool in the factory. Robots are ideal replacements for humans inrepetitive, dangerous, or boring factory task.

Robots can be programmed by software coding or by use of the "teach mode" to perform tasks. In the teach made, a human operator moves the robots through its sequence of operations manually and instructs the robots to remember these movements. Robot software language is now evolving from machine language (assembly code) to higher-level languages such as BASIC or FORTRAN. This will make the programming of robot operations easier and more efficient.

The technological advances needed to bring about the widespread adoption of robots in factories are the two feedback senses of touch and sight. As pattern recognition software and sensory equipment and adaptive feedback mechanisms become available at even lower costs, robots will be qualified to perform many assembly and parts selection tasks now requiring these exclusively human feedback factors. Figures 3a to 3d show the four basic application working space shapes-spherical polar co-ordinates; cartesian co-ordinates; revolute co-ordinates; and cylindrical polar co-ordinates.

The following listed and briefly described items are several critical to be considered when evaluating robots for applications in manufacturing:

Work envelope: The cubic space the robot will be expected to provide arm motion in.

Number of axes of movement: Most sophisticated robots use a form of arm comparable to human's from the shoulder joint to the hand. The more axes of movement a robot has, the more flexible it is in application possibilities. In addition to axes of movement, a related criterion is the type of movement the robot performs-either in spherical coordinates or X-Y-Z

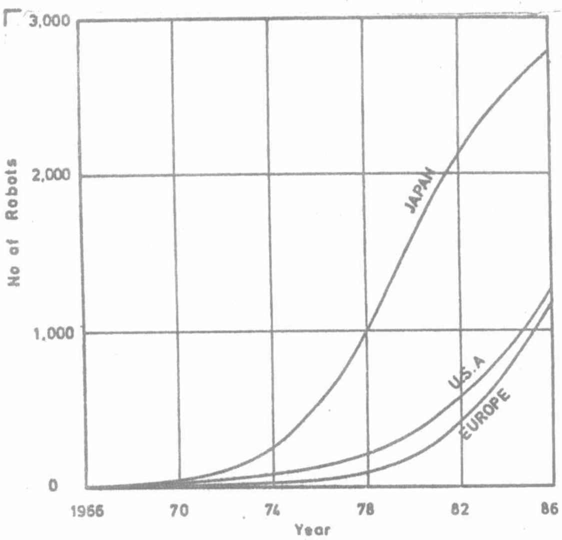
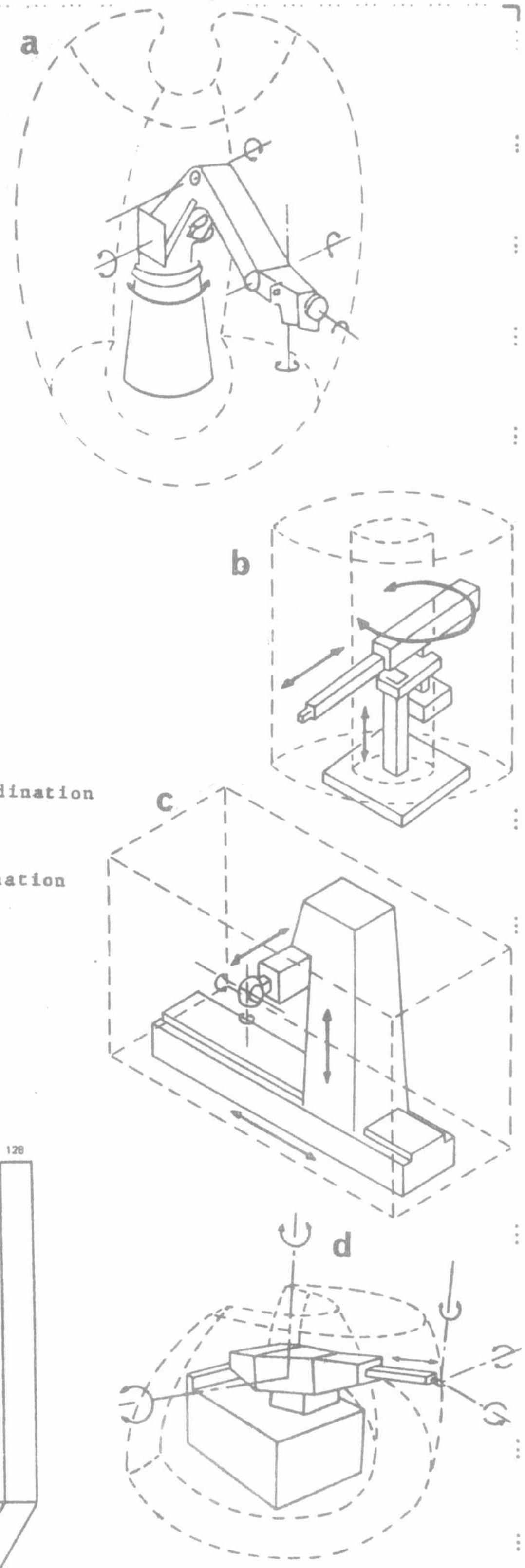


Fig.1. Robot in the world industry.



a- Revolute Co-ordination

b- Cylindrical polar co-ordination

c- Cartesian co-ordination

d- Spherical polar Co-ordination

Fig.3. Basic application working space shapes.

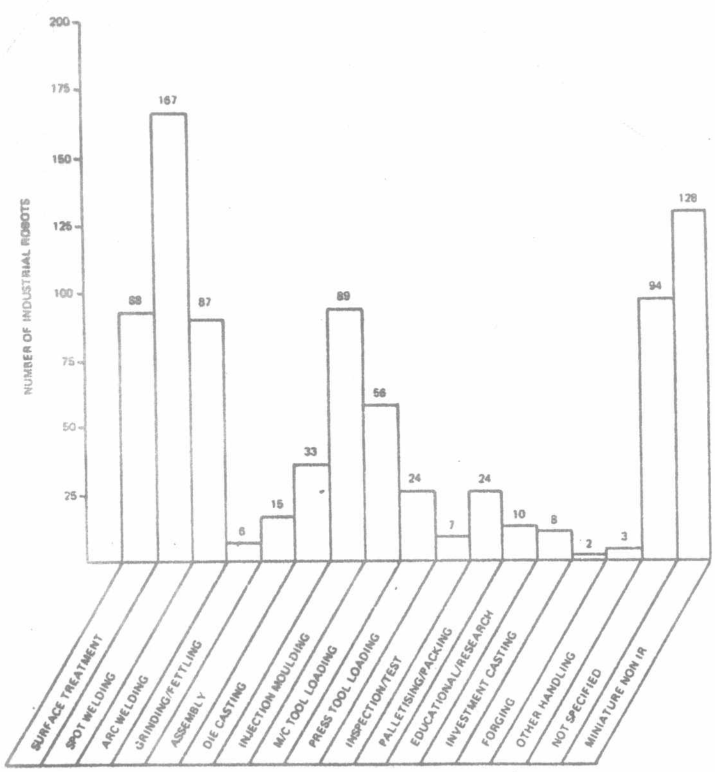


Fig.2 Robot distribution within the UK Dec. 81.

rectangular coordinates.
Load capacity: Most robots are designed to work over a limited range of load capacity, such as from 0 to 5 pounds, or 0 to 50 pounds.
Speed: Note only is the speed robot arm movement important,but often the speed at which the effector (the hand or gripper) acts becomes a consideration.
Type of movement: As in NC machine tools, this can be point-to point or continuous path movement. The latter requires more computer memory to store movement data points, Fig.4 illustrates the basic motions for the polar and cylindrical robot configurations.
Precision: Precision refers to both the concept of accuracy and repeatability. Accuracy refers to the robot's arm positioning.

Capability relative to the programmed target point. Repeatability refers to how closely to a specified location each arm movement comes to the previous cycle's movement.

ROBOT BENEFITS

Industrial robot can contribute to increased productivity and relieve workers of hazardaus and physically exhausting tasks. Industrial workers are nowadays pressing for vastly improved working environments. At the same time companies have to increase productivity to maintain or improve their position on the market. Industrial robot system has been making a distinct contribution to fulfilling these requirements. The robot can work continuously day in and day out in environments which, for human beings, would be uncomfortable or dangerous.

Generally purpose industrial robots are most likely to be economical and practical in applications with the following characteristics:

1. Hazardous working conditions

In job situation where there are potential danger to a human operator or where the workplace is hot and uncomfortable,industrial robots are likely candidates for the job. Robots have become especially important in these types of jobs situations since the Occupational Saftey and Health Act (OSHA) became effective in 1971.

2. The job is repetitve.

Many manufacturing jobs fit this description. Even if the cycle is long and involves a sequence of many separate moves, an industrial robot may be feasible. One requirement is that the sequence of actions must not change from one cycle to the next.

3. The Component to moved is heavy.

Some industrial robots are capable of lifting items as heavy as several hundred kilogrames.

A sampling of tasks performance by industrial robots would be include the following more typical applications:

Parts handling: A large variety of pic-and place jobs, moving workparts from one location and repositioning them at another location.

Machine loading and unloading: The types of production equipment involved include stamping processes, forge presses, die casting machines, injection molding machines and most types of metal-cutting machine tools. In many instances, the robot is set up to control and synchronize the operation of equipment.

Spray painting: The spray point nozzle is attached to the robot's arm. The arm is programmed to move through a sequence of continuous-path motions to complete the painting operation.

Welding: Both spot welding and continuous welding. Perhaps the most typical applications in this category are on body fabrication lines of the automobile manufactures.

Assembly: In simple mechanical assembly, robots perform operations which are basically an extension of their pick-and-place motions.

Robots are well established in paint spraying, welding and assembly applications as well as glass making, [3] . The men were supposed to work an 8 hour shift but, because of the extreme heat and heavy nature of the job, they could only manage about two hours on and two hours off. The robot works two shifts and produces upto 36 variations of cones and screens in lead glass. For some of the larger workpieces productivity improved by 100% consistency of component has increased, and the rejection rate is lower.

Robots can be used with conventional, airless and electrostatic atomisers for painting or poweder coating. The actions of skilled hand sprayer can be duplicated by a robot by guiding it through the spraying sequence for a particular workpiece, [4] .

Automation has doubled production for a canadian firm with one of its programmable welding robots, [5] . After using the robot for six months output is said to have doubled from 25 to 50 stoves a day. The installation has also brought savings in consumable materials and keeps end welds free from the inequality of produced by hand welding.

In addition, lower technology costs are enabling robot manufacturers to begin delivering products with acceptable payback periods. The Robot Institute of America estimates that the cost of most robots is recovered within the first two years of use[6] . Because of these trends increasing computer power on microprocessor chips and declining costs of technology-robots are becoming a reality for high technology manufacturing.

Rapid returns on investment

Owing to its versatility and programmobility, robots system provides new possibilities of minimising machine investments and the capital tied down in raw materials and work in progress. Previous investments in machinery can be better utilised. In other words, there are several reasons why companies should review their production set-ups and consider the advantages of robots. The benefits, both economic and otherwise, of investments in such systems are considerable: no hazardous environments for shopfloor workers, higher productivity, elimination of unpopular heavy or monotonous manual routines, more advantage taken of earlier investments.

Robots to replace expensive special machines.

Given more advantages for FMS. Robot can weld, grind, deburr, polish, glue, cut, etc. with great flexibility. It can thus often replace a more expensive special machine. Using robot instead of a special machine usually means large savings in machine investments. In addition, a whole series of problems can be solved. Special problems of the future can be tackled using the same machine.

ROBOTS WITHIN FMS

FMS has been developed to provide some of the economics of mass production to small batch manufacture. The flexibility is obtained by linking together the three main elements of an FMS systems, these being: Potentially independent NC machine tools, assembly machines and inspection sections; storage, transportation and orientation systems for parts and tooling; An overall computer control system that co-ordinates all the functions of the above through a comprehensive robotic system.

Robot producers are currently concentrating on the development of robots for use in advanced, or integrated manufacturing systems. The combination of NC machines and robots makes it possible to produce not only identical small batch parts but also parts with a variation of the same basic operations. When using robots for small batch production, several important factors have to be considered. There is the cost of special auxilliary equipment such as grippers, fixtures and magazines, the initial cost of programming the robot, the expense and time required for changing grippers, fixtures and programs.

A robot-controlled production group including one or more robots. This does away with the need for buffer storage between the machines and considerably reduces the throughout time. Furthermore , it often increases the capacity of the production group so that any waiting ahead of the group is eliminated. The high precision, compact design and high-capacity program memory of robot and vital factors. Having a robot-controlled production group will result in the reduction of capital tied down in machine tools and work in progress as well as a higher rate of production.

The large program memory and high reliability of robot allow a production group to be operated almost entirely unmanned,...

6

Machines are prepared and magazines are filled in the evening and completed items are ready for collection in the morning This results in large savings in machine investments compared with normal one-shift operation. The subsequent high rate of production means faster capital turnover.

The successful application of robots in FMS application is due to entirely to the principles of Computer Aided Manufacturing (CAM). The most important benefit derived from robotic applications is the ability to extend the degree of control away from the confines of the production machine into the surrounding working area[7] . This was achieved initially by stand alone robot devices designed to provide the maximum number of different applications which enhanced their value. To the widest range of potential users of FMS's.

Robot devices have a further attraction in that they are able to link several stand alone machine tools together to turn a co-ordinated production cell and many working examples of such groupings are currently in operation. Applications like these can v ry from a simple linkage between two or three machines to the latest development of comprehensive production facilities on a factory scale which relay entirely on robot linkage. Figure 5 shows a typical robot application to a vary multi machine production cell. Examples of installations are as varied as the production processes themselves ranging from a group of machine tools turning and milling components to the grinding of castings and the polishing of stainless steel sink units.one of the more widely known fullscale applications in Japan where a factory for the manufacture robots has been specifically designed to use the ability to fully co-ordinate a number of machines and so create a fully automatic component production system. The following FANUC systems are some main examples from 20 systems which are now in operation[8] . The SCAMP system recently introduced by the UK, has achieved the same level of automation for a range of components used in the manufacture of lathes[7] . Another application where robots have been particularly effective is in the plastic injection moulding, here the combination of CNC controlled handling and processing has enabled both quality and output to be improved It is uncommon for as many as 50 or 60 moulding machines producing a variety of plastic components to be serviced by robots. The robot is particularly adaptable in systems involving the transfer to complex parts between processes, their storage and operating areas. Some examples for the general application of robots within FMS are shown in Figs. 6&7.

ATTRIBUTES OF FMS ROBOTS

Industrial robots are implemented in various fields of the manufacturing industry. Apart from a few exceptions they are mainly used as stationary units. It is becoming more apparent however, that only a limited number of even the large manufacturing companies are able to justify and afford such implementation on large scale. The majority, of companies are inves-

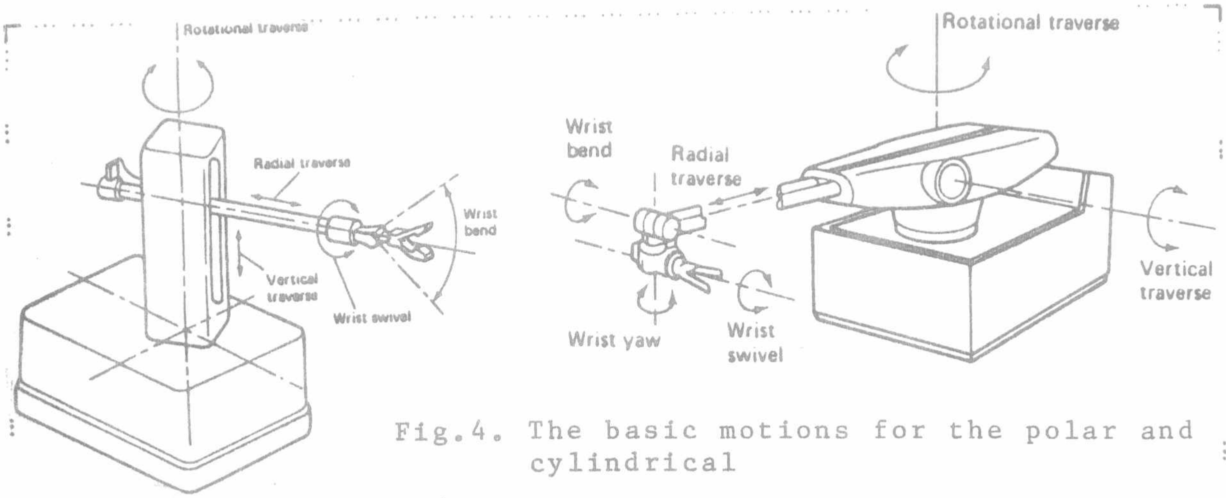


Fig.4. The basic motions for the polar and cylindrical

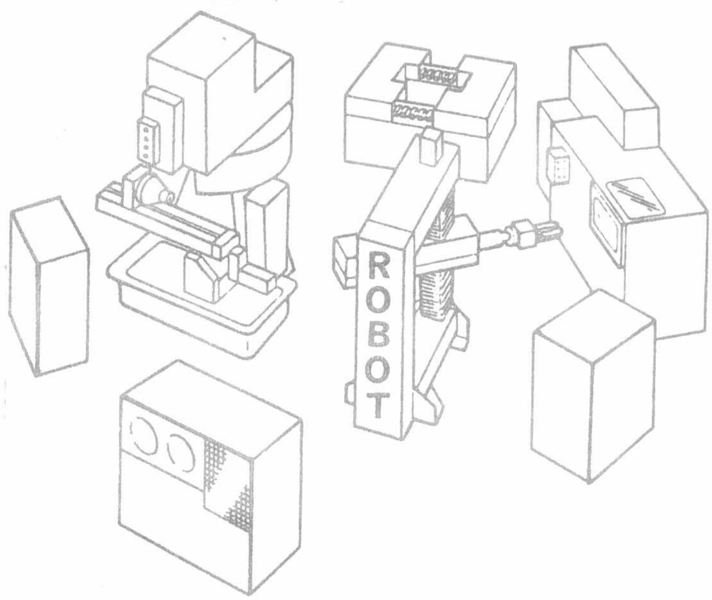


Fig.5 Typical robotic application to a multi machine production cell.

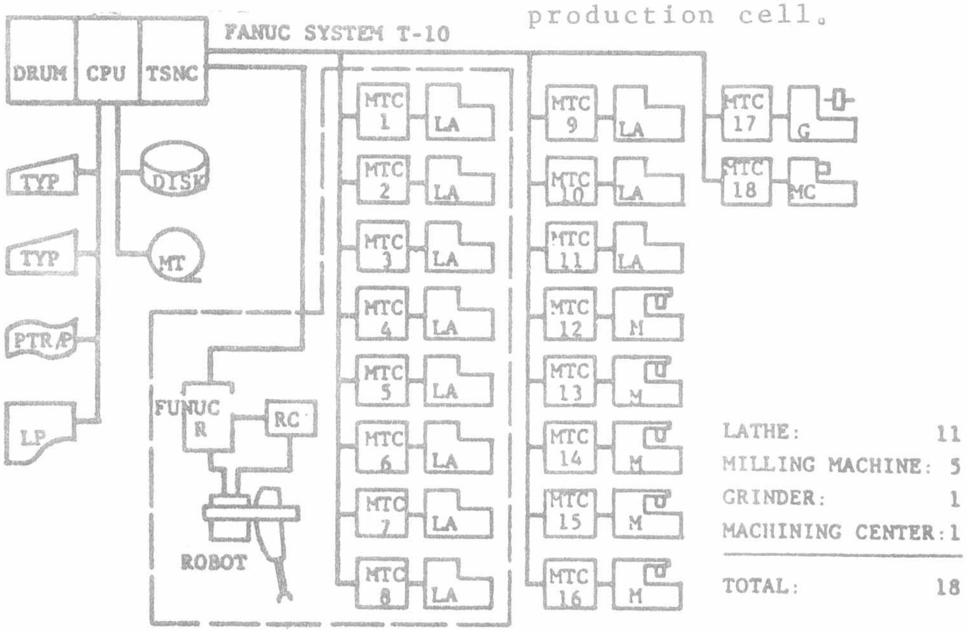


Fig.6 Example of robot-DNC system.

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tigating the smaller individual cells and taking a planned step by step approach.

The application of industrial robots to production cells in FMS has, however, been rather limited. This is probably due to their relatively high cost, the need to distribute the cost between machines in the cell and the problem of balancing machining operations throught the all to maintain component flow. Only 15% of the industrial robots are applied to machine tool cells, their main application being in welding and paint spraying.

When industrial robots do provide a justifiable solution they are normally located in front of the machine tools. This, unfortunately, prevents manual operation and restricts supervisum and maintenance such that when one machine is down, complete cell production stops,[9-10]. Machine tools employing industrial robots ought, therefore, to be served from the rear so that the front remain accessible to the operator and setter, Fig.8. Many of the attributes required to make industrial robots practical in an industrial environment and more useful in FMS include good positioning repeatability, reliability,flexibility, easy programmability and adequate load capacity. Attributes of commercially available robots, table 1, seem to be not sufficient to satisfy FMS requirements[11] .

Table 1. Altributes of commercially available robots.

1. Work space command with six infinitely controllable articulations between the robot base and its hand extremity.
2. Teach and play back facilities realizing fast,instinctive programming.
3. Local and library memories of any practical size desired.
4. Random program selection possible by external stimuli
5. Positioning accuracy repeatable to within 0.3 kilos.
6. Weight handling capability up to 150 kilos.
7. Point-to-point control and continuous path control, possibly intermixed in one robot.
8. Synchronization with moving work pieces.
9. Interface allowing compatibility with a computer.
10. Palletizing and depalletizing capacity.
11. High reliability-with not less than 400 hours MTBF.
12. All the capabilities available for a price which allows purchase and operation within the traditionally accepted rules for economic justification of any new equipment.

Insufficient uitlization of the technical and tempora availability of robots, especially in the area of loading and unloading of machine tools, are limiting the scope for an economical successful application even if a technical realisation would be possible.

The use of inductively guided electric vehicles-Robots vehicles in recent years represents perhaps the most important step in

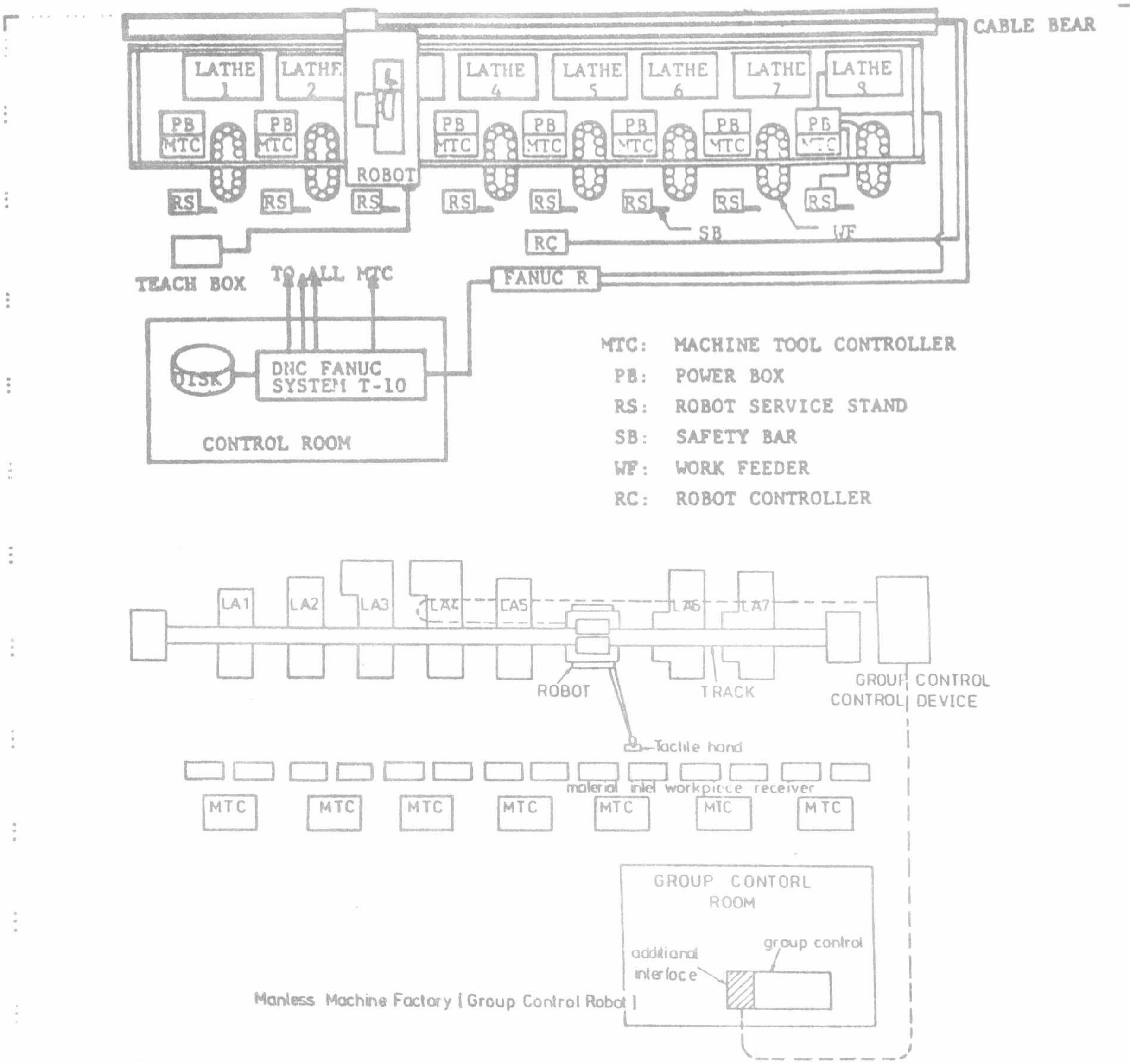

Fig.7. Different examples of robots within FMS.

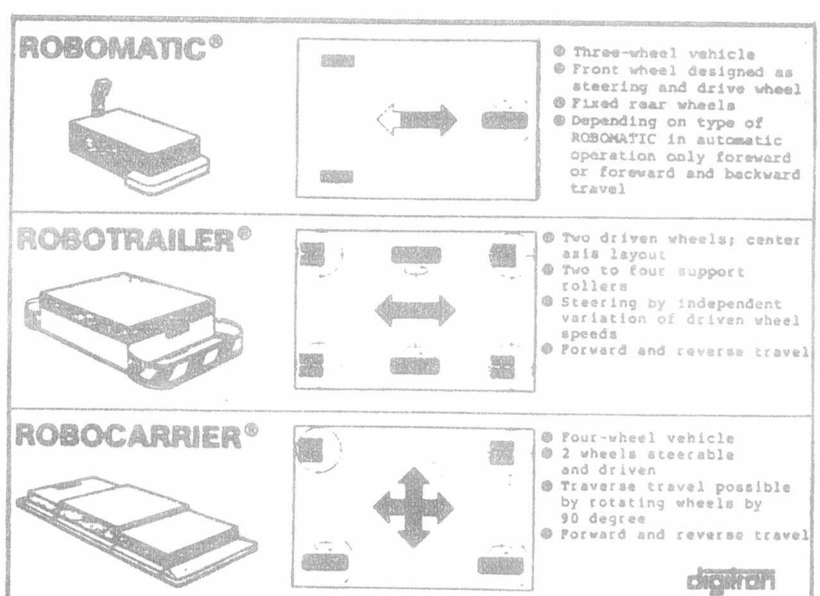

Fig.8. The drive and steering system of the 3 standard types of robo vehicles.

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this direction. Automatic systems of the early vehicle types have been further developed and offer substantial advantage with respect to safety, flexibility and ambient conditions. The use of automatic loading and unloading equipment and the integration of microprocessor controlled vehicles in central control and data management scheme have given rise to new and profitable applications.

The application concepts of inductively guided vehicles and their possibilities regarding flexibility, spatial considerations, integration in overall systems proved its capability in use for assembly of medium sized unit loads, Robomatic, fast and highly maneurenable vehicle for loads of 300-300kg, Robo trailer, and suitable as a work plat form or for in plant transport of large objects Robo carrier, Fig.9.

The newly developed robomatic system for car industry-ideally fulfills the demands made upon it with regard to working conditions, flexibility and operational relability. It is the first step in this direction which demonstrates its superiority over inflexible conventional transport systems and the low investment involved[11-12] .

Apart from limitations in load capacity and sensory ability,it is the size of the operating range which is restricted the applicability of industrial robots to FMS. A possibility to solve this problem is to give industrial robots a mobility which enables them to flexibly serve several machines or work stations. Application of stationary robots in circular arrangements for the attendence of several machine tools have such disadvantages as difficult access to the machine tool and limited space between the robot and the surrounding machines.

Linear mobile robots are characterised by one stranslatory usually horizontal axis. Unflexibility in regard to branches and changes of the travel path as well as interruptions in other functions of the internal material flow are the disadvantages of this track bound transport principle, space mobile application with a freedom of movement in three axes can be achieved e.g. by a modified bridge crane. Solutions with floor bound devices, e.g. with a specially designed forklift truck, may also be possible. Considering the present technical development, mobile robots with area mobility may become useful means to enlarge the economic application of industrial robots in FMS.

The near-term developments needed in industrial robots to suit more application in FMS are more extension for the available robot attributery with emphasis on greater robot flexibility and versatility of movement, speed and ease of programming. Thus robot manufacturers put the most important targets for development include: reduced production costs, smaller installation space requirements, greater flexibility, larger carrying capacities, modular robots components to enable a building block approach to diversification of functions and visual and tactile feedback and recognition systems.

DEVELOPMENT AND TRENDS

Developments and Trends of FMS Robots

Automatic production processes no longer have to be one-way streets. The facilities offered by modern control technology render increasingly complex procedures possible and in doing so add economic feasibility even to comparatively substantial investments, since they can be used for a variety products simultaneously. This extraordinary flexibility has been made through the application of FMS and possibly by freely programmable robots as welding robots, with a fully automatic Robo carrier system and a computer using highly sophisticated software. A programmed welding robot for each car body type is no longer anything special. The portal type welding stations—Robogate—were developed to satisfy this requirements.

To increase the intelligence and consequently the flexibility of industrial robots to suit its application in FMS, the robot needs to be able to interpret the three dimensional world in which it must operate. Thus sensor controller movements of robots appear to be a highly desirable feature of the present and future applications of robots in FMS. Now, the efforts are concentrated to remove some of the constraints of binary vision and to provide other effective and economical means for achieving robot vision. Coherent fibre optic bundle which can carry optical images have been used to retrieve an image from the robot grepper area. Lasers, ultrasonics, tactile sensing have been shown to be useful for the second generation vision system. It is expected that by 1990's 60% of all robots will be equipped with sensors.

Infact the research projects are primary directed toward making robots more intelligent and versatile with vision research being given a high priority. Other research projects aimed at increasing robot speed, coordination of multiple arms, dextarous robot hands with tactile recognition capability for automatic assembly, sensory development, location control and application software development.

The technology for robot miniaturization, modularization, high speed operation, and computer control has advanced to the point where it is now available and will grow in popularity and acceptance in the first half of this decade. Technology for part recognition and position determination is also currently available, but won't receive wide spread application until the second half of this decade. Technology for color and behaviour recognition, automated assembly, and machine tool and casting robotics will not become adequately advanced until later in the first half of the decade and therefore would not achieve wider spread popularity until the second half of the 1980's.

During the 1980's robot sensory and control capabilities will improve to the point where robots can find and load unoriented parts, or in some cases, even pick parts out of a bin filled with randomly oriented parts lying on top of each other. Eventually, extremely fast, accurate, dextrous robots will be programmed and respond to a wide variety of sensory caues. By 1990 robots may begin to have a significant impact on FMS. Perhaps around the turn of the century, robot technology will develop to the degree necessary to produce the totally, automated factory.

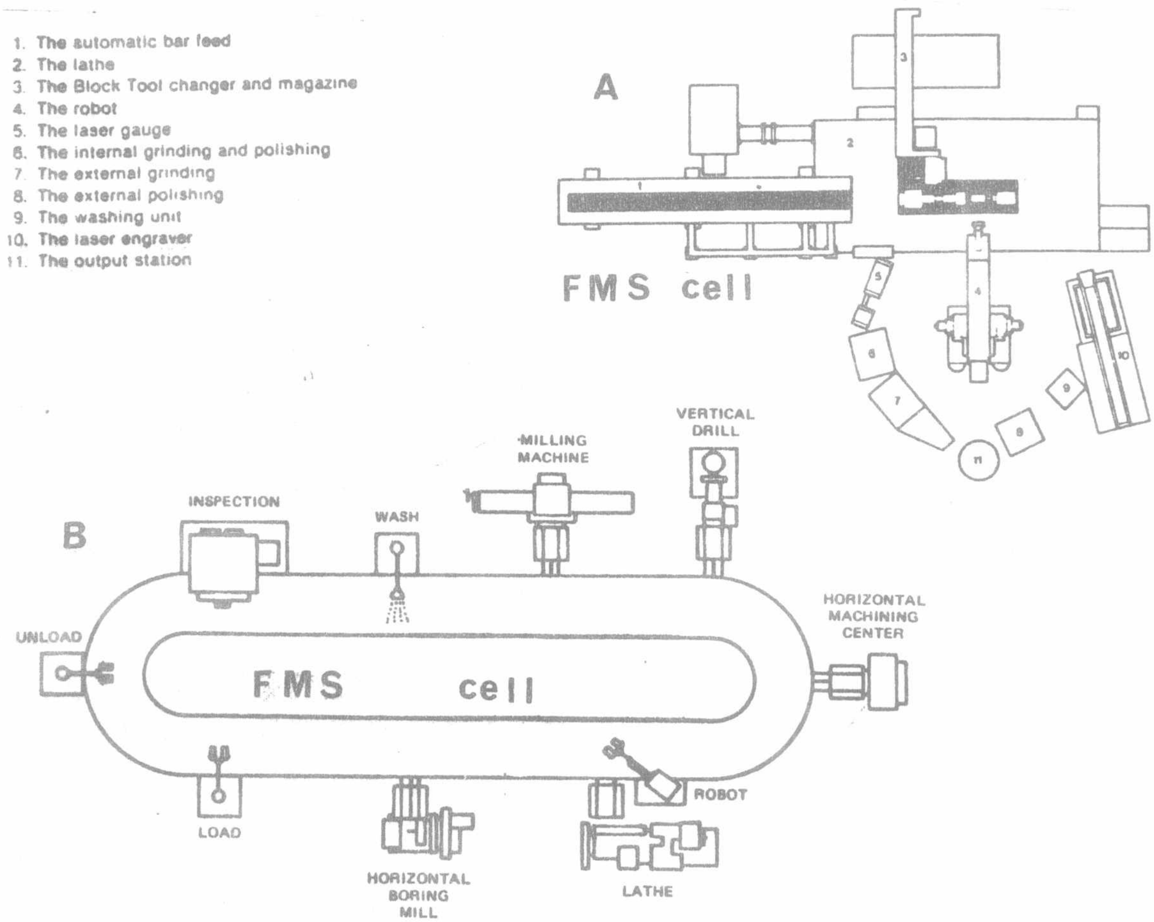

Fig.9. Two automated production Cell (FMS).

CONCLUSION

The introduction of FMS will be for the majority of a gradual process with planned development of small production cells which can later be integrated into a larger system. A limited manufacturing companies are able to justify and afford such complete system, applying modern handling methods by means of robots and integrated parts changers. The majority of companies are investigating the smaller individual cells and taking a planned step by step approach wind mostly by using industrial robots.

Industrial robots are implemented in various fields of the manufacturing industry. Apart from a few exceptions they are mainly used as stationary units. The lack of mobility versatility, flexibility, speed and ease of programming of to days industrial robots causes restrictions which have limited their use in FMS. However recent research and development is being directed towards greater flexibility and dexterity,inclusion of adaptive controls, eye sight, tactile sensing,...etc. The challenge is to combine and apply the developed technologies for the benefit of manufacturing industries.

In summary, what we see emerging are robots, initially used on a small scale in FMS but with the increasing intelligence, sensory capability, and dexteirity they will be used on a large scale. Perhaps around the turn of the century,robot technology will develop to the degree necessary to produce the totally automated factory.

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