

How to succeed in robotic arc welding

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How to Succeed in Robotic Arc Welding

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abstract

An introduction of a robotic system requires a great deal of caution. Selecting, buying, and installing a robot in a hasty way will certainly lead to an inefficient system. Taking into account a number of factors and carrying out a thorough analysis before-hand is necessary to be able to guarantee a successful introduction of the robot system. This paper describes the integral and multidisciplinary approach of robot projects, and the testing of the feasibility regarding technical, social-organizational and economic factors. This takes place on the basis of a real-life case, and is concentrated on robotic arc welding.

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ABSTRACT

An introduction of a robotic system, requires a great deal of caution. Selecting, buying and installing a robot in a hasty way, will certainly lead to an inefficient system. Taking into account a number of factors and carrying out a thorough analysis beforehand, is necessary to be able to guarantee a successful introduction of the robot system. This article describes the integral and multidisciplinary approach of robot projects, and the testing of the feasibility regarding technical, social-organizational and economic factors. This takes place on the basis of a real-life case, and is concentrated on robotic arc welding.

Keywords: Industrial robot, flexible arc welding systems, integral and multidisciplinary project approach, welding oriented product design, guide lines for automated arc welding, management.

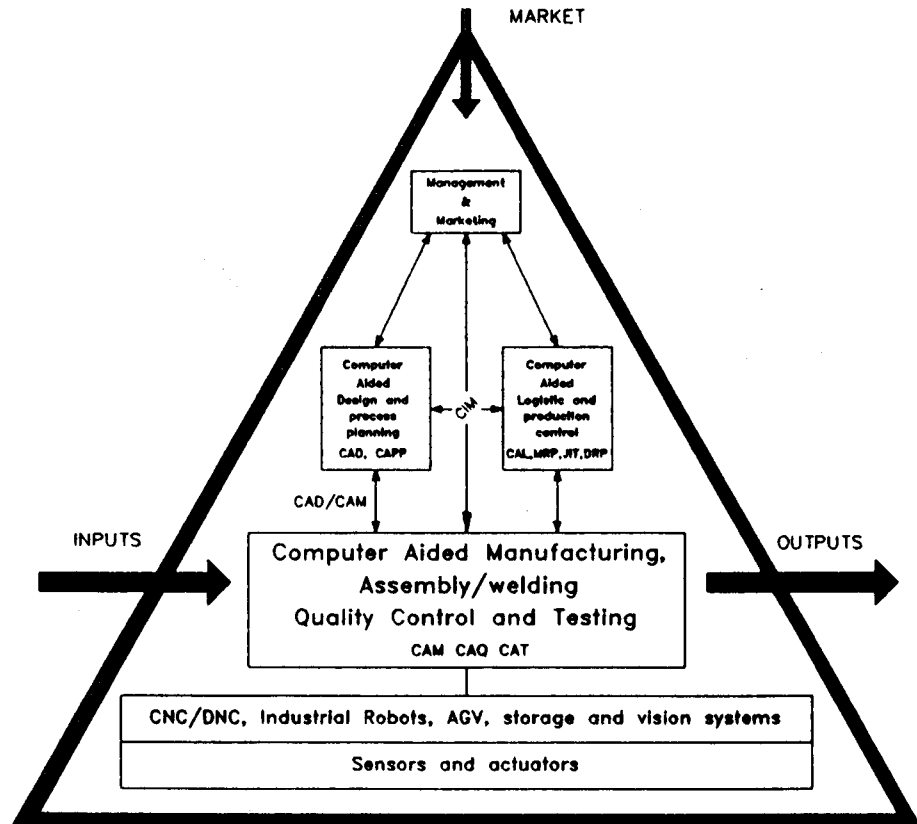


Figure 1: Computer Aided Activities

INTRODUCTION

It is known from experience that robotization must be approached from a managerial point of view and from there it should be developed on the basis of an integral and multidisciplinary project approach. This means that not only the technical aspects should be taken into account. It should happen in such a way that an integrated system is created, in which man and robot system work together in an efficient way. To introduce the robot system successfully, it is of vital importance that market, organization, work planning, product development, production process, technology, means of production and man are geared towards with another (1). Figure 1 shows the computer-supporting activities within an innovative production company. In figure 2 the field of robotic arc welding is represented.

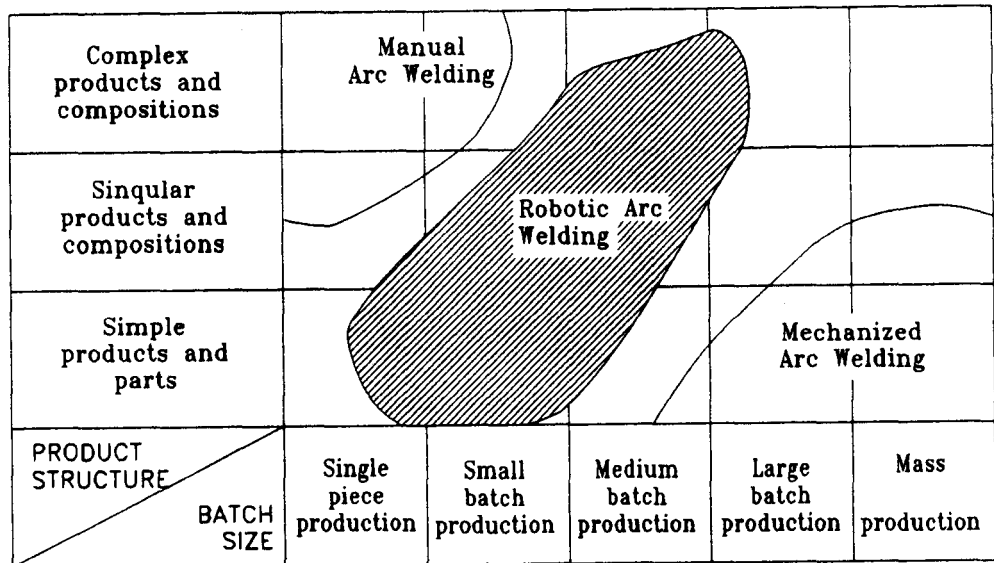


Figure 2: Domain of robotic arc welding

PROJECT APPROACH

The introduction of a robot system is to be distinguished in 5 phases (2), see figure 3. After each phase a go/no - go decision takes place. In this article only the first two project phases are discussed, namely:

- 1 the strategic phase:
industrial typology, project management and project objectives;
- 2 the orientation phase:
product and process analysis, problem definition, functional

system specifications, development of system concepts, system selection and consequences when introducing the robot system.

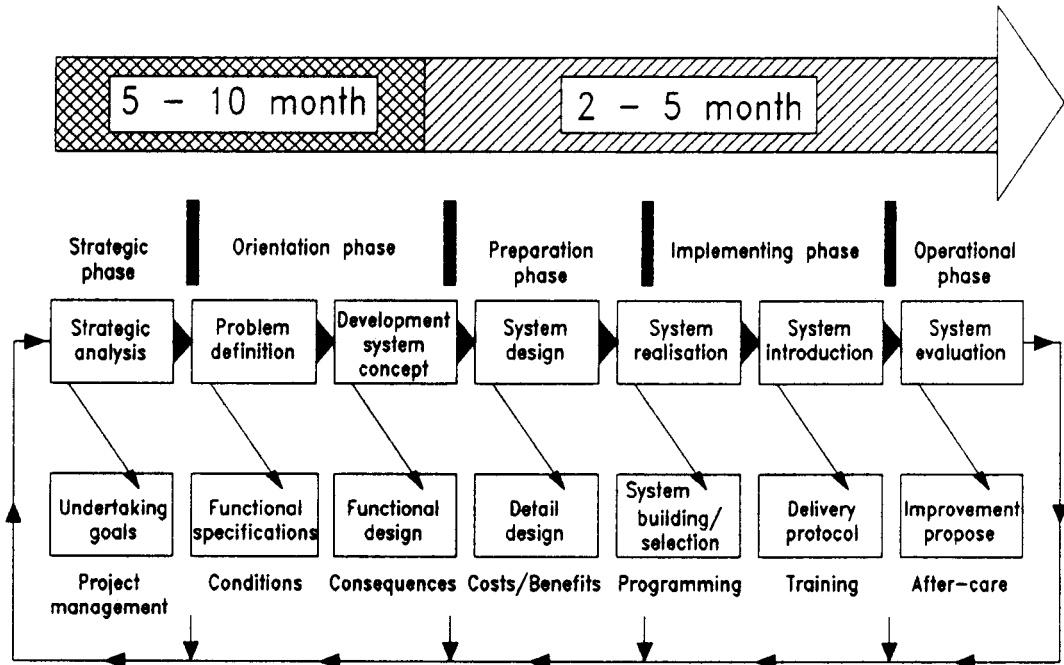


Figure 3: Projectphasing

STRATEGIC PHASE

The production firm in question is a hierarchically structured organization with a work force of about 300 employees. The working situation was analyzed also on the basis of a questionnaire. During that investigation questions were put to junior and senior executives, and were concentrated on responsibility and the function in the firm. In the light of these answers some insight was obtained into the present and the desired work situation. Based on this, the industrial typology was determined. This concerns, for instance, the type of the branche of business, production structure, production order, production specification and production scale.

Eventually, the analysis of the working situation resulted in the establishment of the industrial objectives mentioned in figure 4.

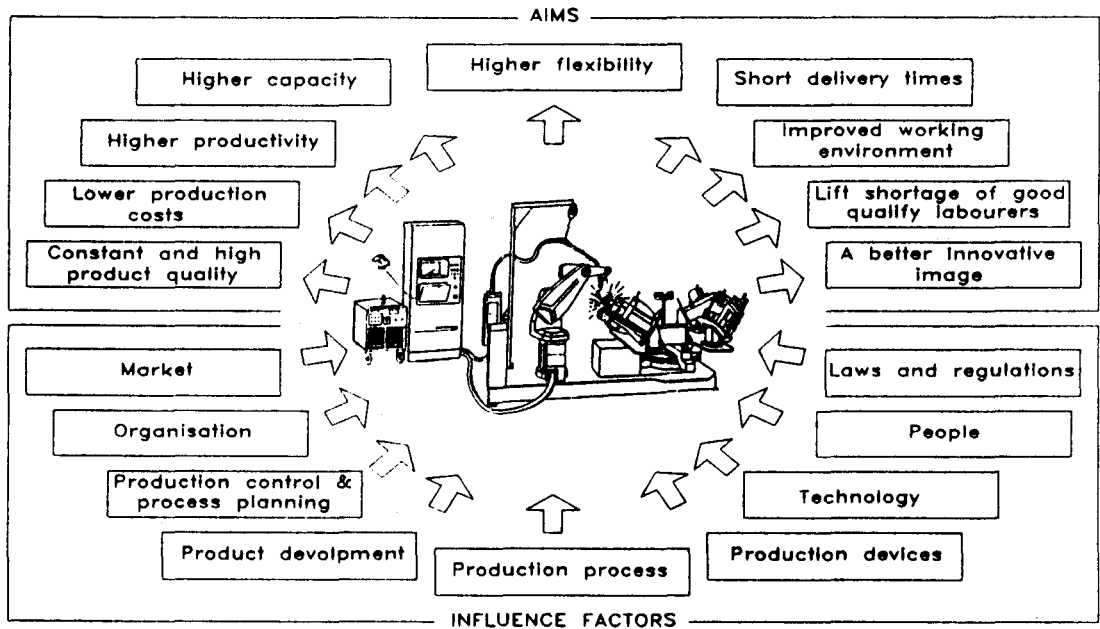


Figure 4: Aims and influence factors

The main question in this phase is: which products, produced by this firm, have market prospects. To realize the objectives mentioned above, a project team was made up in order to investigate the feasibility of robotization. This team was under direction of a project manager, an external consultant and the employees in question from various departments. The tasks and means of this project team as well as the project planning and the project budget were determined ahead of time.

ORIENTATION PHASE

ANALYSIS PRODUCTION PROCESS AND PRODUCTS' PACKAGE

For the sake of the system specifications of the robotic arc welding system to be drawn up, the present products' package and production process have been analyzed. Taking into account hereby are, among others, the production preparation, the product variants, the size of series, the production volume, the product design, the design of welding fixtures (design for automation), the flexibility of the means of production, the accuracy of the preprocessing of the product parts, the logistics on the shopfloor and the welding process.

The analysis of the product package consisted of the selection of products for robotization. The aim of this selection is to define the task setting of the robot system, thus being able to use the system as optimal as possible in the production process.

The selection was based on the following criteria: production volume, size of series, size of products, material thickness, welding length, the weight of the product, the number of manual welding hours (including fastening and clamping), the required welding quality and the product complexity. On the basis of these criteria a number of product variants have been selected group-technological. The most important conclusions were that most products are not designed to robot friendly, that the present welding equipment is not fit for robotic arc welding and that the organization of the shopfloor is very chaotic, with much intermediate storage and internal transports, which is accompanied by long throughtput times.

FUNCTIONAL SYSTEM SPECIFICATIONS

Two important basic assumptions with regard to the structured approach of robot projects are:

- 1 first specify, then design;
- 2 splitting up the robot system in small manageable subsystems

The specifications of the robot system are part of the development of the system concepts and for the negotiations with robot suppliers. The specifications of the individual subsystems of the robot system form part of the preparation phase of the robot project. The specifications of the robot system can be distinguished in, among others (3):

- bearing capacity 5 - 10 kg and an accuracy of +/- 0,2 mm.;
- good programming facilities; a user-friendly programming system, the presence of welding application software and the possibility of off-line programming. This result in a short programming time of the robot, which contribute to a high degree of utilization of the system (4).
- the possibility of applying a freely programmable positioning equipment (minimal 2 external axes);
- high productivity; short cycle time and a continuous supply and removal (manually) of products is required;
- a high capacity of the system; reckoned with a minimum daily output of 10 hours (figure 13) and a high inset duration of the welding current source because of the long arcing time with robotic arc welding;
- expandibility and intergratibility; respectively modular construction and data communication possibilities (computer link);
- a sufficient size working space c.q. good accessibility; R-R-R-configuration and 6 degrees of freedom.
- possibility of reacting to variations in the production process; interaction with complex sensor systems;
- a high availability c.q. reliability;
- good working conditions; especially concerning the safety of the personnel and the ergonomic conditions;

- good accessibility to the individual subsystems; optimal layout;
- offering good services.

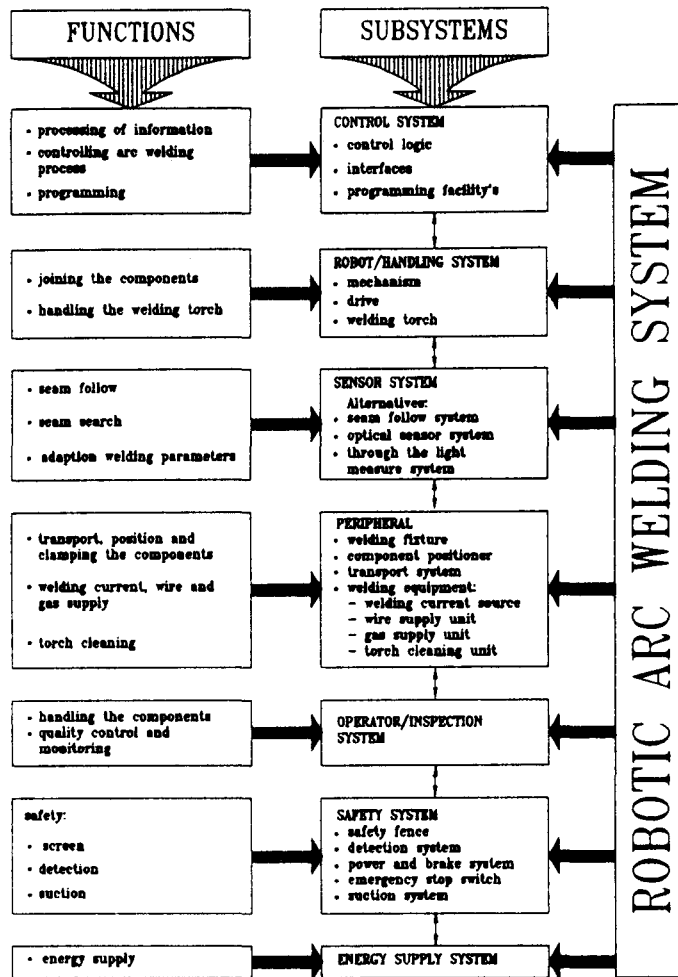


Figure 5: Functions and subsystems robotic arc welding system

SYSTEM CONCEPT

The starting-point with respect to the multidisciplinary development of the robot system is represented in a model in figure 5, in which the system functions and the subfunctions are

represented. Since the production system must be integrated in the whole industrial organization, this approach incorporates the technical as well as the non-technical aspects.

With regard to the robot system, the following subsystems can be distinguished (figure 5):

- Control system; control logic, interfaces programming facilities and external computer. The most important functions of the robot control unit are:
 - * processing of information;
 - * controlling the arc welding process; the accurate controlling and checking of the position, orientation and speed of the welding torch;
 - * communication with the periphery;
 - * programming the robot system.
- Robot; mechanism, drive and welding torch.
- The number of degrees of freedom and the configuration of the robot determine the freedom of movement, the work range and the accuracy of the system. Also because of the large work range, mainly robots with an R-R-R-configuration are being used for arc welding, see figure 6.
- Sensor system; in order to bring about changes in the environment.
- Periphery; fixture and component positioner, as well as the welding equipment consisting of welding current source, wire supply unit, gas supply unit, torch cleaning unit, etc.
- Operator/inspection system; for the purpose of operating and monitoring the system.
- Safety system; the most important safety precautions for robotic arc welding are detection and protection (5).
- Energy supply system.

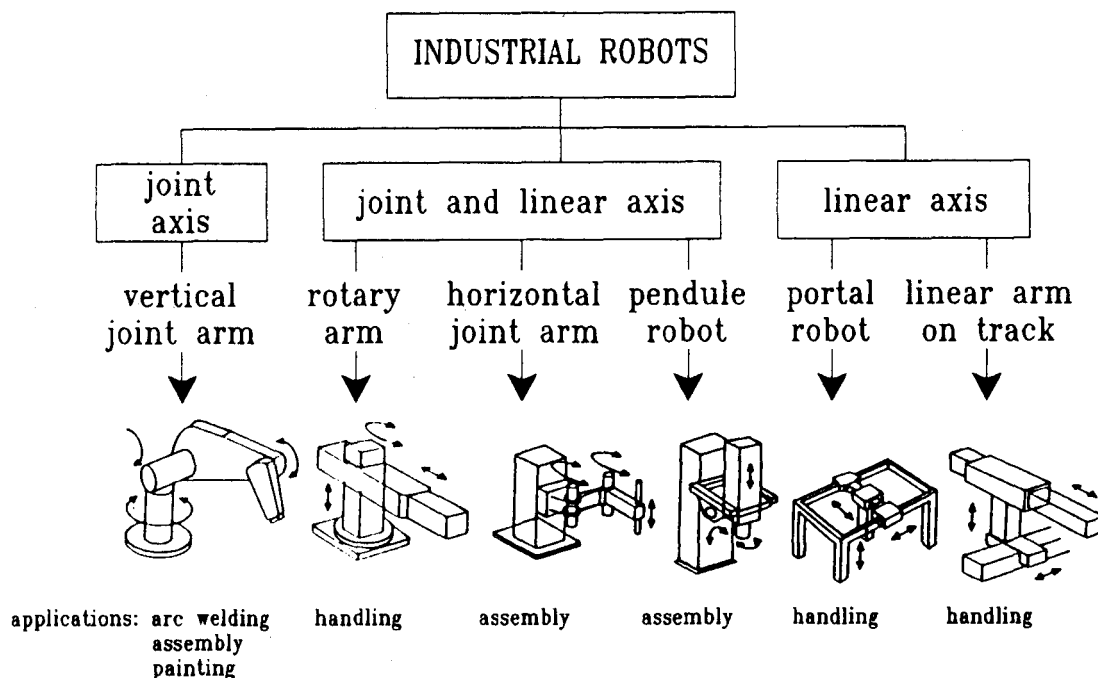


Figure 6: Configurations of industrial robots

ALTERNATIVE SYSTEM CONCEPTS

Devising solutions for the flexible automation of the welding process will have to include the earlier mentioned system functions and subsystems (figure 5) and will have to meet the system specifications mentioned. On the basis of the foregoing, three alternatives are devised:

- alternative 1, on the basis of a stationary robot;
- alternative 2, on the basis of a suspended robot;
- alternative 3, on the basis of a suspended robot on a track.

Of course, a number of other alternative robot formations are possible. For technical and economic reasons, however, these alternatives are not taken into consideration.

ALTERNATIVE 1

Figure 7 shows the formation of the first alternative with the corresponding system components. With this robot system a standing robot with a sufficiently large work range and a component positioner is taken as basis. For the sake of accuracy, the robot and the component positioner are mounted on one frame.

Because of the placing of often critical weldings, at which a good welding position is most important, a movable component positioner is assumed. Because of ergonomic reasons and to enhance the productivity, the component positioner has been carried out as one stationary rotating table with two stations, instead of two separate stations. Because of this the operator doesn't need to walk back and forth between the stations. In this setup the robot welds a product at one station of the rotating table, whereas the operator takes care of the parts supply and removal at the other station of the rotating table.

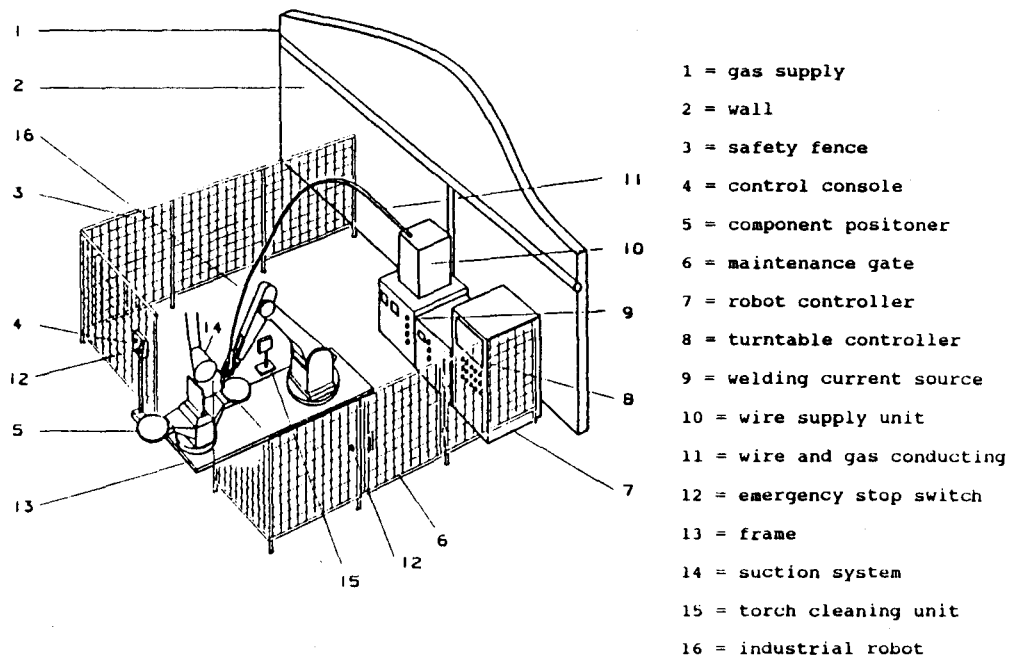


Figure 7: Alternative 1

In the middle of the rotating table a screen has been set up, taking care that the operator is being shielded from the welding process. When the operator is ready with the supply and removal procedure, he signals the start of the next cycle with the press of a button. The personnel is protected against the robot by a two-meter-high metal fence around the working space. Moreover, emergency stop buttons have been installed at places which are easily reached.

ALTERNATIVE 2

The second alternative is represented in figure 8. In this case the starting-point was a hanging robot on the gallows instead of a standing robot. The remaining system components are equal to those of alternative 1. It is possible for the gallows to be implemented in a fixed or rotatable way, depending on the required work range of the robot. Installing the robot in a hanging position, extends the working space.

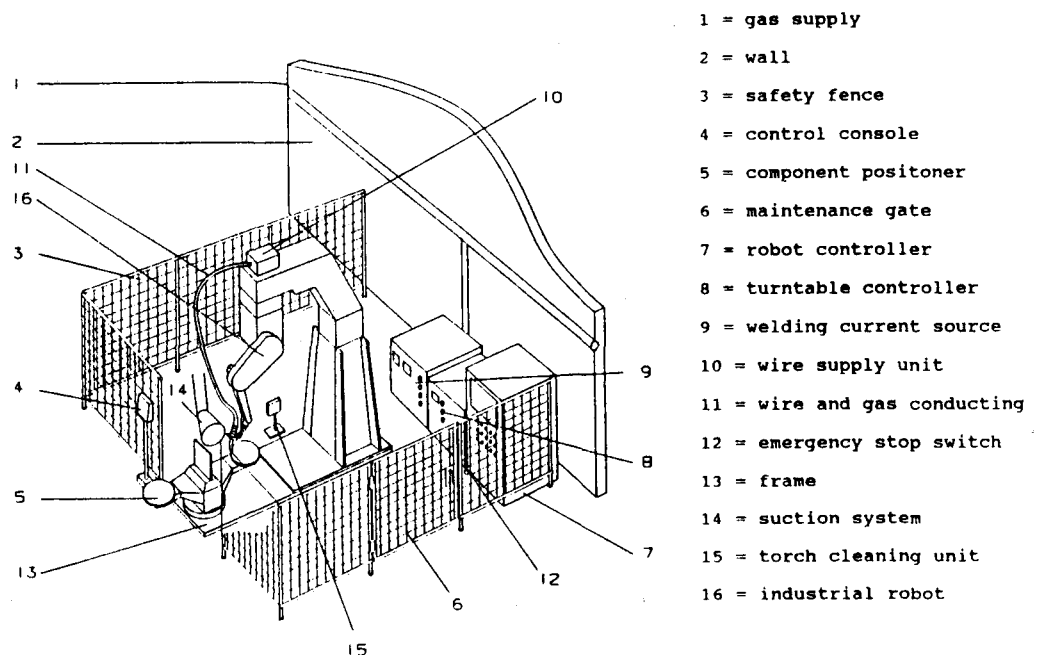


Figure 8: Alternative 2

ALTERNATIVE 3

Figure 9 shows the setting up of the third alternative. In this case the starting-point was a hanging robot being attached on a track, which results in a greater working space. Of course, this

involves an extra high investment for the track. This system is mainly suitable for welding products with large dimensions.

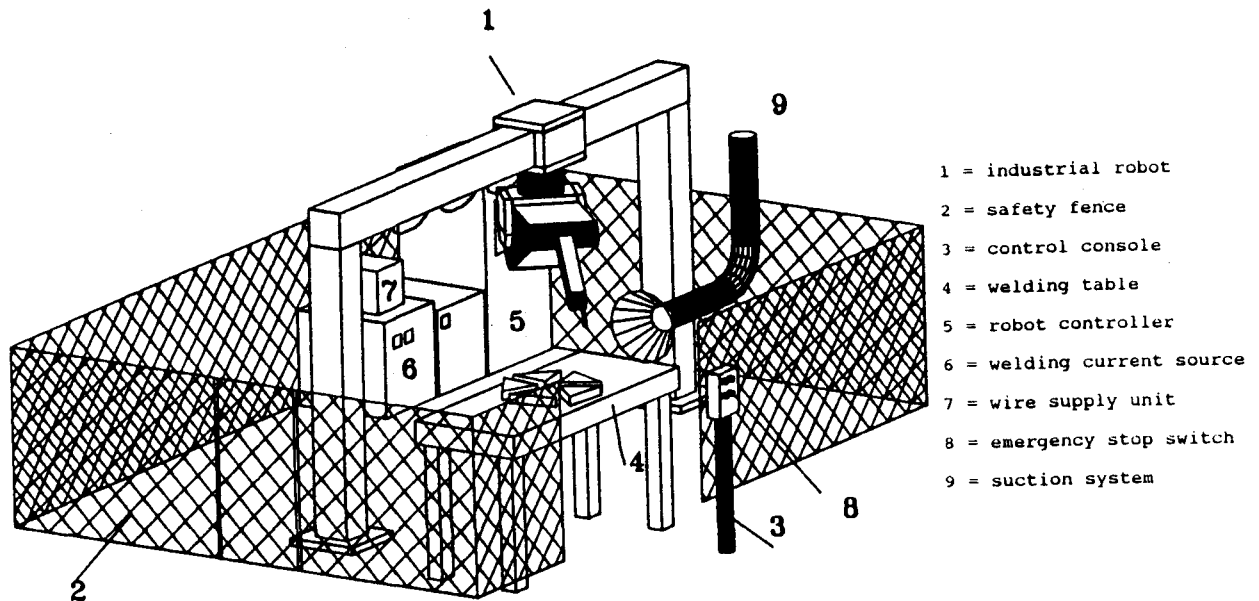


Figure 9: Alternative 3

SYSTEM SELECTION

Based on the preceding, alternative 1 is preferred. The most important reasons to choose alternative 1, are:

- a sufficiently large work range of the stationary robot for welding the selected products, whereby the combination component positioner and adaptive product design makes "reversed" welding possible;
- invested capital is more favourable;
- the accessibility to the robot and with that the maintenance is more favourable than in the case with the hanging setting up;
- there is a maximal contribution towards the quality of labour.

TECHNICAL CONDITIONS

With robotic arc welding a product design towards the robot is of great importance (6 and 7). For this, the following recommendations can be made (see figure 10):

- reduce the number of product variants;
- minimize the use of product components;
- thoroughly consider the choice and thickness of the material;

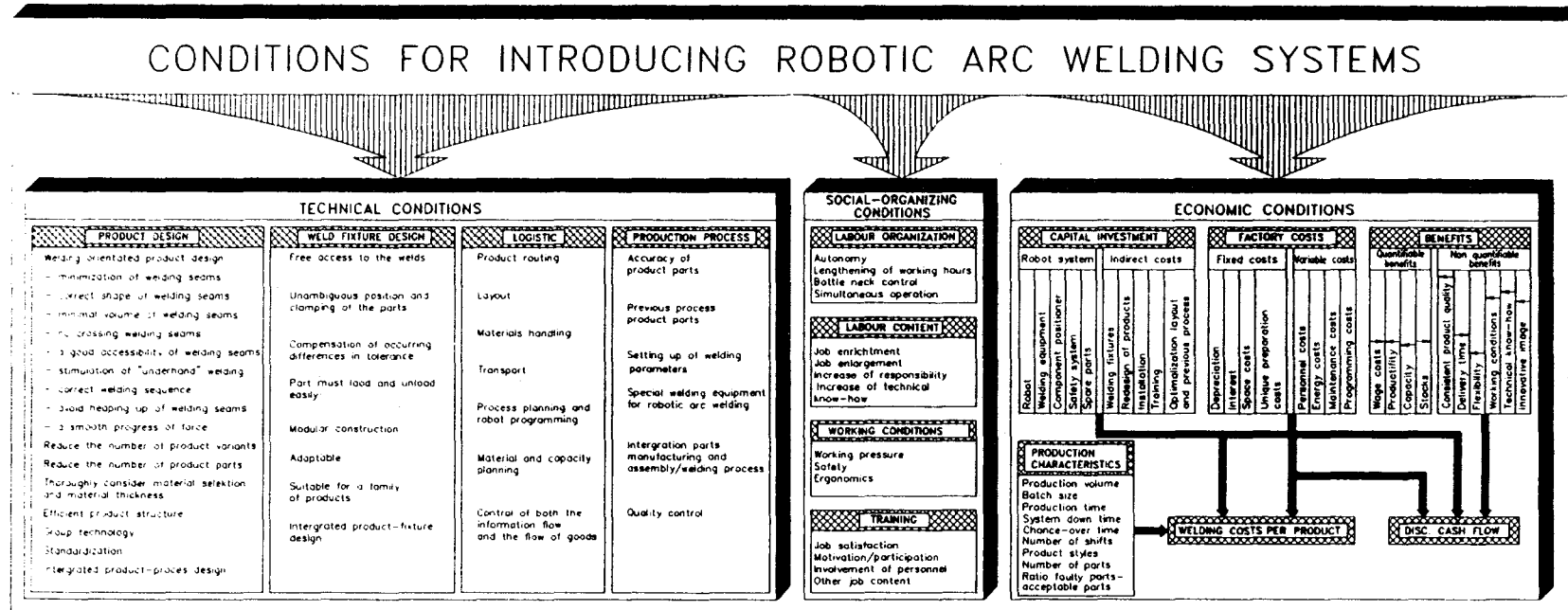
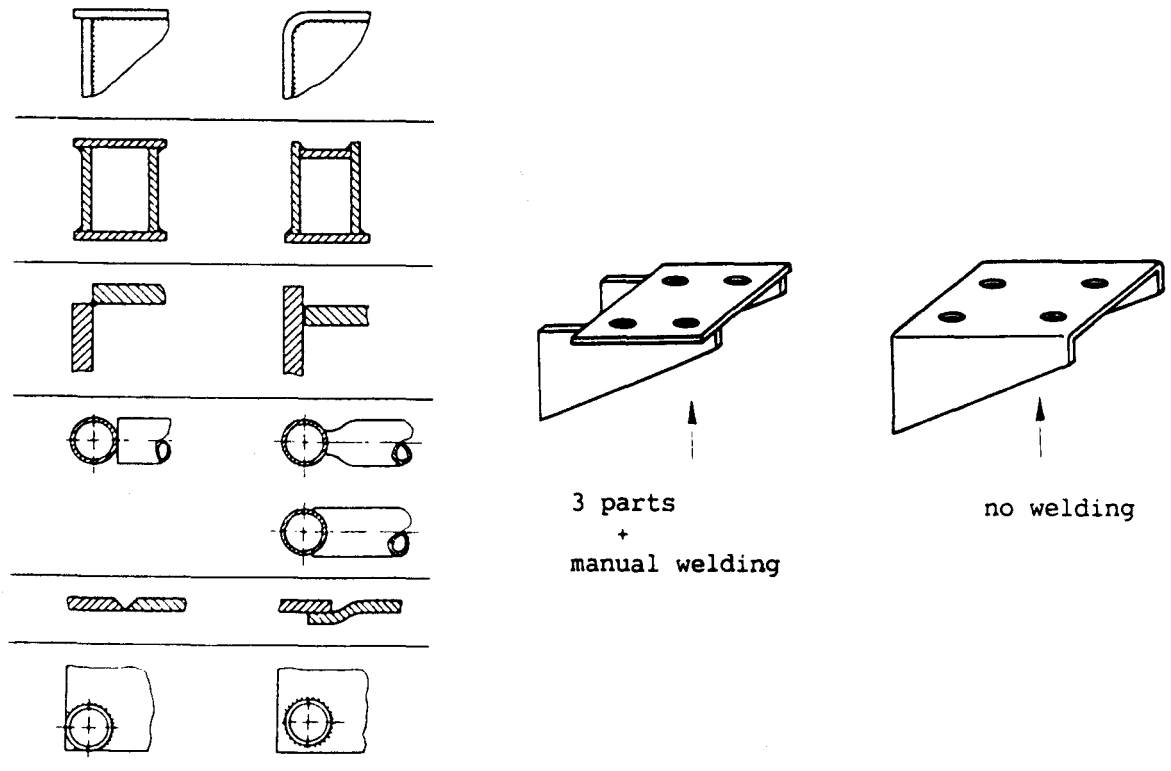


Figure 10: conditions for introducing robotic arc welding systems

- welding orientated product design:
 - * minimizing total welding length; since, the best weld is no weld at all.
 - * choose the right shape of the welding seams with a minimal welding volume. The weld is strongly determined by the type of connection between components. For certain selected products it is recommended to adapt the connection of components (figure 11).
 - * do not use cross weldings
 - * make the welding seams well accessible. The positions of the welding seams and the combination robot-component positioner should make it possible to realize the welding operations as much as possible in one clamp and preferably "reversed."
 - * choose the right welding sequence and connect parts with equal strength. The great introduction of warmth during robotic arc welding has effects on the occurring deformations, which can make it necessary to change the welding order or to apply more symmetrical weldings.
 - * avoid heaping up of welds.
 - * see to a fluent progress of energy.
- reckon with an efficient product structure that is concentrated on group technology and standardization of components;
- integrated design of product and production equipment; integrated product-process design.



The quality of the welding seam is determined by the type of connection between the individual parts. Sometimes alteration are to be recommended.

Figure 11: Welding orientated product design

On the basis of the above mentioned demands certain products will have to be adapted in detail (redesign). This also holds good for the product drawings: indicating dimensional tolerance, dimensioning, positions and sizes of the weldings, etc. In designing new products all these demands will have to be taken into account (8). Besides the accuracy of the robot and the component positioner, also the accuracy of the product components will have to be taken into account. The tolerances of the product components have to be geared for the accuracy (+/- 0,2 mm) of the robot system. In order to be not directly dependent on an expensive and unreliable welding sensor system, the tolerances on the pretreatments of the components to be welded together may not be too wide.

As a result of inaccurate pretreatments deviations may arise which eventually can lead to unpredictable variations in the position and geometry of the welding seam. However, a reproducible welding seam is also dependent on the construction of the welding fixtures. The product components have to be incorporated in the welding fixture in such a way that:

- free access to the welds;
- unambiguous position and clamping of the product components; the welding seams always have to be on equal places.
- the accessibility of the welding seams is optimal; the welding fixture must be designed in such a way that there are no projections and the like which limit the accessibility to the torch of the robot;
- by thoroughly clamping, a possibly occurring tolerance will be compensated for;
- parts must be easily loaded and unloaded so that there may be an optimal use of the high capacity of the welding robot. The supply of components and the removal of finished products is thus geared towards the speed of the robot.
- modular construction and adaptable;
- suitable for a family of products;
- integrated product-fixture design; the design of product and welding fixture must be well geared for one another.

Other important technical conditions are, among others:

- adapting the layout and product routing on the shopfloor to shorten the througput time;
- special welding equipment is required, for robotic arc welding, particularly the welding current source (programmable), wire supply unit and the form of the welding torch;
- ample attention is of great essence to the pre-traject of parts manufacturing and process planning.
- control of the flow of information and the flow of goods;
- integration of parts manufacturing and assembly.

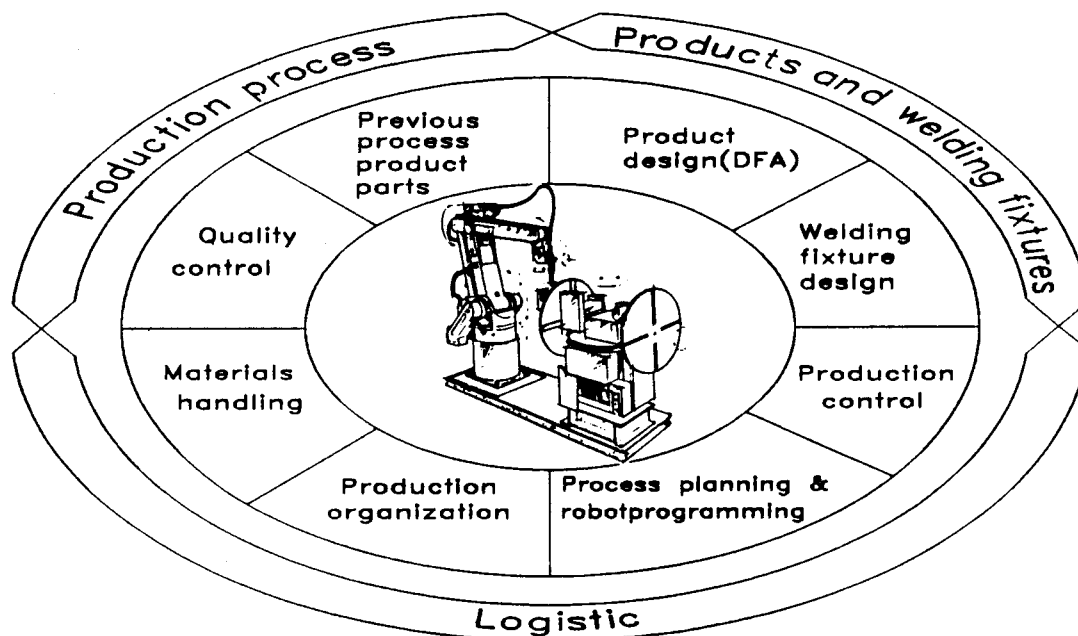


Figure 12: Technical and logistical aspects

All the mentioned requirements have to be met in order for robotization of the welding process to be successful. Figure 12 shows the technical and logistical aspects playing a role in this.

SOCIAL-ORGANIZATIONAL CONDITIONS

It is known from experience that the number of levels in the corporate hierarchy must be minimized; decentralization and delegation of tasks and responsibilities. By creating a greater autonomy within the production, a better use is being made of the ingenuity and creativity of the personnel, which will benefit, for instance, the quality, the throughput times and the flexibility. This can be achieved by creating production units. A production unit is an autonomous group of people and means, manufacturing raw materials and components into as many final products as possible. The division of labour, the administration and the materials control

are carried out by the group itself. Furthermore, with regard to the logistic higher demands are made upon the planning of materials and capacities. The robotic arc welding system has a capacity which is about 2 to 3 times greater than is the case with welding manually.

To make full use of the productivity and capacity of the robot, one should make use of the most of the theoretically available time and reduce the non-productive ancillary times as much as possible. This is to a considerable extent dependent on the place of the possibly present bottle necks on the shopfloor (9). Extension of working hours will possibly have to be considered. In figure 13 the available times are indicated on the basis of a 10-hours' working day. It is apparent from the figure that the productivity of the robot

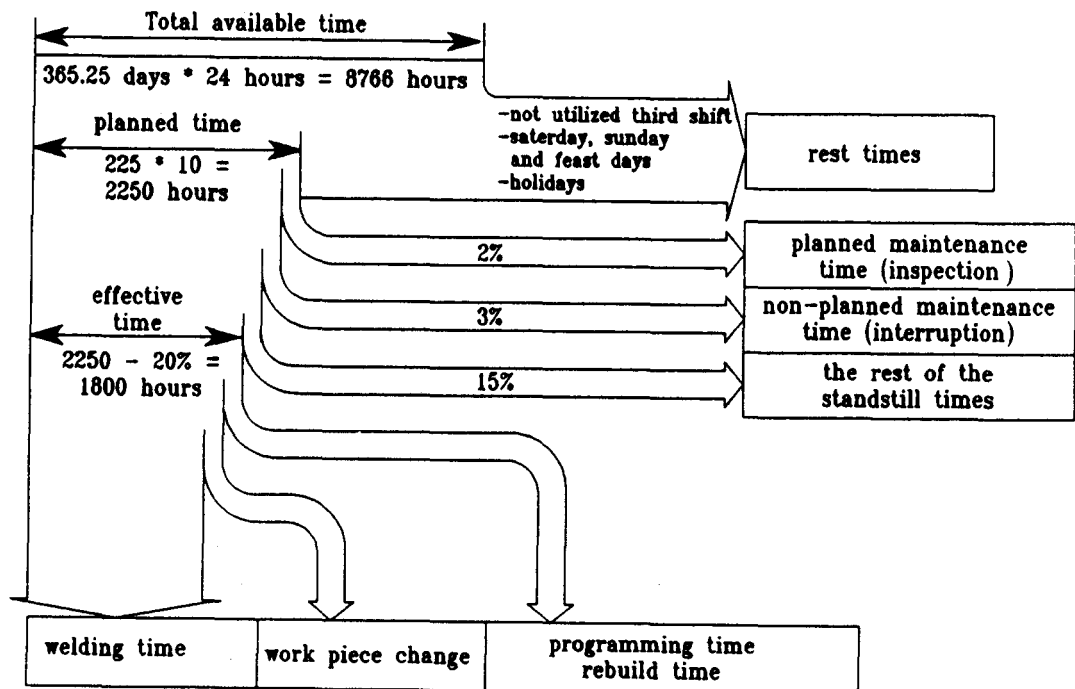


Figure 13: Available time on basis of a ten-hours work day

system can be increased by, for instance:

- shortening of cycle time;
- a quick switch of the parts;
- shortening of programming time;
- diminishing disturbances and maintenance;
- making use of idle times,

While the productivity of the whole production can be increased by controlling it based on bottle necks (9). This also benefits, for instance, shorter throughput times and lower production costs. The

social-organizational conditions can be summarized as follows (see figure 10):

1 Labour organization:

- lengthening of working hours in order to make an optimal use of the high capacity of the robot system;
- production control on the basis of bottle necks;
- decentralization of tasks and responsibilities (autonomy), as well as an efficient production planning for the sake of a flexible and efficient organization;
- optimization of the production organization and simultaneous operations in order to minimize the throughput times and the stocks;

2 Job content:

- there is task enrichment and task enlargement because of the showing up of new activities; programming, operation and maintenance of the robot system.
- increase of responsibility and technical know-how with robotization;
- workmanship is required when setting the welding parameters

3 Working conditions:

- there is an improvement of the working environment for the personnel; however, there is more monotonous work, namely the loading and unloading of the welding fixture.
- a greater working pressure because of the working speed imposed by the robot.

4 Training:

- participation of all those involved in the introduction process is essential, which benefits the motivation of the personnel and the productivity of labour;
- counseling on the objectives of the organization and the project;
- training in conjunction with task revision and/or expansion.

ECONOMIC CONDITIONS

To be able to judge the investment in the robotic arc welding system, the costs and the benefits have to be contrasted with one another. The costs and the savings are represented in figure 10. However, a great part of these benefits are difficult to quantify. Therefore, decisions on investments are mostly taken on the basis of strategical considerations, like delivery time, flexibility and quality. Furthermore, the welding costs will have to be determined per product, which is a function of among others:

- equipment costs; robot, welding equipment, welding fixture, etc.
- production bound costs; batch size, production volume, number of shifts, production time, change-over time, system down time, etc.
- product bound costs; different product styles, number of parts, ratio of faulty parts to acceptable parts, etc.
- manual costs; operator and supervision costs.

CONCLUSION

As appears from the preceding, the introduction of a robot system requires, first of all a number of adaptations of technical and

social-organizational nature. These are the basis of a phased and successful introduction of the system. For this purpose it is necessary that market, organization, logistics, process planning, product design, production process, means of production, technology and people ought to be integrally geared towards one another (see figure 4). With the introduction of robotic arc welding systems it is recommended to take the following practical data into account:

- 1 ratio of programming time to cycle time: 20:1 - 100 : 1;
- 2 reconstruction time: from 15 min up to a few hours
- 3 reduction cycle time: 30 - 50%
- 4 cost ratio robot - periphery: 1:1 - 1:3
- 5 pay-back period: 1 shift 3 - 5 years
2 shift 2 - 3 years
- 6 period of use: 6 - 8 years
- 7 failure rate is favourable: 1 to some %
- 8 labour saving: 1 - 1.5 man year per robot
- 9 starting period: longer than expected (figure 3)

Finally, some recommendations are stated below for prospective robot-users:

- 1 First familiarize with, among others: market, organization, logistic, process planning, product design, production process and people (figure 4).
- 2 First define "the problem", do not immediately start with robotization.
- 3 Organize and optimize before starting mechanization or automation.
- 4 Involve personnel - when introducing the robot system - by means of training and information.
- 5 Only then appeal to the robot suppliers when you really know what you want.
- 6 Approach the project in an integrally and multidisciplinary way.

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