Introduction of Robot Technology into a small Enterprise

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Abstract

Since the re-unification in 1991, small and medium enterprises in the New Bundeslaender in Germany have undergone a painful process of organisational restructuring to find a position on the German and European market. The government has understood the importance of preserving traditional regional structures and has implemented funding programs to support an economic and technological re-organisation.

The paper describes a case study of introducing robot-based arc welding and cutting equipment to a small metal-working factory and discusses some methodological aspects of upgrading from handcraft manufacturing to high level automation for small enterprises.

Keywords

Robotization, small enterprise, automation, robotized arc welding, robotized cutting

1 INTRODUCTION

The enterprise profile

The enterprise has manufactured pressure tanks under changing social and economical conditions. Before the re-unification, it held a safe market share in the former German Democratic Republic. Since then, it has lost most of its former customers. The quality of the tanks must meet the requirements of customers which now have the choice among several manufacturers.

The factory has been re-privatized and the ownership has been transferred into the hands of the former owner family. It is managed by a mixed team of two generations. The young marketing manager has realized the need to raise the quality of the tanks and to head towards

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an ISO 9000 certification. The elder technical manager and former head of the production division argues for simple automation solutions and traditionally proven manufacturing sequences. The staff has been reduced from 40 workers to a team of about 15 workers on the shop floor. Four persons work in the field of production planning.

Enterprises with comparable products from the Old Bundelaender have recently advanced to robot-based technology. The increase of flexibility enables them to serve new market segments and they have developed into serious competitors.

The decision to head for robot based production involves a leap from workshop oriented manufacturing with a high degree of hand craft and semi-automated sequences to numeric controlled and programmable machines. The enterprise has some deep knowledge and skill in hand guided welding and cutting with simple devices. However, since workers and technical management have no experience in programming, a fundamental precondition for an efficient operation of the new equipment is lacking.

Regional economical aspects

With respect to the employment situation in the area, the management has decided not to dismiss any of the current workers. Workers which, with respect to education and old age, cannot cope with the requirements of robot technology are designated for new jobs in a future steel trading division of the enterprise.

From an economical point of view the costs for investment, production re-organisation and training can only be met with financial support from regional funds. Since an agency for the technology transfer is involved and is a main driver and co-funder of the project, political goals concerning the region play an important role as well. There is a strong interest to demonstrate that traditional enterprises can operate and handle advanced technologies such as industrial robots. A manufacturing equipment modernisation is essential for most enterprises in order to maintain and expand their market share. In addition, a location near the border to eastern European countries such as Poland or Tschechia increases the pressure for better product quality to compete against the low wage based production of eastern countries.

On request of the technology agency TINA, the IPK Berlin was asked to accompany and organize the introduction of robots. As a research institute engaged in industrial related research in the domain of robotics, the role as a consultant for a small enterprise and the task of developing a suitable automation concept is new. The experience in 'high-end' automation has turned out to be valuable for the project.

2 THE MANUFACTURING TASK

The range of products focuses on similar shaped steel pressure tanks for water and compressed air. The tanks have to withstand pressures from 4 to 16 bars. The capacity ranges from 150 to 1000 litres (see Figure 1).

At the current level of production, some 40 medium sized tanks (300 litres) can be manufactured in a daily shift. By reorganising the production flow, a productivity increase of circa 20% has been gained without additional investments in new machines.

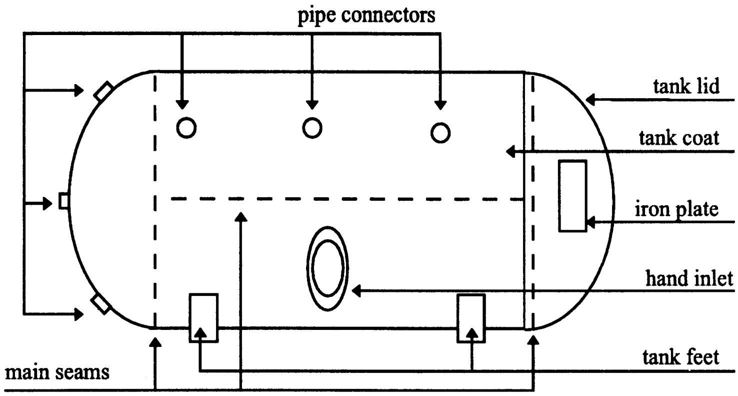

Figure 1 A typical tank

The present production organisation of the tanks is divided into four main steps:

1. Manufacturing of tank lids: The shapes for pipe connectors are burned into the lid, the connectors and the tank feet are attached by MAG welding
2. Manufacturing of tank coat: The shapes for pipe connectors are cut into the plane metal sheet. The sheet must be bent to the cylindrical shape of the tank. The edges of the cylindrical coat are pre-fixed and welded.
3. Assembly of lids and coat: Lids and tank coat are pressed into shape, fixed by electrically welded spots and finally welded using MAG technology.
4. Fixing of additional parts: Pipe connectors, steel consols for pumps and plates are pre-fixed and attached by MAG welding to the tank body.

In general the welding and cutting equipment is worn out and in a poor condition. The circular shaped seams joining the lids with the tank coat are welded with old plate guided welding torches. The device for moving the cylinder coat under the two torches for the top and bottom lids have been designed, built and optimized by the workers. Two machines for the long coat seam are in use and represent the current highest level of automation. However, these machines were restricted to straight seams. Additional parts were pre-fixed by electrical weld spots and finally welded in a hand guided MAG welding sequence.

The cutting of steel plates is conducted with compressed acetylene gas. The shapes are cut with the help of magnetic rollers which travel along a metal plate and prescribe the track of the torch. At first sight, the cut edges appear jagged and, cutting in the old manner, cannot fulfill tolerance requirements for robot welding. In addition the applied technology is restricted to cutting on plane sheets. But as figure 1 shows, some cutting on the convex lids is necessary and circular shapes at the outer section of the lids can only be approximated.

3 ANALYSING THE REQUIREMENTS

A project group was established with members from the technical staff and the IPK. The IPK supplied expertise in the domain of robot welding, cell layout planning and economic consulting. One key person from each partner established the kernel group and a road map for project work was established covering the following steps:

1. Detailed analysis of three typical products which cover some 70 percent of production
   . description of welding seams and cutting shapes
   . description of applied technology
   . analysis of manufacturing sequences
2. Analysis of current welding and cutting equipment
   . rating of productivity and efficiency of devices
   . selection of a subset of equipment to be operated in the future
3. Specification of welding tasks for robot welding
4. Requirement definition for work cell components
5. Design of two manufacturing cells
   . layout definition of an integrated station for cutting and welding tank lids
   . identification of equipment and devices for the welding and cutting station
   . layout definition of a welding station for the tank coat seams
   . identification of equipment and devices such as turn tables and clamping devices
6. Re-organisation of manufacturing sequences for different automation stages
   . optimization of material flow
   . definition of sequence of manufacturing steps
7. Documentation of the requirements for robot and welding equipment suppliers
   . suggestions for the work cell layout of the projected cells
8. Discussion of suggested solutions with robot suppliers
   . cost evaluation of proposed concepts
   . evaluation of flexibility and future upgrade potential
9. Selection of the final concept
   . definition of a step by step implementation schedule

As a specific situation for the small company, the available data and information about the product and the production organisation was poor. Detailed and up to date production drawings of the tanks are lacking. The close analysis of the welding seams and cutting edges has led to a catalogue with a geometric and technological description of each seam and edge.

The analysis of manufacturing sequences led to a schedule defining the distribution of tasks. With respect to an efficient work load, the first work cell was desigend to perform cutting and welding tasks as well. It was discussed whether a mixture of cutting and welding tasks or one type of technolgy should be conducted per work shift. At this point, the analysis showed that the future robotized work cells might lead to a basic reorganisastion of the factory work from one to two shifts a day, with economical reasons strongly supporting the two-shift-a-day solution.

The mapping of logical manufacturing sequences to operation sequences of the robot and the operator was documented in tables. Based on the documentation, a project group developed the design of two workcells, one for mixed production and one for arc welding only. The first cell was designed to completely perform the cutting and welding of the tank lids. The second roboter welds the main junctions of the lids and the tank coat. In addition, all pipe connectors, plates and consoles on the coat are welded. The fixture of the tank body demands some elaborated fixing and positioning aid. Figures 2 and 3 depict the preliminary layout of the work cells.

With the introduction of robotized welding, a major obstacle on the way to fully automated welding was the need to manually pre-fix the smaller parts with spots from an electrical welding torch. With respect to the accuracy of the part positioning, pre-fixing and adjusting by hand is a major source of problems for future robotized welding. In addition the overall manufacturing tolerances were remarkably high. The ground shape of the tank revealed itself to be elliptic rather than an ideal circular shape. At that stage of the project, there was no clear idea whether equipment with sensor devices would compensate the spatial tolerances.

During the design phase, the experience of the research institute and practical skills of the project members of the small enterprise proved a fruitful combination. From the practical point of view, a list of demands for optimized technology performance was worked out (e.g. preferred welding positions). From the point of view of automation the items on the list were transferred into design criterias for the workcell devices (e.g. horizontally and vertically turnable workpiece table to keep a slightly falling welding position).

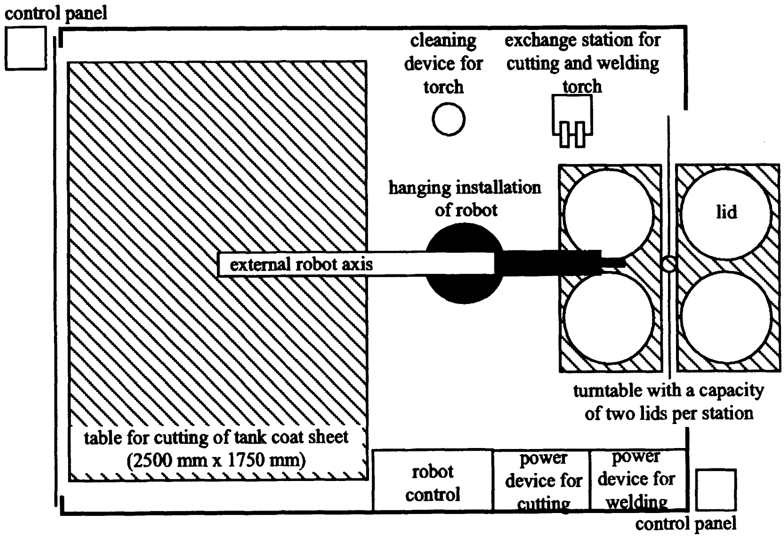

Figure 2 Work cell for cutting and welding of the tank lids

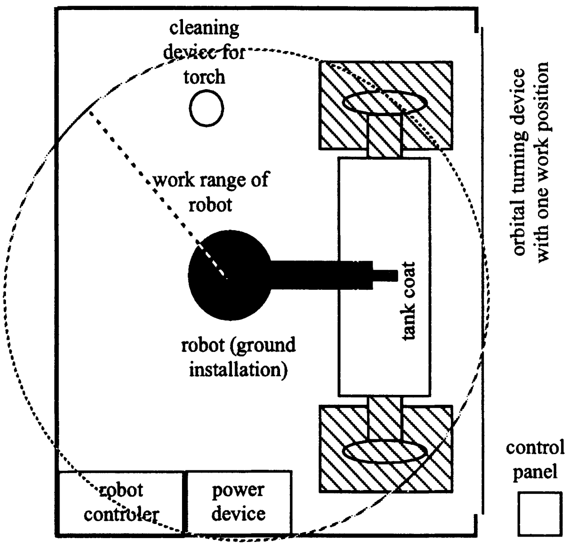

Figure 3 Work cell for completing the tank coat

4 CONCEPT FOR STEPWISE INTRODUCTION

A document with the task description, the requirement definition, the design of the two work cells and a list of open questions was sent to four robot suppliers. They were asked to comment on the work cell design, to propose technical solutions and to give a cost calculation for both of the two work cells.

The proposals of the robot suppliers has revealed two items as the key problems of the automation concept. First, to realize the work range necessary for the lid manufacturing, the robot has to be mounted on an additional axis. Second, the geometric tolerances of the tank coat can only be managed with sophisticated sensors for tracing the welding seam. From the technical point of view, a laser sensor equipped work cell for the manufacturing of the tank coat has turned out as the state of the art solution. As sensor based welding operations increase the time for a manufacturing sequence, time calculations have shown that future use of the semi-automated machines for the circular shaped seams joining the lids to the coat will be advisable.

The knowledge concerning the clamping devices for the work pieces is held by the workers of the enterprise. For an effective operation of the robots this knowledge has to be transformed into devices optimized for robot operations. This process of design and opmitization is conducted parallel to the first phase.

Discussions with robot suppliers have led to a redefinition of the automation goals. The substitution of hand guided pre-fixing of parts is deferred and defined as a long term goal to be realized after two to three years of basic experience with the robots. They strongly advised the designation of a period of six months to one year to acquire experience with a simple welding and cutting work cell for the tank lids. The implementation of a more complex work cell for the tank coat will follow after that.

For the operators, a training concept with three steps has been defined to prepare and guide the robot introduction. First, basic skills for the programming of robots will be taught in a work shop by the robot manufacturer. Second, a training week on the shop floor at the installed first work cell will support the start of the robot based production with the first robot. Third, after installing the complex cell for the tank coat manufacturing, an introduction to advanced programming techniques such as synchronising the orbital positioning device and handling the sensor devices is planned. It shows that developing the skills of the future operators in stages will be essential for the success and the acceptability of the robots.

With respect to a stepwise introduction, the overall design of the work cells has been redefined. The design now focuses on future extendability of the equipment. Figure 4 shows the concept currently being discussed in the project. Work cells are located along a linear axis. The axis may carry one ore two robots. New work cells can easily be added along the basic axis. As the figure depicts the number of robots may be smaller than the number of work cells. This gives the chance for a cost effective and stepwise enhancement.

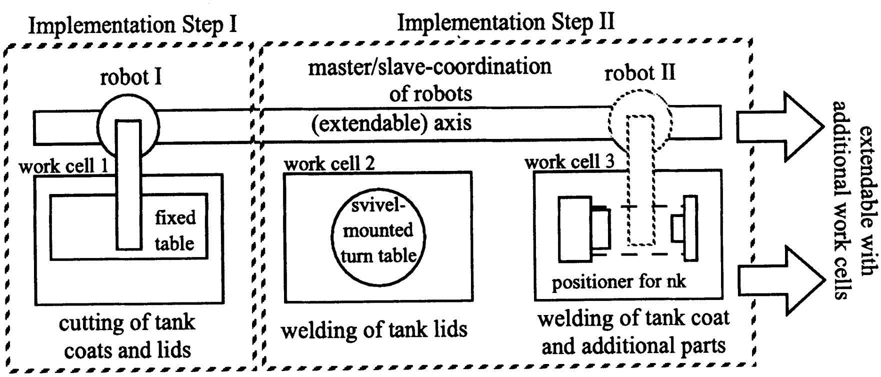

Figure 4 Extendable concept for robot work cells.

5 CONCLUSION

At present the design and decision making stage is completed and the first hardware implementation is just ahead. So far, the project has shown that the introduction of advanced automation technology to an enterprise, which for the first time is going to operate programmable equipment, demands a step by step introduction. Skills necessary for operation and maintenance have to be established along with well defined steps of hardware implementation.

From the methodological point of view the following proceeding can be advised: On the basis of a close analysis of the product design and the manufacturing sequences, an advanced technological solution has to be identified and defined as a long term automation goal. Next, short and medium term goals with respect to the training of the operator and programmer team have to be worked out and the hardware design of the future work cells has to be developed. Third, the preliminary solutions have to be redesigned with respect to stepwise implementation and future extendability. Following this road map and dedicating a realistic amount of time to each introduction step, the risk is minimized that robot introduction may overcharge the skills available at the enterprise.

6 REFERENCES

Schreck, G and Landvogt, W. (1995) Automation Concepts for Arc Welding Applications, in *Recent Andvances in Mechatronics* (ed. O. Kaynak et al.), Proceedings of the International Conference on Recent Advances in Mechatronics, ICRAM `95, August 14-16, Istanbul, Turkey.

Aggteleky, B. (1990) Fabrikplanung: Werkentwicklung und Betriebsrationalisierung, Band 2, Hanser.

7 BIOGRAPHY

Gerhard Schreck, Dipl.-Ing., has studied mechanical engineering at the Technical University of Berlin. Since 1985 he works at the IPK Berlin. He works on off-line programming systems and is engaged in control systems development. At present he is head of the department of robot planning systems.

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