METHODOLOGY FOR CONFIGURATION OF ROBOT WELDING CELL FOR SMEs UNDER CONDITIONS OF SMALL AND MEDIUM SIZED PRODUCTION USING MIG/MAG PROCESS

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Abstract: Increasing competitiveness in global markets and quality requirements for produced goods require reduction of prices in welding industry. Solution to the problem in metal working industry lies in implementing welding robots for large scale production. In case of small and medium series production the use of welding robots is economically and technically more complicated and requires considering different aspects.

In the current article the methodology for configuration of robot welding cell for SMEs is presented. The research is limited by conditions of MIG/MAG (GMAW) welding, nevertheless it can be expanded to other technologies.

The basis for this research is the implementation of four different robot welding cells in SMEs. Information collected during the process is analyzed and recommendations are given.

Key words: robot-welding cell, SME, small series production.

1. INTRODUCTION

In Estonia and in the Nordic countries there is an increasing demand for implementation of welding robots due to deficiency of qualified hand welders. The research is conducted under the framework of IMECC project (Innovative Manufacturing Engineering Systems Competence Centre) the subproject of which considers automation of processes for SME-s using robotized welding cells. This project includes several issues from implementation of robot welding cell to welding technology of the product.

The basis for this research is the implementation of four different robot welding cells in SMEs. Information collected during the process is analyzed and recommendations are given. According to the research, while implementing the robot welding cell certain issues must be considered to ensure the correct configuration of the robot welding cell and to guarantee the suitability for SMEs needs. This approach enables to divide the complex process into more easily manageable topics. The main domains to be considered are the following: product, technology, jig, components of robot welding cell. Criteria for each domain are proposed.

For decades robots were used only for mass production. Robots usually conduct repeated and long-term actions. Mainly the cycle time and its reduction is the main criterion for such systems. When implementing a robot in small and medium sized production the criteria also change. In case of small production batches the importance of rapid setup and implementing of new products is more important than only short cycle times.

For configuration of the robot welding cell for SMEs it is vital to consider the following issues (Figure 1):

- Product (product families, classification of products);
- Technology (welding technology, production process);
- Jigs (main criteria for jigs considering robot welding);
• Components of robot welding cell (main criteria for selection of components);
• e-Manufacturing (maintenance of the cell, user support).

Fig. 1. The main criteria influencing the configuration of robot welding cell

The main company profile in Estonia is SME therefore the fulfillment of their technological needs is an important issue. One of the main directions is the implementation of new technologies known as transfer of technology. To make it possible several stages must be considered according to the enterprise needs. As they lack the resources considering knowledge, finances and manpower for implementing of new technologies, it is important to make this process as plain as possible.

In this article the methodology is proposed to make selection of components for welding robot cell and to implement production technology which is suitable for enterprise needs.

Enterprises qualify as micro, small and medium-sized enterprises (SMEs) if they fulfil the criteria laid down in the Recommendation by EU (Table 1).

<table>
<thead>
<tr>
<th>Enterprise category</th>
<th>Headcount: Annual Work Unit</th>
<th>Annual turnover</th>
<th>Annual balance sheet total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-sized</td>
<td>≤ 250</td>
<td>≤ 50 or ≤ 43</td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>≤ 50</td>
<td>≤ 10 or ≤ 10</td>
<td></td>
</tr>
<tr>
<td>Micro</td>
<td>≤ 10</td>
<td>≤ 2 or ≤ 2</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Enterprises size definition in EU, based on [1]

In addition to the staff headcount ceiling, an enterprise qualifies as an SME if it meets either the turnover ceiling or the balance sheet ceiling, but not necessarily both.

2. METHODOLOGY

Transition to automatic or robotic welding does not only involve obtaining devices and programs, but also planning, organizing and leading the entire work process. A flexible welding system is better in case it is not clear whether a certain product is going to stay in production for a long period.

In planning also weld fixtures should be considered. It should be possible to fix the welded detail to the fixture and later remove it quickly and easily.

In case of automatic/robotic welding quality requirements can be stricter than in case of hand welding. Products produced applying new technology should be tested before transition to automatic welding. It must be considered that quality requirements and control may change.

Other regulations and criteria influencing this process and final product must be considered. Fixing devices must be renewed. Positioning devices may appear necessary to maintain accuracy and quality of welds. In case of automatic welding all phases are performed by machine (mechanically or electronically). Automatic welding can be partial or complete. If the device performs one or several similar operations, the process is called fixed automation. In case the device performs different operations, the process is called flexible automation. Flexible automation is recommended in case of SMEs.

Multiple-programmed robots are the most flexible. The task of the automatic system is to reduce production costs, raise productivity and quality of welding. Thus, different operations can be performed, while using less floor space, the amount of
unfinished products can be reduced and production capacity increased. Production will be a success, if the process is carefully planned, economically justified, supported by cooperation of management, designers, engineers, workers and maintenance team [2].

2.1 Definitions, scope

During the research several terms used for describing the system. The most used and essential ones are given below.

TIG welding process is perfectly adapted to very thin products, making it possible to obtain high quality welds, with a low output. Welding speed is between 100…500 mm/min, although in automated welding higher speeds are possible. The welding parameters are determined by the nature and composition of the base metal, the thickness to be assembled and fastening method. The parameters set out in Table 2. Parameters can be adopted as starting values for the adjustment of machines.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Preparation for TIG welding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,5...2 mm</td>
<td>No preparation and without gap; no filler</td>
</tr>
<tr>
<td>&lt;5 mm</td>
<td>60° V chamfer or no preparation with gap equal to half its thickness</td>
</tr>
<tr>
<td>&gt;5 mm</td>
<td>70° V chamfer – gap = 2.5 mm</td>
</tr>
</tbody>
</table>

Table 2. Preparation steps for TIG welding

For thin steel products, MIG/MAG welding is the process most universally employed. For thickness higher than or equal to 20 mm, it is ideally suited. For thinner materials, the conventional MIG/MAG process is more difficult to use; in this case, the pulsed mode makes it possible to obtain satisfactory operational weldability. The wire is of carbon-manganese type according to standard NF EN 440 for solid wire, with the possible addition of alloying elements: molybdenum, nickel and chromium, principally, in order to obtain the properties of mechanical strenght in the molten metal.

The wire is chosen according to the base metal and mainly the mechanical properties that weld must guarantee [3]. The method takes its name from the type of gas which is used: MIG (Metal Inert Gas) or MAG (Metal Active Gas). The full name of the method is Gas Metal Arc Welding, abbreviated to GMAW. The MIG/MAG welding method is becoming more widely used than any other method of welding (see Figure 2). Among the reasons for this is the fact that productivity is high and that the method can be easily automated. MIG/MAG welding is gaining ground at the expense of manual metal arc welding, which used to be the most common method. Today, MIG/MAG welding is the most widely used method of welding in Europe, Japan and the USA.

The diagram clearly indicates that MIG/MAG welding is an increasing trend and is more widespread than other alternative welding methods. The main welding methods applied in Estonia are TIG and MIG/MAG. To some extent other methods (FSW, SMAW, spot-welding, laser welding) are used. The automation necessity of these methods is not big. Automatic welding is considerably more effective than hand welding. On the other hand, it is not easy to apply automatic welding for SME-s, as core competence and resources are missing.

Fig. 2. Proportions of various welding methods in Western Europe. MIG/MAG, MMA (Manual Metal Arc welding) and SAW (Submerged Arc Welding) [4]
For thinner material (thickness 2 mm and less) the CMT (Cold Metal Transfer) welding process can be used. The basic operation mode of CMT is characterised by an arcing phase during which a molten droplet is formed on the end of the wire electrode and a weld pool created. After a set duration the wire electrode is fed forward to make contact with the weld pool/base material creating a short circuit. During this phase material transfer is initiated and the arcing current substantially reduced. After a defined period the electrode is mechanically retracted, this rearward motion aiding in pinching the molten globule into the weld pool. The arc is then reignited and the cycle repeats. The process is unique in that not only is deposition controlled by the forward and rearward motion of the electrode, the electrical characteristics are also controlled with the result that material transfer takes place at both low current and low voltage. A typical CMT transient waveform and definition of cycle instantaneous values is shown in Figure 3.

![CMT Cycle Instantaneous Current and Voltage Values](image)

**Fig. 3.** CMT cycle instantaneous current and voltage values based on electrical transients. One duty cycle is shown considering Arcing Phase and S/C Phase accordingly.

### 2.2 Product analysis

To select suitable products for robotic welding, the enterprise studied several product designs. Products were grouped and weld types were analyzed. The most important data for robotic welding qualification were the following: production quantity, product size, product mass, type, length and number of welds. After studying the data the test weldings were performed. Visual control of test welding was carried out, photos were taken. As a result, welds for lab tests were selected and micro/macro polishes performed to prove the adequacy of welds to quality standards and process needs.

### 2.3 CMT process implementation

To be convinced about the necessity of robotic welding by means of CMT process in SMEs, product suitability analysis and welding tests were conducted. Objectives of this study were the estimation of welding parameters for robotic CMT welding for small or medium production series. Goal was to find optimal welding parameters for the welding process in order to achieve the best results. The above described methods were used for this process. Method of product analysis was established to have a better overview of products and create product families for welding.

Potential products for robotic CMT welding process were found and suitable welds were chosen for the experiments. Experiments were conducted according to information obtained from literature and using welding parameters given by CMT power source. The fabricated specimens were inspected visually among which a certain amount of specimens were chosen for laboratory research. According to the metallographic analysis it was possible to decide which types of welds are difficult to perform and where problems might emerge...
using CMT power source welding parameters. Base materials and filler metals were recommended by company and used also for manual welding. Goal of these experiments was achieving maximum welding speed and productivity of welding with acceptable quality of the weld.

3. ROBOT CELL CONFIGURATION

For configuration of robot welding cell several steps must be followed:
• product portfolio analysis and technology charting;
• product classification according to production times and production quantity;
• welding process analysis, evaluation and verification;
• selection of jig design and clamping elements;
• selection of robot welding cell components based on product and welding process analysis.

Based on these steps recommendations are given below.

3.1 Product classification

Classification of products for a robotic welding cell can be done by grouping the products according to welding time and production capacity. This recommendation is done based on research of 4 robot welding cells and their products. The groups are following:
• products with big production capacity and short welding time (20 seconds to 5 minutes);
• products with medium production capacity and medium welding time (5 to 30 minutes);
• products with small production capacity and long welding time (30 to 90 minutes).

3.2 Welding process

The analysis of welding process is an important issue when implementing products for robot welding. The technological process (welding) must have the primary focus because the automation process is technology-based. By gaining the clear understanding about the process itself, the automation of the process can be carried out by the means of the process knowledge. Also the welding process (MIG/MAG, TIG) must be verified before the implementation of the robot welding cell. It can be done by welding tests and laboratory analysis of welds.

3.3 Fixture design

To connect product and robot welding cell components together the fixture for welding must be designed. It is important to follow the next requirements:
• the fixture should be strong and light but rigid enough to ensure accurate alignment;
• the fixture must permit quick and easy positioning by positioner, balancing of the fixture may be necessary;
• jig accuracy and elaboration must not be greater than required, only essential product dimensions must be controlled in a fixture;
• a fixture must be built around the work and be located and clamp components in position;
• the fixture must ensure a single correct assembly only;
• the fixture must permit freedom of movement to avoid residual stress in the completed weld;
• welded joints must be readily accessible for welding - by slots or other means, the fixture should readily present seams on the reverse side of the object;
• for final accuracy the parts must be pre-bent in the fixture, if necessary;
• clamps must operate quickly, screws and moving parts must be protected against weld spatter;
• grounding of the workpiece is important in fixture design, since it affects the arc action, quality of weld;
• fixture design must enable the welded product to be easily removed.
3.4 Robot cell components

After the analysis of the product and welding technology and fixture initial design the robot cell components must be selected. Main components and issues must be considered for robot complex are:

- robot – (size, accessibility);
- manipulator – (accessibility, welding position, capacity, size);
- welding device – (number of parameters, adjustment, welding process, capacity);
- control devices (programming, device connection, control);
- safety options (guarantee of operator safety).

3.5 Deployment

Before making final decision about the robot welding cell implementation the payback time and efficiency must be calculated. Accordingly to product nomenclature and production capacity the range can be different. Deployment time can be rather long. As SME-s usually have many products, preprogramming is necessary and the usage of the robot under maximum load is limited. Breaking point is achieved about two years after deployment. Proportion is then between welding and programming can be 50/50 accordingly and a year later 80/20 in favour of welding. As soon as all products have been inculcated, the programming time is between 5 to 10 %.

CONCLUSION

Configuration of robot welding cells using division of tasks enables to introduce complex technologies in SME-s. This approach is not final and needs additional development. The classification is based on analysis of 4 different robot welding cell implementation projects. The main steps needed for configuration are: product analysis, welding technology analysis, fixture design and selection of robot cell components. Although theses points do not cover the all issues, they are most important. Further research is needed considering calculation of payback and welding time.

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REFERENCES


