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CASE STUDY REGARDING EFFECTIVENESS AND PROFITABILITY OF AUTOMATING THE WELDING PROCESS

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Abstract: *One of the greatest challenges for a modern manufacturing enterprise is developing intelligent manufacturing (IM). IMT and IMS are key factors. In an environment where "mass customization" and shorter product life cycles have led to the need for more flexible manufacturing systems, SMEs have developed a significant need for rapid implementation of integrated and complex technologies and systems. A key issue concerns economic expediency and completeness of the complex. This case study describes the implementation of a modular welding robot and the resulting economic effect on a SME. The effectiveness of this method was evaluated in the form of measurement results for the project's critical success factors and key indicators.*
Key words: *case study, IMS, industrial robots, welding, industrial automation*

1. INTRODUCTION

Manufacturing has been the basic foundation of the economy and the living environment from the industrial revolution to the information era. Due to the economic downturn and the need for lower manufacturing costs, manufacturers face the major challenge of developing manufacturing intelligence (MI). In 1989, Professor H. Yoshikawa (University of Tokyo) defined an Intelligent Manufacturing System (IMS): "a system which improves productivity by systematizing the intellectual aspect involved in manufacturing, flexibly integrating the entire range of corporate activities – from placing orders to design, production, and marketing – to foster the optimum relationship between men and intelligent machine" (Zhou et al., 2010).

Because this century has seen a growing need to develop intelligent manufacturing systems, studies in this field have become more significant as well as broader. In 2009 the Innovative Manufacturing Engineering Systems Competence Centre IMECC was launched with one of its strategic fields being development cost and time efficient solutions for SMEs (Small and medium enterprises) for process automation and innovative emerging manufacturing technologies – a very important field given the structure of European industry and the number of SMEs.

One opportunity is to make manufacturing more intelligent by integrating smart technology with manufacturing systems. This study is part of the development of an IMS model for SMEs in connection with the problems entailed by application and implementation of complex and high-technology systems in SMEs. This case study was conducted to investigate the profitability of welding robot cell implementation and the effectiveness of a potential "modular approach" (Sarkans & Roosimölder 2010).

SMEs are related to two key factors when it comes to developing an intelligent manufacturing system – first of all, the complexity of systems and second, profitability. Technologies, competences, integration, designing and flexibility are factors that determine the profitability of the complex system in SMEs (Fig. 1).

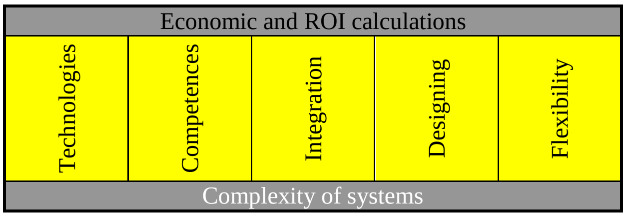

Fig. 1. Challenges for SMEs in creating an IMS

2. PROJECT METHOD

This article describes research based on a case study for robot cell, conducted from August 2009 to December 2010 at a metal furniture manufacturer. The objective of the project was to come up with a suitable model for SMEs looking to develop welding technologies and automation processes for metal-working industries using welding robots. It is oriented towards manufacturing environment, consisting of production equipment, technologies and processes. These determine the productivity of manufacture and quality of products. The welding technology (process automation based on SME robots) and production system consists of:

- Best solution for robot cell structure
- Methodology to determine intelligent assembly
- Design of jigs and fixtures (advanced sensors feedback system)
- Optimised welding parameters (excluded in the research)
- Optimised production process (included next operation for preassembly for synchronizing flow)
- Integration of robot cell activities to the manufacturing (completed layout)
- Balancing the workload between workplaces

In project's preparatory part, the necessary technology and methodology were selected in conformity with the company's manufacturing system. On this basis, the robot cell (Fig. 2) concept was developed in conjunction with the enterprise.

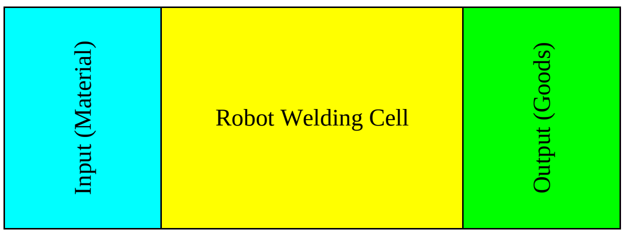

Fig. 2. Basic robot cell schematic

The most important aspects of this concept are the following:

- Comprehensive manufacturing of product (instead of batch production was implemented full kit production).
- If necessary, flexible and rapid fixture replacement.

- Intelligent diagnostics and feedback for the fixture, presuming the option of further development of the complex for robotization.

The basis of the comparative data was a parallel manual welding process. The existing manual welding process (MIG type) consisted of three working areas, in which six different fixtures were used, the schematic for which is shown in Fig. 3.

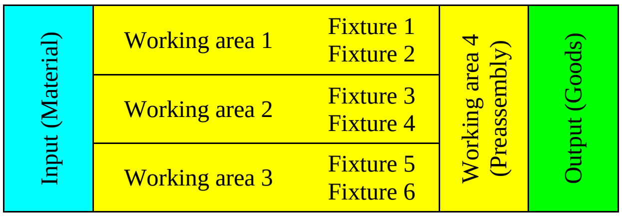

Fig. 3. Manual welding schematic

The objective of the study was to contrast manual and robot welding and the resulting economic effect. The effectiveness of this case study was evaluated in the form of measurement results for the project's critical success factors and key indicators.

3. RESULTS

Table 1 shows two targeted and measured Critical Success Factors (CSF) set as objectives and measured in the strategic planning process (Johnson & Friesen, 1995) along with the corresponding Key Performance Indicators (KPI) (Kaplan & Norton, 1996). The strategic success factors in the given project are Cost and Quality. The selected key indicators Effectiveness (1), Improved Space Utilisation (2), Simple ROI (Return On Investment) (3), Quality Performance (4) and Improvement (5) best characterize the company's future potential Critical Success Factors as a result of the project.

CSF	KPI	Man	Robot	Improvement
Cost	E	52.7%	78.4%	48.8%
	ISP	1061 €/m²	1800 €/m²	69.90%
	ROI	41.60%		
Quality	QP	95.7%	98.2%	2.6%
	Reduction in Defects			21.8%

Tab. 1. Result of measurement

The results in the table were calculated as follows:

- Effectiveness (E)

$$E = \frac{Ideal\ Cycle\ Time * Total\ Pieces}{Operating\ Time} \quad (1)$$

- Improved Space Utilisation (ISP)

$$ISP = \frac{Sales\ turnover\ of\ area}{Number\ of\ square\ metres\ of\ area} \quad (2)$$

- Simple ROI (ROI)

$$ROI = \frac{Gains - Investments\ Cost}{Investments\ Cost} \quad (3)$$

- Quality Performance

$$QP = \frac{Total\ Pieces - Faulty\ Pieces}{Total\ Pieces} \quad (4)$$

- Improvement

$$I = \frac{Robot\ Welding - Man\ Welding}{Man\ Welding} \quad (5)$$

4. DISCUSSION, EVALUATION, CONCLUSIONS

To sum up, the growth in efficiency and economic effects of automating the welding process as described was greater than expected. The achievement of the given outcome was supported significantly by two aspects:

- Intelligent technical solution
- Intelligent system solution

If the manual welding principle served as the basis for implementation of the robot centre (Fig. 3) the expected economic effect would certainly be smaller. Above all, valuable time would be lost in configuring the fixture, which has an impact on efficiency. Non-complex welding of various components would significantly increase the need for usable space. The above is certainly a factor on the ROI results. With regard to quality indicators, only two key indicators are shown, but further study on impact and correlation with workforce expenses and competence should be conducted in this field.

Thus we can conclude that the benefits from integrating different comprehensive technologies and systems could be many times greater. Implementing the integrated modular welding robot system described in the article in SMEs, we can by induction argue that productivity and quality will improve, and that profitability of the investment has been proved. The fact that the company does not have competence and/or a product group for developing technical solutions may prove problematic.

5. ACKNOWLEDGEMENTS

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