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WELDING ROBOT CELL IMPLEMENTATION IN SME-S USING MODULAR APPROACH - CASE STUDY

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Abstract: *During recent years the automation of production processes in SME-s (SME – Small and Medium Enterprise) has been subject of interest. The economy of scale and increased volume of production can be achieved by selecting the right strategy for the automation.*
The automation systems mainly are complex and their implementation is resource consuming. The lack of resources and competencies often limit the implementation of complex systems in SME-s.
This case study is based on robot welding cells implementation in several enterprises. Introducing robot welding cells in SME-s is quite difficult task because of the extent of the project and lack of competencies in small companies. For realization such projects the complex tasks must be divided into smaller and simpler targets using modular approach.
The success of implementation could be achieved through particular definition of modules/ spaces/ subjects, needed competencies and time. This makes possible to implement project steps in parallel.
Key words: System implementation, modularization, SME, robot-welding cell

1. INTRODUCTION

Robots are used long time mainly in mass production. The tasks done with robots are usually repetitive and do not change during the long period of time. The cycle time reduction is actual task for companies.

By implementing robots in small and medium sized productions the criterions are also changing. When the production batches are small, the importance of rapid setup and introduction of new products has high significance.
Special robots and manipulators producing small batches and great variety of products will help here. Manufacturing of cost efficient and client-based products is top important for SME.
The need for industrial robots supporting humans in work process has been rapidly increased.

1.1 Trends in Robotics

The implementation of industrial robots has been an increasing trend in the world.
In 2006, about 951,000 robots were installed in production industry worldwide. During the year 2012 the estimation of robot installations is 1,057,000 units worldwide [[1]].
The implementation of robots exceeded the number of 100,000 installations per year in 2004 and the trend is increasing.
The development of robots has been rapid during last decade. The increased possibilities of manipulators and new directions of computer technology are introduced.
In the 3D virtual robot environment the on-line and off-line programming is more process-oriented and makes it easy to grasp for the operator.
The robots were introduced also in areas where the implementation was earlier considered not profitable or impossible (construction, logistics).

One of the trends is more rapid implementation of robots in SME-s. The availability, competitive prices and plain programming made it possible and feasible.
Introducing robot welding cells in SME-s is quite difficult task because of the extent of the project and lack of needed competencies in small companies. To realize such projects the complex tasks must be divided into smaller and simpler targets using modular approach.
This approach gives an integral overview of the system and makes the tuning more precise and effective for each system or process part separately.

2. METHODOLOGY

Several researchers have been analyzed the robot implementation by different scope. Published works include several subjects and focus on specific areas like welding, calibration, programming etc. Used approaches do not support the implementation of the whole complex system.
The articles cover following domains:
1) General trends in world (field of use, robotization volume) [1]
2) Programming of robots (programming systems, optimizing programs, off-line programming) [2]
3) Coordination, calibration (using cameras and sensors) [3]
4) Welding processes (MIG/MAG, laser+MIG, quality assurance) [4]
5) Scheduling of operations, workload [5]
6) Criterions for robot selection, modeling system, (modular architecture, product family) [6]
7) Kinematics and singularity [7]
8) Production process (reuse of process knowledge, cycle time, bottlenecks) [8]
9) Monitoring, controlling of system [9]

These items do not support the implementation of whole (complex) system they can be used for division of such systems.

2.1 Definitions, scope

During the research several terms are used for describing the system. INCOSE (International Council on Systems Engineering) defines a system: A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected." [10].
Complex systems tend to be high dimensional, non-linear and hard to model.
The need for systems engineering arose with the increase in complexity of systems and projects. In this context complexity incorporates not only engineering systems, but also the logical human organization of data. A system can become more complex due to increase in size and due to increase in the amount of data, variables, or the number of fields that are involved in the design. Systems engineering encourages the use of tools and methods to better comprehend and manage the systems complexity.
Various informal descriptions for complex systems have been defined to extend the concept:
• A complex system is one that by design or function or both is difficult to understand and verify.
• A complex system is one in which there are multiple interactions between many different components.

Main properties of complex systems:

• Highly structured system with variations
• Sensitive to small perturbations

• Difficult to understand and verify
• Constant evolution over the time.
• Multiple interactions between components.

A module is a structurally independent building block of a larger system with well-defined interfaces.
A module is fairly loosely connected to the rest of the system allowing an independent development of the module as long as the interconnections at the interfaces are well thought of [11, 12].
In this paper the implementation refers to actions from system selection, technology description up to introduction of real product.

2.2 System decomposition

Implementing of complex systems in SME is challenge that needs special approach and competence.
Investigations of robot suitability for SME were performed under the European 6:th Framework called "SMErobot" [13].
Dividing the implementation process into smaller/manageable parts will help the introduction of robot systems in SME. Each level of the system includes different implementation process part(s), and it is possible to move between levels, to add information and interconnections data.

Problems derived from the complexity:

• Integration of the system with factory opportunities
• Appling local production technology for production robots
• Lack of staff competency
• Development of suitable jigs
• Economic and ROI calculations

3. RESEARCH

During the research three robot implementation case studies are introduced:

1) Robot-welding cell for mini-loaders (Case 1). It was used for welding of mini-loaders base-frames, tools and lifting beams.
2) Robot-welding cell for cylinders (Case 2). It was used for welding of cylinder tubes and cylinder rods.
3) Robot-welding cell for bed frame (Case 3). It was used for welding of bed base frame components.
These systems can be treated as complex systems.

3.1 System layers definition

Main system layers of the robot-welding cells are shown in Table 1.

Table 1. Robot-welding cells and layers

Layer	Case 1	Case 2	Case 3
Product technology (policies)	Lot of products, different requirements	Lot of products, similar requirements	Product family, similar requirements
System (hardware)	Large and complex system, flexible	Large system, flexible	Small system, less flexibility
Facility (virtual testing)	RobotStudio, CAD, Rapid, Omron	RobotStudio, CAD, Rapid, Omron	RobotStudio, CAD, Rapid, Logo!
Installation (facility)	Additional set-up in factory	Additional set-up in factory	Additional set-up in factory
Jig (hardware)	New product, additional jig	New product, jig upgrade	New product, new jig
Program (software, policy)	Lot of movements, sophisticated programs	Little movements, sophisticated programs	Lot of movements, simple program
Production (facility, policy)	Welding process complex, parameters	Special requirements for process	Mild requirements for process
Modules (functions, behaviour)	Program modules, measuring, production time	Program modules, production time, cleaning	Program modules, production time

Dividing the implementation process into different layers will help to understand and manage the process more properly. The division of the robot-welding cells can be made as follows. Based on INCOSE definition of system [10] two main groups of system parts can be distinguished: 1 - physical and 2 - virtual.

System layers can be defined on the following base:
- Process (type of product and kind of production)
- System configuration (hardware used for production)
- Installation (needed means and steps for set-up)
- Variables, modules (main affecting variables)
- Program (production set-up)
- Simulation

Following layers for the implementation of complex systems can be defined:

1) Product analysing layer (technology charting). The example of the technology chart configuration is shown in Figure 1.

Drawing	665031	F		Welding parameters	v	w	I
					mm/s	m/min	A
Name	Lifting beam			wld250v8sh11	8	7,5	250
Module number	M_2.mod			wld100v2sh12	2	8	100
Workstation	Grille	STN1		wld250v6sh11	6	7,5	250
Workobject	wobjGm_2			wld250v10sh11	10	7,5	250
Programming time	700	min		wld200v6sh14	6	12	200
ROBOT TIME		min		wld100v4sh16	4	8	100
Welding time	30	min		wld150v9sh15	9	9	150
Positioning time	5	min		weld100v6sh16	6	8	100
Maintenance	4	tk		wld150v9sh15	9	9	150
OVERALL TIME 1	35	min		wld200v8sh14	8	12	200
Leadtime				wld200v14sh14	14	12	200
Jig setting time	30	min		wld70v6sh19	6	10	70
Loading time	10	min		wld50w6u4	6	6	50
OVERALL TIME 2	40	min		wld100v8sh16	8	8	100

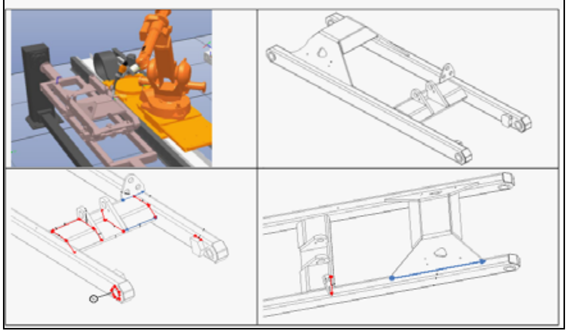

Fig. 1. Technology chart in robot-welding cell (Case 1)

2) System configuration layer based on technology analysis of the system (hardware can be selected). The system configuration can be represented as it is shown in Figure 2.

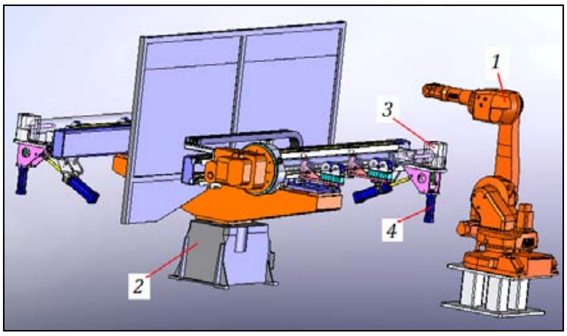

Fig. 2. Robot-welding cell system configuration (Case 2) 1 – robot, 2 – manipulator, 3 – product, 4 – jig.

3) Simulation layer – feasibility testing of the of the system and product by using software (CAD, ANSYS, RobotStudio).
4) Facility layer – real system installation in the factory.
5) Installation layer – includes information and policies for system support and installation.

Installation layer topics are shown in Figure 3.

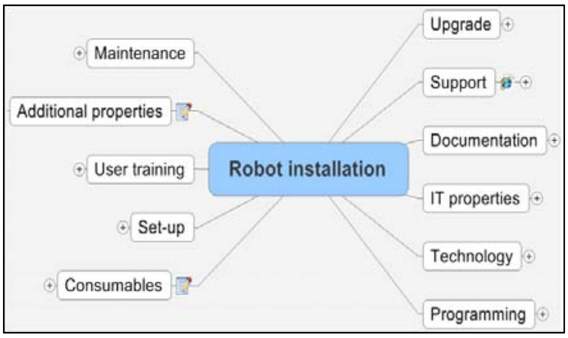

Fig. 3. System installation layer for robot-welding cell (Case 3)

6) Jig layer – to connect system and product.
7) Program layer – includes program modules, welding positions and other modules.
8) Layer for technology – real process & production.

The main issues concerning this layer are shown in Figure 4.

9) Layer for modules – used for system adjusting & update. The layer contains only main affecting modules.

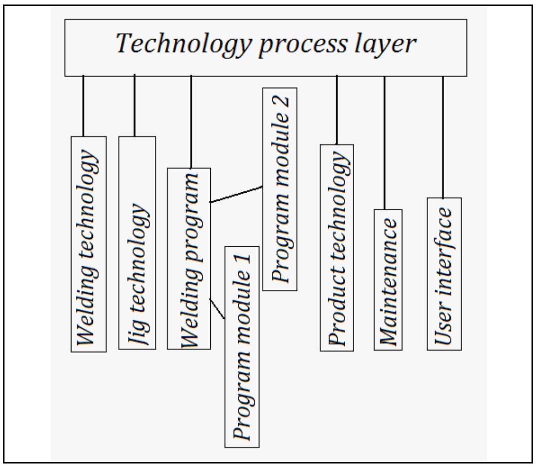

Fig. 4. Technological process information hold in layer

3.2 Virtual model for implementation of complex systems

The layered virtual information model for implementation of complex system is proposed.
Different levels of system layers information can be inserted (hardware, software, policies, modules). This information (knowledge) is extracted during system implementation at different stages of the process.
The model can have as many layers as needed. The proposed layered virtual model is shown in Figure 5.
This model can be filled with system information and process knowledge during the system creation phase. Layered structure helps to grasp system properties. Here is easy to describe interconnections between different parts of the system.

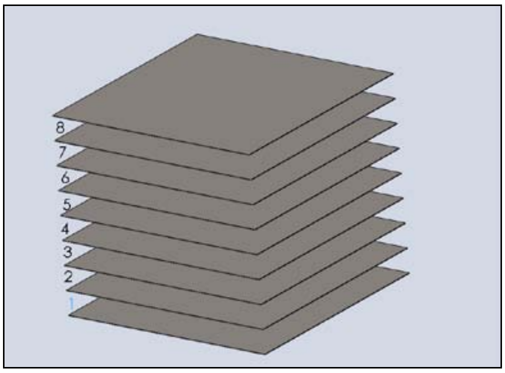

Fig. 5. Layered virtual model for complex system implementation

Depending of the system several approaches can be used for defining layers. If the complex system is used for example for the production, the leading layer must be dedicated to the production technology. Other layers are connected with leading layer via different variables. Indexing is good to use as well.
Each layer has to be defined with distinct detail level. It is possible to move between layers and update them.

4. CONCLUSION

The layered virtual information model for implementation of complex system is proposed.
An approach how to share actions between different layers and to manage complex systems implementation is given.
Layered virtual model helps to prevent problems during the system setup and increases the speed of implementation.
Layered virtual model approach gives clear system and processes overview and the economy scale as well.
Particular tasks division helps to introduce complex technologies in SME-s.

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