ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XV [2017] – Fascicule 2 [May]

ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

[1.]Jukka HEMILÄ, [2.]Juha VANHANEN

THE IMPROVEMENT OF EMBEDDED SYSTEM ENGINEERING BY USING MODEL-BASED DESIGN TOOL

[1.]VTT Technical Research Centre of Finland Ltd, Business Ecosystem Development, Espoo, FINLAND
[2.]Oy M. Haloila Ab, Ruskontie 16, 21250 Masku, FINLAND

Abstract: This paper is about manufacturing industries providing complex embedded systems, composed of mechanical, electronic and software components. Only a smooth integration of these parts can ensure their functionality and should be the basis for a successful business concept. The embedded systems engineering processes have to ensure multi-disciplinary, multi-life cycle, multi-site and multi-organisation at the same time. Generally, the digitalization is bringing entire new kind of opportunities not only for embedded systems, but also for the engineering processes. This paper describes the electric cabinet engineering challenges as a part of entire embedded system engineering and manufacturing in single case study. Within the case study supplier-customer collaboration companies are using common engineering tool.
Keywords: Engineering processes, embedded systems, model-based design, supplier collaboration

1. INTRODUCTION

Manufacturing accounts for over two thirds of EU exports and two thirds of the financing of the total private sector investment in research and development in Europe, and manufacturing serves as a powerful engine for growth [1]. Despite technology industries have been the backbone of European economy, it is having today challenging times in several parts of the Europe, for example in Finland. As an exception to the recent growth trend of other Western European economies, Finland's GDP has failed to pick up [2]. The production volume of Finland's key export sector, i.e. industry, has fallen back to the levels reported in 2009 and exports are not expanding [2]. Tax and cost hikes, high unemployment and a weak performance in the industry sector have been reasons for Finnish industries to grow [2]. Digitalisation has been recognised as one of the main trends shaping the industrial economy. In a vision of the future of manufacturing industries, the pervasive networking of people, things, and machines will create completely new production environments. From the business process perspective, the nature of smart, connected products substantially changes the work of every function within the manufacturing firm [3]. Digitalised industrial companies will be connected to industrial value chains by providing entirely new product-service solutions with embedded intelligence in their end-products, digitalised processes supporting traditional operational processes and the value chain member are integrated together with next generation digital tools and platforms. The core functions (product development, IT, manufacturing, logistics, marketing, sales, and after-sale service) are being redefined when moving more towards digitalization, and the intensity of coordination among them is increasing. Entirely new functions are emerging, including those to manage the staggering quantities of data now available. All of this has major implications for the classic organizational structure of manufacturers. There are four major trends in manufacturing industries according Frost & Sullivan [4]. Firstly the integration of ideas, technologies and processes between the worlds of Information Technology (IT) and operations technology (OT) will form the future Industry Convergence IT-OT. Secondly, exploring newer avenues for service innovations, such as cloud-based service platforms and evaluating potential for new profit centers. These opportunities are becoming as industrial services 2.0. Thirdly, supply chain evolution is becoming when digitalization and increased connectivity is set to disrupt and realign existing value-chain networks in the future. Fourth major trend has many names (e.g. Manufacturing 4.0 Business

Ecosystem, Industry 4.0), as advanced ICT technologies will promote new inter-relationships and interdependencies giving way to unexpected business collaborations and partnerships in the future.
The merging of the virtual and the physical worlds through cyber-physical systems and the resulting fusion of technical processes and business processes are leading the way to a new industrial age. The slow economic growth during recent years has boosted the development of product-related services and services have brought increasing revenue for the manufacturing companies in place of traditional product sales [5]. However, without new installed base (i.e. new product sales) is hard to get new service sales. Today, embedded ICT and other modern technologies in products are bringing about a competitive advantage for manufacturers and opportunities for service offerings [6]. At the moment, there is a global hype on digitalization, and it can provide enormous advantages for industrial companies. For being competitive and aiming for cost efficiency, the automation and digitalization of the processes is crucial today. Different digital tools can provide entire new ways for supplier collaboration, but also internal design and engineering processes. The digitalization in manufacturing industries can be seen in three operational areas (see next Figure 1):

1. Future customized product-service solution offerings by digitalized factories
2. Seamless integration of collaborative environment to Product-Service Solution value creation
3. Integration of digitalized products and service environments

Development of complex, industrial products and services requires several engineering, operative, marketing etc. skills for making continuous trade-offs and successful design decisions. Each customer delivery includes tailored parts for specific, business customers' needs regarding, for example, specific automation processes, workflows and hardware configurations. Guidelines from standards are usually too complicated for Small and medium sized companies (SMEs) to follow completely, so SMEs require easy and practical guidelines [8a]. Previous research has shown that the better the product development team members are connected to each other and to key external parties, the more successful the project is likely to be [8]. The study focuses on engineering part of the digitalization in manufacturing. Services engineering or service business are not in the focus of this study. Service engineering has completely different challenges as product engineering.

Figure 1 – Digitalization in manufacturing industries domain

1.1. Embedded system and engineering characteristics

This research is about embedded systems engineering, which requires the integration of several disciplines: mechanical, electronic and software. In addition to being multi-disciplinary, the development of embedded systems is usually multi-life cycle, multi-site and multi-organization at the same time [9, 8]. Multiple disciplines involved in embedded systems have been illustrated in Figure 2.

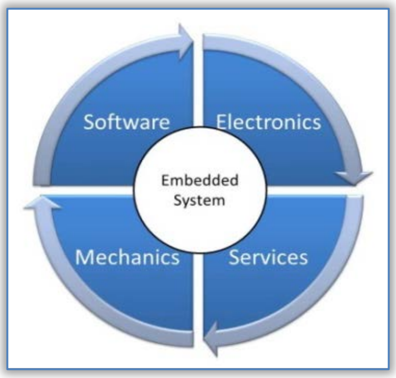

Figure 2 – Multiple disciplines involved in embedded systems [8]

These embedded system features are creating a huge challenge for small and medium sized enterprise (SMEs) and their collaboration partners, despite there are common standards and procedures for HW/SW engineering available [9, 10]. The reason for this challenge is the lack of utilization of standards. According the case study, the standards could be helpful but at the same time hard to realize and follow in practice. SMEs with limited resources are facing the challenge of utilizing available standards; they rather create ways of engineering by themselves. This research attempts to find a new approach to the improvement of embedded systems engineering processes by taking care of collaboration challenges with supplier network. This paper describes how to utilize a common model-based engineering tool in customer-supplier collaboration and which kind of advantages can be achieved.

2. RESEARCH DESIGN

2.1 Methods

The purpose of the study is to find out the supplier-customer collaboration challenges faced by manufacturing SMEs in the engineering process of providing embedded systems. The qualitative case study research approach was used to gain both theoretical and empirical insight into this topic [11]. The case study form was seen to work in the research for discovering the causalities of the phenomenon [12, 11]. The research is based on constructive research tradition, where a new construct for supplier-customer engineering collaboration was developed, based on the generic process framework and tested the approach with an empirical case. As the study takes both a constructive model testing perspective as well as an empirical case data analysis perspective, the role of the researcher was twofold: firstly, there was the role of facilitator of the research process and thus ensuring the process was carried out properly and assessing how the framework worked in the case environment. Secondly, the purpose of the researcher involvement was to gather data from the process and insights from the approach. The experience and insights of the business informants were considered essential in order to make in-depth sense of the phenomena [11].

2.2 Empirical case

In this study focus is on the case of Finnish machine manufacturer SME, or in other words, small and medium-sized Original Equipment Manufacturer (OEM). The subject of the case study is a manufacturer of wrapping machines, called Oy M. Haloila Ab, whose typical customers are globally operating construction, tissue papers and food industry companies. The case company uses different-sized companies as tier one level suppliers of engineering, mechanical components, sub-systems, software and services. Case company has outsourced electric cabinet engineering and manufacturing to the supplier. Both customer and supplier have started to use same model-based design and engineering tool, which have created huge advantages for the collaboration. The case company has sales in Finland but more than 70 % of its turnover comes from exports. It has strong supply chain integration, information sharing and IT supported processes internally and externally, which makes it competitive and profitable in the markets. By using workshops, was developed the engineering and collaboration models for the case company. During and after the workshops, several documents were created and consulted to enable triangulation: minutes of the meetings, proposals, progress reports, presentations.

3. EMBEDDED SYSTEMS ENGINEERING PROCESSES IN MANUFACTURING SME CASE

Engineering part is the core of the automated product design process. It starts with acting on the collected customer requirements and converting them to product specification, taking into account required quality, reliability and safety regulations. In this case study, production is just final assembly, while the manufacturing of parts, modules or components has been outsourced to suppliers. The entire manufacturing environment was called as "Industrial Process", as the research team named it (Figure 3). The reason behind the naming was the case company's own practices, when five basic processes were named as:

1. Product Life Cycle Support – The R&D process
2. Consulting sales – The sales process
3. Industrial Process – Production process including supplier collaboration
4. Maintenance – After sales services
5. Modernization – After sales services second phase

The Industrial Process includes the production environment and manages the collaboration with suppliers. A customer order is received by the sales team and then the industrial process begins. The factory sales team checks the customer order and ensures manufacturing capacity and they also coordinate the required tailor-made solutions with R&D. In the Industrial Process, case company itself generates Product Card, which includes all technical details for the final product. For the electric cabinet supplier, the Product Card includes all required information for electric cabinet engineering and manufacturing: dimensions, connection points to other electrical systems, and required functionalities. The supplier has responsibility for electric cabinet design, engineering and manufacturing. Supplier collaboration starts with the kick-off meeting. There product engineer presents Product Card for the supplier. Together with supplier's engineer they check specification and functionalities of electric cabinet, by using under electrical design tool. The tool is called as Electrical CAD, later eCAD. After kick-off meeting, supplier begins own manufacturing process. Firstly, engineer creates project folder under eCAD.

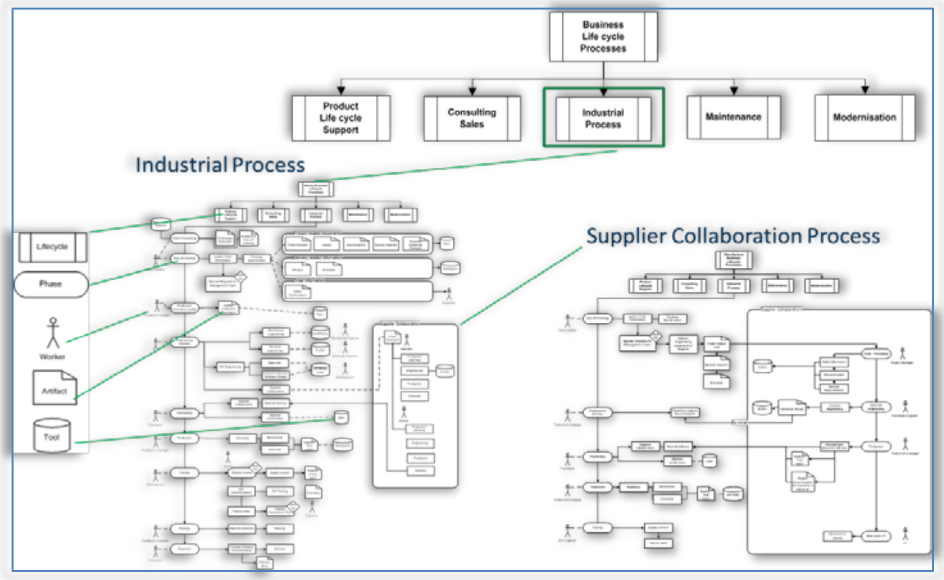

Figure 3 – Industrial Process and Supplier collaboration process

Within eCAD, there is Excel based generator with 80 macros for different predefined projects. Then engineer opens the eCAD and import selected macro. From the selected macro, engineer gets basic features and specification for the electric cabinet. Automatically engineer got electronic circuit, component lists, connectors and connection points, cables, cable colors and manufacturing information for ERP system. eCAD include lot of component macros provided by global component suppliers. After the engineering of electric cabinet, the supplier does the manufacturing and assembly of electric cabinet. Then the finalized electric cabinet will be delivered for the case company, to be assembled as a part of the wrapping machine. At the same time, final data and drawings are sent to case company to be attached as documentation for customer, but also for later maintenance and other purposes. Next chapter will discuss about the results of the study by using model based tool in supplier-customer collaboration.

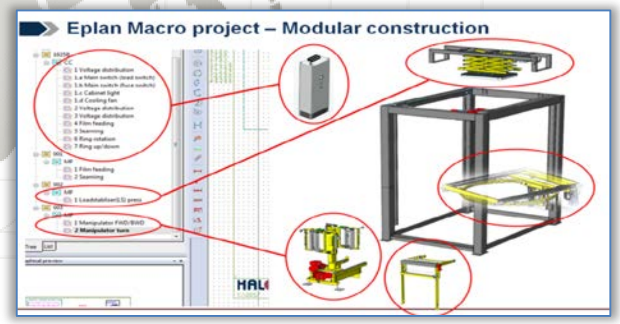

Figure 4 – eCAD utilization as a part of product engineering

4. RESULTS

The model-based feature brings a huge advantage, because each electric cabinet design has typically 80% of same components. Only 20% of components are project based, but also for those components can be found macros. Supplier can create automatically documentation for own manufacturing but also customer documentation, like installation guides, specification, component lists, etc. These documentations can be used directly for case company's end-product documentation. After all, the engineering and manufacturing of electric cabinet can be done with 10% less time and effort. When multiplying in all electric cabinets done during entire year, the savings is huge. Additionally, the less manual work in design and engineering creates fewer errors, easier to share information and better quality in processes and products. These advantages are hard to include in key performance indicators, but qualitative advantages are still really important in collaboration. Specific customer requirements are still challenging and require lot of information sharing vie emails, Skype calls, and sometimes even face to face meetings and negotiations. Customer requirement information should be share immediately for supplier network, but sometimes information is achieved too late and supplier has already done electric cabinet according original specification. The delivery times are challenging, when case company requires for example seven days from order to delivery, but the component delivery times can be even three weeks. As 80 % of components remain the same in each electric cabinet, these components can be stored and ordered from component suppliers even before order from case company. When looking the improvements achieved in product point of view in case study, there is good improvement in the:

- Decreasing amount of "Change for delivery/ Product Card“
- Decreasing amount of "After shipments/ Product Card" in industrial process

Change for delivery / Product Card means that how many change requests there have been during the production process from fixed customer order until delivery time. It means that customers are still willing to change something in their order, despite order is already confirmed by supplier. After shipments means the amount of changes made after the delivery. These after shipments are e.g. manuals, software version, etc. Exact figures presented in following Table 1.

Table 1 – Product related improvements

	Product Card	Change for delivery	After shipments	Change for delivery/ Product Card	After shipments/ Product Card
2011	190	223	137	117 %	72 %
2012	212	282	221	133 %	104 %
2013	222	312	176	141 %	79 %
2014	202	290	92	144 %	46 %
2015	176	210	83	119 %	47 %

As a summary of achieved results, in the study have been collected some quantitative data about the process improvements during the development project as follows:

- Faster response on customer needs: faster design to delivery process
- -10 % working time / electric cabinet, (average 40 h / cabinet)
- Around 200 machine per year
- Overall working hour savings 720 h / year

Some of the improvements are purely qualitative, which might be hard to measure in figures. Following qualitative improvements were listed during the project, because in implementing Industrial Process and streamlining supplier collaboration, usage of tools and after learning how processes should be running:

- Effective utilization of Process support Tools and methodologies.
- Decreasing manual work
- Paperless offices / factory
- Once added information available in all process parts
- Better understanding of processes, "how my work is related on others work"
- Better supplier collaboration: visualized processes
- Decreasing process interference (as is – to be)

As a conclusion of the results, companies should understand their business processes, so that each individual realizes their position and relation to other process parts. In the case of SMEs, processes are not typically well documented. Next chapter will discuss about findings and conclude the study.

5. DISCUSSION AND CONCLUSIONS

From the academic perspective, it is important to understand the embedded systems characteristics and the meaning of collaborative engineering processes for the success of the manufacturing firms. The R&D function should ensure that a product can be installed, maintained and operated as planned. Within the case company, the main R&D function is developing a product-service offering (HW, SW, Mechanics, Electronics, Services design). Supplier collaboration is used for developing new manufacturing methods, product development and searching for new technologies, materials and components. Machines are now extremely complex structures with more and more embedded intelligence, the latest electronics and software, and also mechanical design. Communication across company borders poses additional difficulties, e.g. due to factors such as lack of trust, differences in ways of working, and legal issues. Geographical distance, a factor that massively reduces communication, is almost always present in these kinds of situations. Model-based IT tools are used for engineering, and a future challenge will be to harmonize different tools with the supplier network, not only the electric design and engineering tool as in a case study.

Digitalization of industries will have one main research question in the future: how advanced information and communication technologies can boost value creation in industrial product-service contexts? Digitalization of industries aims to achieve production-related advantages by creating a networked, flexible, and dynamically self-organizing manufacturing process for highly customizable products and services. In the tight competition of industrial manufacturing of different systems and services, the importance of customer intimacy is continuously increasing in many manufacturing domains. Today, companies needs to pay serious attention to customer specific products and services. Aim is to continuously create value by improving the quality, production, environmental aspects and cost efficiency of their customers' processes.

Note
This paper is based on the paper presented at The International Conference Management of Technology – Step to Sustainable Production (MOTSP 2016), organized by the Faculty of Mechanical Engineering and Naval Architecture, Croatian Association for PLM and the University of North, in Porec/Parenzo, Istria, CROATIA, June 01–03, 2016.

References

[1] Sanz, F. European manufacturing a 'powerful engine for growth, The Parliament Magazine on 28 September 2014, www.theparliamentmagazine.eu/articles/opinion/european-manufacturing-%E2%80%98powerfl-engine-growth%E2%80%99 .
[2] Economic outlook, (2016)1, The Federation of Finnish Technology Industries publication series. teknologiateollisuus.fi/sites/default/files/file_attachments/0297_tt_situationoutlook_1_2016_0.pdf.
[3] Hemilä, J.: Service Innovations based on Internet of Things in Industrial Context, The Proceedings of ISPIM Innovation Summit, 6-9 December 2015, Brisbane, Australia.
[4] Internet of Industrial Things: The Vision and the Reality, Industry visionary reports by Frost & Sullivan
[5] Kowalkowski, C., Witell, L., Gustafsson, A.: Any way goes: Identifying value constellations for service infusion in SMEs, Industrial Marketing Management, 4282013)1, January 2013, 18-30.
[6] Hemilä, J., Airola, M.: Collaboration in industrial product and process innovations. Proceedings of the 2014 ISPIM Asia-Pacific Innovation Forum. Singapore Management University, 7 - 10 December 2014, Singapore.
[7] Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, SE Handbook Working Group, INCOSE, January 2010..
[8] Hemilä, J., Airola, M., Vanhanen, J.: Supplier-customer collaboration in embedded systems engineering processes - Principles and case study. The Proceedings of 6th International Conference on Operations and Supply Chain Management (OSCM), 10 - 12 December 2014, Bali, Indonesia.
[9] Lefftz, V., Bertrand, J., Casse, H., Clienti, C., Coussy, P., Maillet-Contoz, L., Mercier, P., Moreau, P., Pierre L., Vaumorin, E.: A design flow for critical embedded systems, Proceeding of Industrial Embedded Systems (SIES), July 7-9, 2010., University of Trento, Italy.
[10] Bouchhima, A., Chen, X., Pétrot, F., Cesario, W. O, Jerraya, A. A.: A unified HW/SW interface model to remove discontinuities between HW and SW design, Proceedings of the 5th ACM international conference on Embedded software, 2005, New York, NY, USA.
[11] Yin, R.: Case study research - design and methods, 3rd edition, Applied Social Research Methods series; v. 5. 2003,Sage Publications, Inc.
[12] Jensen, J. L., Rodgers, R.: Cumulating the intellectual gold of case study research, Public Administration Review, 61(2012)2, 235-260.

ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering