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USING PETRI NET TO MODEL PRODUCTION PROCESS OF SHIPS ENGINE CRANKCASE IN PROCESS REENGINEERING (CASE STUDY).

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SUMMARY : *The paper presents findings from research that has been carried out during performing production process of a ships engine crankcase reengineering. Method based on Petri net has been applied. Authors present the most distinctive elements of Petri net and define methodology of manufacturing processes modeling. The outputs from this stage were evaluated and complemented by outputs from additional methodology performed – Rapid Re. Comparison of both methods based on pre-defined eight criteria was performed. Suggestions to develop the hybrid solution combining the advantages of both methods are presented.*

KEY-WORDS : *Petri nets, corrective design, modeling manufacturing processes, IDEF0 methodology, reengineering*

1. INTRODUCTION

In the analyzed company the need for an reengineering of the production process of a ships engine crankcase was identified. Applying simulation to reengineering process was beneficial as any changes in real production process are connected with serious costs, due to big size of product and application of the high specialized processing tools. The aim of the simulation was to provide the guarantee that the solution chosen would be suitable for analyzed company. The Petri net methodology was applied in simulation creation. Due to the fact that the outputs obtained from simulation process were not sufficient to make final decision, some additional information were collected with Rapid Re methodology. The research conducted in analyzed company provided a basis for comparison of the advantages and disadvantages of both methods. It was stated that the most suitable solution for the similar problem would be a hybrid method combining features of Petri net and Rapid Re.
The paper is organized as following: in Section 2 production process of a ships engine crankcase is identified. In Section 3 theoretical background of the research regarding Petri nets is presented and the developed simulation procedure is discussed. In Section 4 Rapid Re methodology is described and in section 5 the comparison of both methods is provided. Final conclusions are stated in Section 6.

2. IDENTIFICATION OF SHIP CRANKCASE MANUFACTURING PROCESS.

The project was based on 6RTA62U ship crankcase manufacturing process. The engine is manufactured by HCP and licenced by Warstsila. It is a slow-rotation two-stroke engine for cargo ships. The engine works with the speed of 92 to 115 rpm. The engine has 6 cylinders, diameter 620 mm. The horsepower of the engine is 15 550. Its size is 10.63 m of hight, 5.25 m of width and 7.5 of lenght. Manufacturing cycle is about 7-8 months. Figure 1 presents the crankcase element of a ships engine and figure 2 and 3 present operations: welding of whole and treatment.

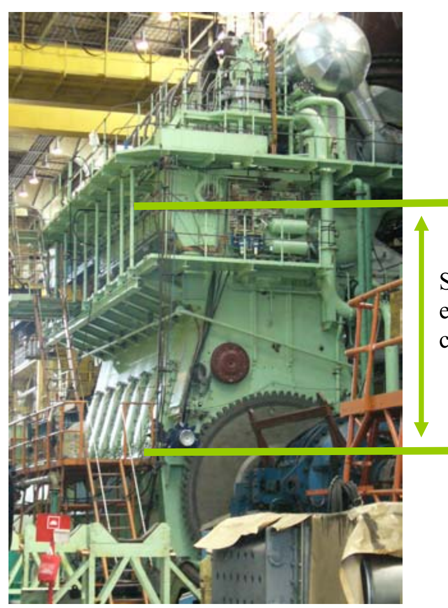

Figure 1. Crankcase element of ships engine.

Figure 2. Ships engine crankcase - welding of whole

Figure 3. Ships engine crankcase – treatment operations

At the stage of identification a process card is designed (Dworczak, Grochowy, 2006). It is fundamental template for data collection, as it includes activities carried out within ships engine crankcase manufacturing process. On the basis of the information presented in the form of process cards (Dworczak, Grochowy, 2006) a process map can be developed. IDEF0 methodology is a tool for map drawing up. Figure 4 presents a context graph of ship crankcase construction process, and figure 5 presents the main processes (Dworczak, Grochowy, 2006):

A – Burning
B – Execution of prow part
C – Execution of stern part
D – Joining prow and stern parts
E – Treatment

Whole process is composed of 58 operations.

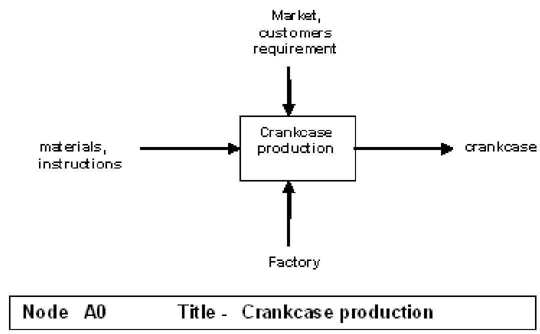

Figure 4 Context graph of ships crankcase production process (Dworczak, Grochowy, 2006)

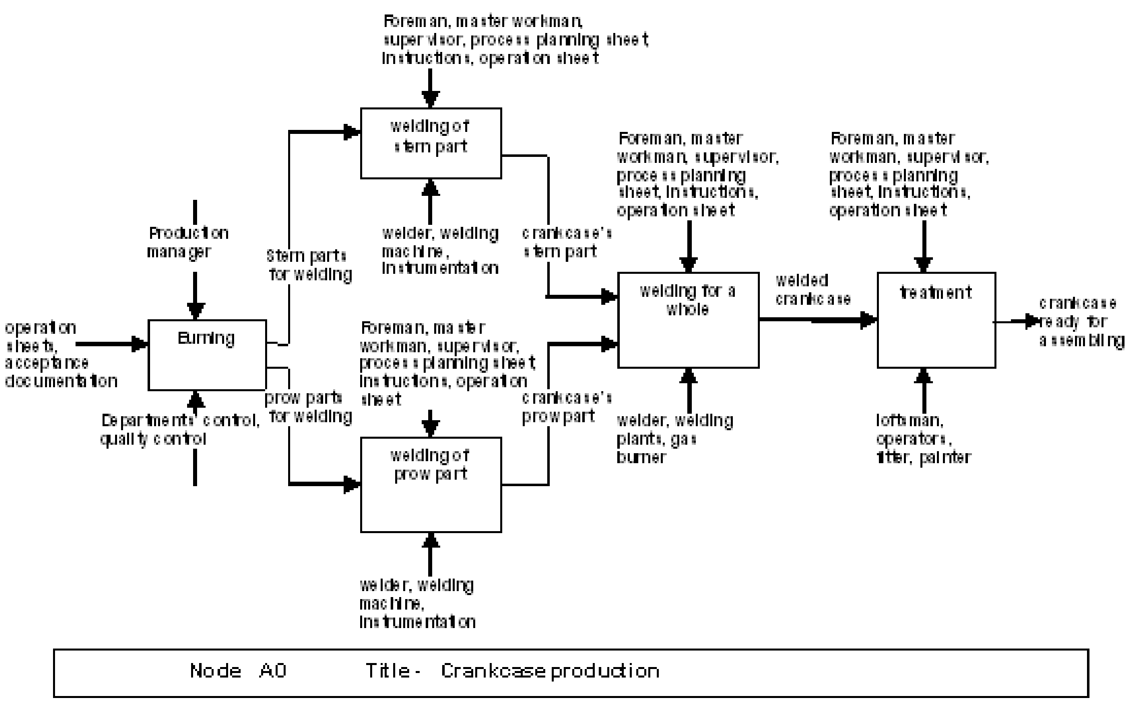

Figure 5 Graph of five main sub-processes in ship crankcase manufacturing process (Dworczak, Grochowy, 2006)

3. METHODOLOGY BASED ON PETRI NET

Petri net (Aalst, Desel, 2000), (Chen 1990), (Peterson 1981), (Reisig, 1988) is one of several mathematical representations of discrete distributed systems. As a modeling language, it graphically depicts the structure of a distributed system as a directed bipartite graph with annotations. As such, a Petri net has place nodes, transition nodes, and directed arcs connecting places with transitions. Petri nets were invented in 1962 by Carl Adam Petri in his Ph.D. thesis.

Nets enable a survey of system features and they are applied for a description and study of information processing systems. Their theory is becoming one of the basic research directions. They are mostly applied in: data analysis, software engineering, work organization, parallel programming. Lately a large number of research and theoretical works concerning the application of Petri net in business process modeling has been published (Aalst, Desel, 2000). These publications provided a strong impetus for the project presented.

For the purpose of modeling the ship crankcase manufacturing process with Petri net a following procedure has been drawn up: (Aleksandrowicz, Ciemna 2006):

STEP I Choice of the process that is to be modeled
STEP II Definition of initial stage – In this case initial stages are technological processes and process maps.
STEP III Definition of the place- places represent such factors as: type of means of communication, conditions or states. In process analyzed following places are distinguished: finished sheets, burning process.
STEP IV Definition of transitions– Transitions define such variables as shifts, events, transformations e.g. burning process, control.
STEP V Definition of tokens - Tokens represent such objects as: human resources, machines, goods, states of objects, conditions, information, state indicators (e.g. indicator of the state in which process or object is)
STEP VI Modeling of relations between places, transitions and tokens with tree graphs. It consists in division of crankcase manufacturing process into successive production stages, which are parts of ship crankcase manufacturing process. They are connected with arrows.
STEP VII Definition of attainable states –Attainable state is the state that can be achieved from the current state, arising because of starting the sequence of possible shifts i.e. shifts between tokens and transitions. In the case analyzed attainable states are: burning process, manufacturing process of crankcase's stern part, manufacturing process of crankcase's prow part, process of joining prow and stern parts.
STEP VIII Definition of dead states – dead state is the state in which none shift is possible. Such states are not distinguished in the research conducted.
STEP IX Model is transferred to VisualObject Net software.
STEP XConclusions and evaluations.

Figure 6 and Figure 7 present models for main crankcase manufacturing process and burning process.

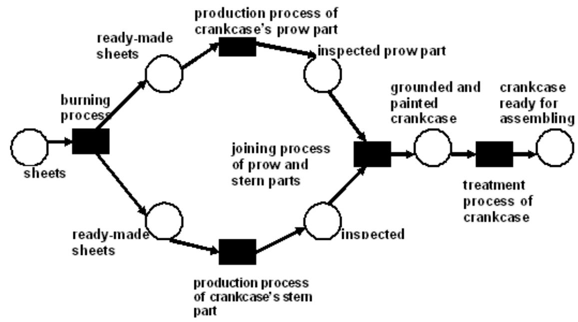

Figure 6 Crankcase manufacturing process (Aleksandrowicz, Ciemna 2006)

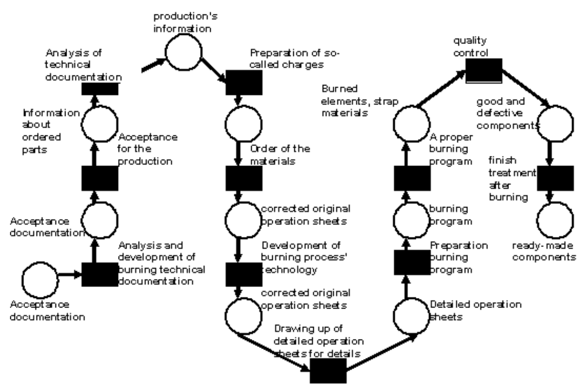

Figure 6. Burning process (Aleksandrowicz, Ciemna 2006)

The application of Petri nets allowed to collect valuable information about production process structure and provided and suitable basis for simulation but the obtained output were not sufficient to make final decision about real process reengineering. The additional analysis with usage of the another reengineering methodology was required.

4. METHODOLOGY RAPID RE.

On the basis of literature study five different approaches to reengineering can be identified. (Cempel 2005):

1. Hammer/Champy approach (Hammer,Champy 1993)
2. Manganelli/Klein approach (Manganelli,Klein 1998)
3. Tichy/Shermann approach(Tichy, Sherman 1993)
4. Davenport approach (Davenport 1993)
5. Durlik approach (Durlik 1998)

Two first approaches can be classified as consulting one, the third approach is purely managerial. The last two approaches can be classified as mainly academic (Cempel 2005).

In the case study presented Rapid Re method was applied due to the fact that it has been described precisely and the literature on the subject provides many examples of detailed problems solutions.

Rapid Re is the methodology which was developed by R.L. Manganelli and M.M. Klein in the beginning of 90's and as a procedure which was described in „The Reengineering Handbook" (Manganelli,Klein, 1998). This methodology consists of five stages (Dworczak, Grochowy, 2006):

1. Arrangements – this stage concerns such matters as making the Board to accept the project, definition of the project purposes, composition of project team, skills of the team members, team training, changes plan development.
2. Identification - concerns mostly processes in an organization, their connections to suppliers and customers processes, process modeling, preparation of the map of the organization and sources.
3. Creating a vision - the stage which is an estimation of existing processes, their influence on general effectiveness, the strategy of the change implementation and the way of its estimation using benchmarking.
4. Project of the solution – technical side– the use of technical sources and technology in modifications and in – society side – method of human resources transformations.
5. Transformation – methods of work progress inspection, success estimation, pilot tests.

Within the researches according to Rapid Re methodology, the procedure of correcting a crankcase manufacturing process was elaborated. The scheme and the results of its implementation are shown in the paper (Dworczak, Grochowy, 2006).

Stage 3 – creating a vision –this stage (Klein, Manganellii, 1998) identifies the actions which create added value, i.e. thanks to which something is created, something which is appreciated by customers and actions of inspection and other. These actions for each main sub-processes were compiled in tables.

Example for Burning process is presented in table 1:

Basing on the tables with classified activities, the actions ratio which generate added value was enumerated in relation to general number of actions.

In the next steps factors which influence the effectiveness of the process and potential sources of errors and problems were described.

Basing on the information collected before, the possibility of process modification was estimated. Modification was evaluated considering the range of modification and difficulties in execution.

No	Activity	Type of activity		
	Burning	**Value-adding**	**Inspection**	**Other**
1	Acceptance to production			X
2	Technical documentation analysis		X	
3	Charge preparation			X
4	Order of materials			X
5	Preparation of detailed operation sheets of details		X	
6	Developing the burning programme		X	
7	Burning process + transport	X		
8	Inspection		X	
	....			

Table 1. Classification of the activities in a burning process- fragment (Dworczak, Grochowy, 2006)

The expected costs of the modification was assessed as well as profits arising from them. The range of advancement was evaluated as well as the risk which arise from introducing the modification.

Estimation of the possibility of reengineering is carried by the table 2:

Accomplishment of the up to the present works let to specifying the vision of the "ideal" process i.e. describing performance of the process when all the parameters are optimal. The execution of basic actions the process is composed of was defined in the way to make it ideal.

RAPID RE methodology is appropriate mainly for business processes, that is why quite a few problems occurred when it was adjusted to reengineering of the production process of the ship crankcase. The method is very responsive to errors connected with compiling data. It is seen particularly in counting the ratio of the actions which bring added value to all actions. In the case analyzed its high value is caused by time limitations. They have resulted in compiled data based mainly on technological documentation instead of being based on the direct observation. However compact and specified vision of the process was successfully offered and enabled reengineering definition. It seems that further works should be directed to defining more strict requirements connected to quality of the compiled data in order to have no doubt when calculating the factor which is the measure the of the potential of redesigning the process. On the other hand it seems to be impossible to build formal model of the process so that it could be simulated and results of redesign would be observed.

Possibility of reengineering	Modification	Difficulty	Advantages	Risk
Faults elimination which occurs during order reception and technical documentation analysis	Electronic order reception current bringing up to date	Moderate	Accuracy, less work	Low
Fines sentencing for unpunctual orders completing	Modification in agreements signed with subcontractor	Moderate	No delays	May not succeed which results subcontractor change
Optimization of COBURG III utilization	Adequate time scale production preparation	High	Cost reduction of equipment operation	Well qualified production planners
Faults elimination which appear when appointing a date of executing actions included in the whole process	Making a proper time-scale production	High	Time reduction of crankcase production	Well qualified production planners
Quality inspection carried out adequately early after delivery annealed crankcase to subcontractor	Quality inspector checks up the delivered crankcase	Low	No possibility of receipt the wrong annealed crankcase	Low

Table 2. Estimation of the possibility of the ship crankcase production process rationalization - fragment (Dworczak, Grochowy, 2006)

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5. COMPARISON OF THE METHODS

Collected data enable comparison of the methods.
Methodologies have been compared taking into account following criteria:

1. subject of interest,
2. form of the model,
3. methodology for model creation,
4. availability of software,
5. complete description,
6. application domain.
7. application of other methods ,
8. difficulty within method implementation in given company.

Results were put forward in tables using following notations:

+ appropriate / possible
0 reduced
- inappropriate

The detailed description of evaluation criteria as well as the comparison process can be find in PhD thesis of P. Pawlewski (Pawlewski 1998). The following thesis was based on previous works of K. Kossanke.(Kosanke 1996).
The presented below comparison process was done by team consisting of researchers from Poznan University of Technology and employees of HCP.

Comparison according to the criterion: Subject of interest.

Following domains were distinguished within the framework of the subject of interest:

– functions executed by analyzed system (e.g. company, part of the company sectioned off, a computer system etc.),
– data in a system (source of data creation, completeness of the data and their utilization),
– the scope of decision support,
– time and three-dimensional relations,
– human skills,
– organizational structures,
– system's material resources – flow of the materials.

Subject of the interest	Rapid Re	Petri
Functions	+	+
Data	+	0
Decisions	+	-
Time	+	0
Three-dimensionality	+	-
Human skills	+	-
Organizational units	+	-
System's material resources	-	0

Table 3. Extended comparison of the methodologies according to the criterion: subject of interest

Comparison according to the criterion: Form of the model.

Following forms of the model have been distinguished:
– reference model, pattern to define a destination solution (some authors define a reference model too generally);
– descriptive model to describe a whole system in a coherent manner;
– behaviour model to simulate the operation of the system;
– model that reproduces the actual state and enables to construct a present physical model.

Model	Rapid Re	Petri
Reference model	-	-
Descriptive model	+	0
Behaviour simulation model	-	+
Model reproducing the actual state	+	+

Table 4. Extended comparison of the methodologies according to the criterion: form of the model

Comparison according to the criterion: The way of model creation

This criterion takes into account following ways of model creation:
– hierarchical – consists in the construction of hierarchical model where features from lower level are assigned to the higher level;
– makes allowance for a recursion – structure of the model is made as a result of a number of repeatable activities, and the way of model creation includes assessment and proofread;
– application-oriented – the way on model creation uses techniques and technologies required to develop an application software (e.g. relational databases' model).

The way of model creation	Rapid Re	Petri
Hierarchy	+	+
Recursion	+	+
Application-oriented model	-	0

Table 5. Extended comparison of the methodologies according to the criterion: the way of model creation

Comparison according to the criterion: availability of the software

This criterion takes into consideration predominantly an availability of the software supporting a given methodology. We do not allow the cases when methodology makes use of the other methodologies e.g. IDEF0, that possess a program assistance.

Availability of the software	Rapid Re	Petri
Software	-	+

Table 6. Extended comparison of the methodologies according to the criterion: availability of the software

Comparison according to the criterion: complete description

This criterion above all takes into account the extent of description for a function, data, decisions in a given methodology i.e. a definition degree of the elements that are the subject of interest of the methodology.

Description	Rapid Re	Petri
Functions	+	+
Data	+	+
Decisions	+	0

Table 7. Extended comparison of the methodologies according to the criterion: complete description

Comparison according to the criterion: application domain.

Herein criterion allows for the following domains:
– flow of the information,
– flow of the materials,
– software technology

Application domain	Rapid Re	Petri
flow of the information	+	+
flow of the materials	-	+
software technology	-	+

Table 8. Extended comparison of the methodologies according to the criterion: application domain

Comparison according to the criterion: utilization of other methodologies.

Utilization of the methodology	Rapid Re	Petri
Process mapping e.g. IDEF	+	+
Modeling of the processes	-	-
Others	-	-

Table 9. Extended comparison of the methodologies according to the criterion: utilization of other methodologies

Comparison according to the criterion: difficulty during implementation of the methodology in given company.

Difficulty	Rapid Re	Petri
At modeling of the processes	-	+
At correction in manufacturing process	0	0

Table 10. Extended comparison of the methodologies according to the criterion: difficulty during implementation

The presented comparison of both method allows to make assessment of the advantages and disadvantages of both method.

6. CONCLUSIONS

The comparison of Petri nets and Rapid Re methods presented in previous section has shown that none of them completely fulfills the company requirements for production process reengineering. The method based on Petri nets is suitable tool for identification of process structure as well as an adequate framework for simulation of the analyzed process before and after reengineering. Rapid Re method is not appropriate for simulation, it also lacks the possibility for time analyses of operations and classification of activities is not sufficient for complex production process. The biggest advantage of Rapid Re methodology is that it gives framework for reengineering process design and organization. Its procedure very precisely described it provides many examples of detailed problems solutions. It provides tools and methods for making assessment of processes appropriateness, as well as comparison of activities in the process.

The research conducted in analyzed company has shown that hybrid solution is needed for reengineering of complex production process. The hybrid solution should combine the advantages of both methods. The Rapid Re methodology should be extended by following elements:

a. transition for process map to process model based on Petri nets in order to gain possibility of parallel activities analyses and synchronization

b. supplementation of activity-based indicators used in Rapid Re, by introduction of time-based indicators

c. extension of Rapid Re activities' classification (value adding, inspection, other) by classification applied in ASME methodology developed by American Society for Mechanical Engineers (Cempel 2005) :

– value adding operations,

– operations which do not add any value,

- quality and / or quantity control,

– transport, flows of people, materials, information, documents, etc.,

– downtime, temporary storing, delay or — idle time between operations,

– storing which is not downtime.

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