4th International DAAAM Conference
"INDUSTRIAL ENGINEERING – INNOVATION AS COMPETITIVE EDGE FOR SME"
29-30th April 2004, Tallinn, Estonia

ON RESHAPING OF THE PRODUCT DEVELOPMENT ENVIRONMENT IN TRADITIONAL MACHINERY PLANT

Kakko, A. & Reedik, V.

Abstract: *The aim of the present paper is to analyse the possibilities of improving the competitiveness of the product development in a plant belonging to the traditional machinery industry. Looking for appropriate assessment tool of the product development environment the Concurrent Engineering and Teamwork across Global Industries (CETGI) process was chosen. By this scheme at first the current state or maturity of the company is analysed and on this basis the desired state of the company is defined. Further a gap analysis is provided between the current and the desired states and appropriate action plan is proposed to reduce the gap. The presentation is focussed on applicability of above mentioned approach in conditions of transitional economy. The authors regret that due to ever growing competition some of the future proposals are confidential.*
Keywords: product development, globalisation, heat exchangers, product family

1. INTRODUCTION

The contribution of the present paper is closely related to the evergreen postulate assigned to Jack Welch, General Electric – "If you do not have competitive advantage, do not compete." AS Tallinna Masinatehas (further TMT) has decided to become a competitive international company, therefore it must run product development (PD) in a way giving distinct competitive advantage among its' potential customers and partners. First contacts on the international markets in the form of questionnaires have revealed most critical topics to be concerned. In addition to it an inside PD ability audit of the factory's performance was provided. As a result, a strong demand for altering PD process was identified.

Interest to the global new PD is continuously increasing due to following factors:

- globalisation of the free trade and improvement of logistics;
- increasing product complexity and interdisciplinarity;
- availability of enhanced communication and information technologies.

Therefore all companies have to take actions to improve their PD ability: set up overall business strategy based on innovation and globalisation, upgrading the organisational structures and management modes, facilitating PD team's interaction and communication, setting up the required IT structures and attaining approach to effective PD tools and techniques (Balbotin and Yazdani, 2000).

At first the appropriate PD ability assessment tool was necessary to choose. As there are available several tools for assessing and upgrading PD activities, the choice between them is appropriate to accomplice according to the following criteria:

- method must consider all aspects of PD;
- chosen method must be accepted on the international level;
- method must suggest an action plan.

Large amount of papers are devoted to assessment and upgrading particular aspects of PD process, such as design workflow (Gershenson and Pavnaskar, 2003), selection of an operational model (Ivashkov and Overveld, 2001), application of experience in product development (Badke-Schaub et al., 2001), design process model (Perez et al., 2003), etc., but not many of them are actually used (Bylund et al., 2003). The Mentor Graphics' Concurrent Engineering Assessment tool (Rosenthal et al., 1996) is more or less satisfying the previously set criteria but is too specific for electronic production. The Simultaneous Engineering Benchmarking Tool (Langethem et al., 1994) offers a PC-based statistical approach but needs advanced knowledgebase of the technology. Quite close for our task seems the Readiness Assessment for Concurrent Engineering tool (De Graaf, 1996) but it is more focussed on complex projects rather than on whole PD environment.

The most suitable for us seems to be the Concurrent Engineering and Teamwork across Global Industries (CETGI) process carried-out at University of Warwick (Balbotin and Yazdani, 2000). This methodology distinguishes between corporate and project level. Both blocks are evaluated in three analytical dimensions of company's activities: practices, infrastructure and performance. Each dimension has its own elements in both blocks. As the result a radar diagram is compiled for all of the elements in current and desired states. GETGI process consists of 4 successive steps and starts from defining maturity state of the company. During the following steps, the desired state of PD ability is determined, a gap analysis between current and desired states is provided and action plan is developed to reduce the gap.

2. THE COMPANY'S MATURITY ANALYSIS

To understand the background of the research the short overview of the growth of the company during nearly 140 years of its development is given. TMT was founded in 1865 in Narva. Initially the product range included pharmaceutical, distilling, brewery's equipment and similar items. During 1930 the TMT designed and manufactured equipment for oil-shale processing. Throughout 1950-1990 different types of equipment were produced for chemical and oil industries. In 1963 the production of an Air Cooled Heat Exchanger (further in the text ACHE) was started. From the 1990 it became the main product and approximately from the 2000 it is the only product of the company. Steel casting (sand moulding) has remained second activity but it mainly supports ACHE production and minor part in TMT turnover is steel casting subcontracting.

From the view point of engineering two distinct periods can be observed:

- since the foundation to II World War – main characteristic of this period is very strong engineering team and design of equipment that was innovative for its time.
- post war period – characteristic is that the primary design (ACHE lay-out and heat transfer calculations) and PD has been done in Russian institutes, thus leaving to the TMT only secondary design (strength calculation and drawing) and production.

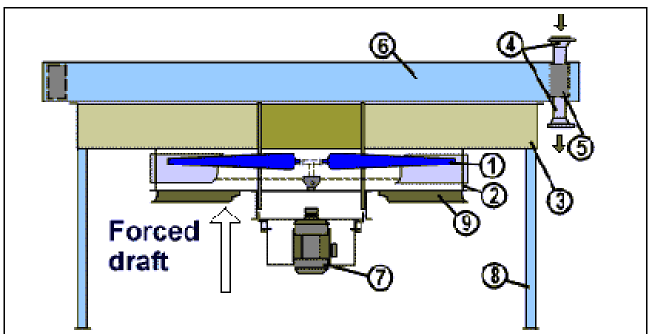
After the reestablishment of the independence of Estonia the sector of the machinery has overcome the most difficult recovering period. Since 2001 the production volume has steadily increased but has not yet reached its peak. On that basis the current state or maturity of the company is defined. In this context the present product development environment and product family are carefully analysed. In order to have a reference point in the past the evaluation period starts from January 2000. Two main reasons for it are that the ownership of the company has completely changed in 1999 and TMT obtained ISO9001:2000 certificate in January 2000. New owners had set up new plans and these are used as goal.

Heat exchangers are widely used in oil, gas, chemical, power, food, air conditioning, refrigerating, car and other industries. Despite the wide range of application there are only a few types of heat exchangers in practical use. Most common of them are:

- shell and tube (S&T);
- air cooled (ACHE);
- plate and frame;
- cooling tower.

In the context of this paper attention will be paid to the ACHE and S&T.

The idea of an ACHE is depicted in the Fig. 1. The fluid enters the tube bundle and flows through it under the pressure. At the same time fan forces the air between the tubes so facilitating cooling. Majority of air coolers have finned tubes in order to extend the heat transfer surface thus decreasing the plot size of the unit. The material of the tube bundle is selected according to the fluid and must have chemical resistance and strength properties to contain pressure. Typically these are carbon steel or stainless steel. The use of titanium is increasing steadily due to excellent chemical and strength properties. The advantage of ACHE is the availability of an air and rather a simple construction.



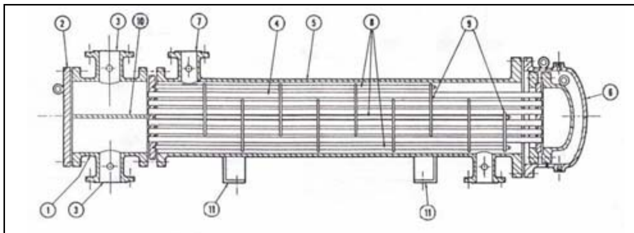
1. Fan
2. Fan ring
3. Plenum
4. Nozzle
5. Header
6. Tube bundle
7. Drive assembly
8. Inlet bell.
9. Column support

Fig. 1. Structural elements of an Air Cooled Heat Exchanger (Hudson Products, 2004)

Typical parameters of an ACHE produced in TMT are:

- maximum pressure in tube (process) side – 320 bar;
- maximum temperature – 300°C;
- unit plot size – 6 x 12m.

Here is appropriate to introduce the perspective for TMT S&T heat exchangers. A simplified scheme of S&T heat exchangers is given in Fig. 2. Two fluids are separated by tube wall and the heat can be exchanged in either direction. If it is used for cooling, then typically in the tube space (in the tubes) is water and in shell space (between the tubes) is fluid that needs to be cooled. In order to increase the efficiency of the S&T, the tube space can have several passes. There are baffles to direct the fluid in shell space. The advantage of the S&T is proven construction and practically no limits to pressure (matter of design) or fluid (matter of material selection).



1. Stationary Head-Channel
2. Channel Cover
3. Stationary Head Nozzle
4. Tubes
5. Shell
6. Shell Cover
7. Shell Nozzle
8. Tie rods and spacers
9. Baffles and Support Plates
10. Pass Partition
11. Support Saddle

Fig. 2. Structural elements of the Shell and Tube Heat Exchanger (TEMA, 1988)

Now is high time to refer to the CETGI process and to proceed on to maturity of PD process of TMT. As the CETGI distinguishes between corporate and project level it is important to determine that corporate level indicates activities performed (or initiated) by management, whereas project level indicates activities performed (or initiated) by departments' heads.

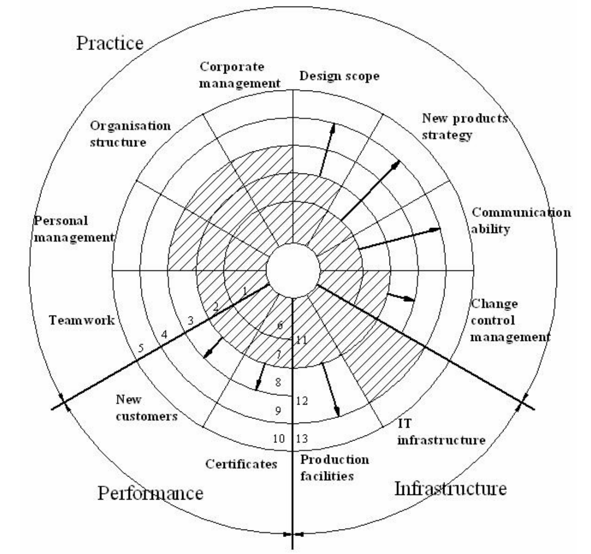
At first, it is necessary to determine key business drivers with possible bottlenecks:

1. *The performance.* For engineering activities there are so far no strict measures. This is the following task after this paper to set measures for design team. Bottleneck here is which measures to choose in order to get the expected result.
2. *The competitive pressure.* In the field of ACHE and S&T the competition is very tough. There are a few hundred suppliers world-wide, beside the fact that the large customers have very high demands for equipment suppliers. The way to international market has already indicated that problem is response time and design scope (TMT is not providing primary design and commissioning).
3. *The environmental pressure.* Medium, because noise and vibration are not considered as dangerous. All the materials can be recycled and discussion about hot dip galvanising as hazardous waste has not yet decreased demand for it. At the moment TMT is using mostly painting.
4. *The communication.* Week, so far. On the one hand management has declared that engineering is a core of future improvement. But on the other hand the production volume increases without alterations in design process, thus postponing the wake up moment. Management plans about

product range and markets do not have full support of engineering team, which leads to misunderstandings and suppresses cooperation.

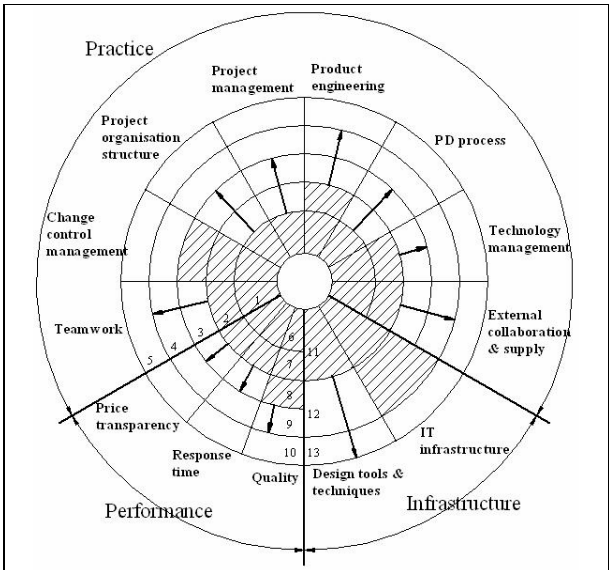
5. *The control.* Week. As mentioned in previous paragraph the true need for design scope alteration is not evident yet. Process flows as it has been done for decades without significant control.

These descriptions were prepared by using TMT documented procedures and informal in-depth interviews with engineers and management.



Hatch is current state, while arrows indicate transition to the desired state.
Stages description: 1 – Ad Hoc, 2 – Repeatable, 3 – Characterised, 4 – Managed, 5 – Optimising, 6 – Inferior, 7 – Average (-), 8 – Average, 9 – Average (+), 10 – Superior, 11 – Basic, 12 – Intermediate, 13 – Advanced.

Fig. 3. Radar diagram of the corporate block



Abbreviations are describet in Fig. 3.

Fig. 4. Radar diagram of the project block

Due to the fact that CETGI method is developed to cover all aspects of PD it can be used as described in the literature, so there is no need to adjust it's components and methodology. But it is necessary to choose the elements in every three dimensions for assessment. The method suggests that every element must be evaluated by questionnaires but due to the time constraint previous questionnaires and prequalification reports were examined. The result is visualized in the radar diagram in Fig. 3 and 4.

The limited space of the paper does not allow to comment all evaluation stages in detail.

As an example the evaluation criteria "design scope" is characterised currently by features:

- so far only secondary design (strength calculation, drawing);
- own design for pneumatic actuators, fans, no sub suppliers used;
- mainly 2D, 3D modelling partially used;
- welding of carbon, low alloy and stainless steels, no titanium.

3. DEFINING THE DESIRED STATE OF THE COMPANY, GAP ANALYSIS AND ACTIVITIES PLANNING

Concerning this part, authors regret that due to hard competition on heat exchangers market some of the future proposals by confidentiality reasons are excluded.

At first, it is necessary to start from product side and to analyse the upgrading possibilities of the present air-cooled heat exchangers product family. Parallel to this the development of a S&T heat exchangers product family must be taken into account. To certain degree the desired state is a speculation and relies on leaders vision, nevertheless it has strong bond to the company.

As the ACHE is quite conservative equipment it is difficult to change it radically. The construction has remained basically the same for ~50 years and inventions are introduced which increase the heat exchange initiating more intensive turbulation of the flow in tubes. So, here the main effort must be on design accuracy, enhancing the product quality and shortening delivery terms. It requires highly qualified engineers, appropriate design tools and suitable production environment. In case of S&T exchangers the situation is basically similar. What makes it attractive for TMT is that the design scope for S&T is quite a similar to ACHE. Furthermore, most customers that are using S&T are using ACHE as well. That means that the production volume of S&T is supposed to be higher in long term run.

Similar to maturity analysis, as an example is used "design scope". List of features in desired state that must be for production of ACHE as well as of S&T, is as follows:

- primary and secondary design according to GOST, ASME, API, including;
    - thermal calculation;
    - strength calculation;
    - steel construction design;
    - modelling of surrounding space;
- sub supplier involvement;
- knowledge of international standards and practices;
- use and technology of welding of new materials, especially titanium;
- commissioning on site.

Before setting up the action plan a gap analysis is necessary to provide between the current and the desired states. Obviously the gap indicated in Fig. 3 and 4 is more complex as missing features and elements strongly depend on each other. In addition to this some of them depend on the customer requirements. The requirements of the current market are becoming more similar to those on the international market as the customers (shareholders) are international. Using the "design scope" one can compare the current and desired state. The features that are missing in the desired state are focussed on primary design, knowledge of international standards and welding of titanium.

Further the action plan is proposed to reduce the previously mentioned gap. Special attention is devoted to the upgrading the product development environment and growth of the core competence. In order to achieve a result it would be reasonable at start-up to concentrate the effort on elements with the largest gap. On the other hand it is useful to remember that the pursuit of ultimate perfection may lead to situation, where nothing is done. Such an edifying pragmatic approach is discussed in detail in (Thoben et al., 2001). So the "design scope" is suitable area of kick-off activities. Detailed plan is depending on basis of real success in following areas:

- commercially available software (thermal calculation);
- certification process (ASME, PED);
- personal knowledge and experience, training.

Road mapping of activities was started by ASME certification process in December 2003. This is necessary as majority of customers see it as prequalification criteria. Decision to manufacture S&T is also made. Formal preparation for design and manufacturing (market investigation, standards, gathering information) is done. Considering the fact that this is new type of production for TMT, it is reasonable to appoint a project manager for S&T with team of 2-3 engineers. In 1-2 years the situation should become stable and the experience from example model is turned to production practice. Software for ACHE primary design must be obtained as soon as possible. When first orders are received it will be too late to run training and alter PD process. There is an idea in the management to create a separate team for international ACHE design.

4. ACKNOWLEDGEMENT

The authors of the present paper would like to thank the management of the AS Tallinna Masinatehas for all-around help and cooperation while gathering data.

5. CONCLUSION

All mentioned activities are necessary for entering into international market, as the situation in current market seems stable. As result of research to the conviction has reached that to keep the 30% Russian market with offering the best price/value ratio for customers of oil and gas processing and chemical industries is a realistic task. If the reshaping of the product development and production environment is fully realised a more aggressive growth and the diversity into new geographical regions are feasible. In order to reach the international market, it is necessary to improve elements, such as: design scope, new product management and external collaboration. As all these activities mainly depend on engineers and their personal abilities and so personal management determines the success. Unfortunately there are some outside matters, which are turbid at the moment. One of these is price of materials after joining the EU.

6. REFERENCES

Badke-Schaub, P.; Stempfle, J. & Wallmeier, S. (2001). Transfer of experience in critical design situations, Proceedings of 13th International Conference on Engineering Design (ICED'01), Design Management – Process and Information Issues, pp. 251-258, ISBN 1 86058 355 5, Glasgow, August 2001, Professional Engineering Publishing, London

Balbotin, A. & Yazdani, B. (2000). The Assessment Tool for Global New Product Development, Proceedings of 3rd International Symposium on Tools and Methods of Competitive Engineering (TMCE), pp. 157-168, ISBN 90 4071983 7, Delft, April 2000, Delft University Press, The Netherlands

Basics of Air Cooled Heat Exchangers, Available from: http://www.hudsonproducts.com/products/finfan/tech.html, Accessed 2004-03-05

Bylund, N.; Grante, C. & Lopez-Mesa, B. (2003). Usability in Industry of Methods from Design Research, Proceedings of 14th International Conference on Engineering Design (ICED'03), pp. 631-632, ISBN 1 904670 00 8, Stockholm, August 2003, Design Society, Linköping, Sweden

De Graaf, R. (1996). RACE: Diagnosing and Improving Product Development Performance, Research Paper, p. 8, Eindhoven University of Technology, The Netherlands

Gershenson, J. K. & Pavnaskar S. J. (2003). Eight Basic Lean Product Development Tools, Proceedings of 14th International Conference on Engineering Design (ICED'03), pp. 85-86, Stockholm, ISBN 1 904670 00 8, Stockholm, August 2003, Design Society, Linköping, Sweden

Ivashkov, M. & van Overveld, K. (2001). An Operational Model for Design Process, Proceedings of 13th International Conference on Engineering Design (ICED'01), Design Management – Process and Information Issues, pp. 139-146, ISBN 1 86058 355 5, Glasgow, August 2001, Professional Engineering Publishing, London

Landeghem , R. V. & De Wilde H. (1994). A Simultaneous Engineering Benchmarking Tool, Proceedings of the International Conference on Concurrent Engineering and Electronic Design Automation (CEEDA'94), pp. 111-116

Perez, R. L.; Ogliari, A.; Back, N. & Martins, R. A. (2003). Development of a Model for Assessment of Design Process Performance, Proceedings of 14th International Conference on Engineering Design (ICED'03), pp. 165-166, Stockholm, ISBN 1 904670 00 8, Stockholm, August 2003, Design Society, Linköping, Sweden

Rosenthal, Ch. W. & Vigeland R. (1996). An Update on a Maturity Benchmarking Process for Electronic Design Processes. *Computers in Industry*, Vol. 30, Issue 1, pp. 5-11, ISSN 0166-3615

Standard of the Tubular Exchanger Manufacturers Association (TEMA), 7th Edition, 1988, New York

Thoben K.-D.; Weber, F. & Wunram, M. (2001). Towards Pragmatic Approach for Knowledge Management in Engineering – Theory and Industrial Application, Proceedings of 13th International Conference on Engineering Design (ICED'01), Design Management – Process and Information Issues, pp. 91-98, ISBN 1 86058 355 5, Glasgow, August 2001, Professional Engineering Publisher, London