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A STUDY OF THE DEVELOPMENT PROCESS IN THE NORWEGIAN MANUFACTURING INDUSTRY

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Abstract

A reorganization of the production process from mainly manual to automated manufacturing and assembly is expected in the Norwegian goods producing industry in the future. Two trends that have been identified are: More effective and flexible production in typical goods production in SMEs and secondly, a high number of products/variants and low production volumes.

This paper presents the results of a state-of-the-art a questionnaire survey concerning the development process in the Norwegian goods producing companies. Product and production development, structuring of development work, concepts, and evaluation are all examined. The survey is the beginning of a research project at the Research Council of Norway that will support the development towards flexible production for future automated production in Norwegian goods producing companies. The product development and production development disciplines were focused on as well as the relationship between them. The survey revealed a surprising imbalance between the two development disciplines.

1 Introduction

In the past there has been a tendency towards using more automated equipment in production. The capital investment in new automated production devices is high and this requires that the degree of utilisation is as high as possible. On average the degree of utilization is high for high volume production where only a few different products are produced and few production stops are required for the changeover. The Norwegian goods producing industry produces a large number of products/variants and to a low product volume with frequent stops for changeover of production. This means that Norwegian companies will have to automate their production to be able to compete against other markets. A possibility is to develop and use automated production facilities that are suited to a broad application range and will reduce the production stops for changeover. The Research Council of Norway has started a research

project that should provide methods that will help companies develop flexible production. In order to get a state-of-the-art overview of the development process in Norwegian companies and identify a common starting point for the planed research work, the development process was examined with help of a questionnaire.
The questionnaire focused on the following topics: Company information about its profile, product range, manuals, interests; Development process and its control; Team formation and cooperation; Use of concepts such as product and production concepts; Evaluation during the development process; Structuring of the development work; Help in visualiying and testing during development; and Production and its development.

2 Background

Using the international definition, more than 90% of the Norwegian goods producing industry lies in small and medium-sized range [TBL00]. The type of production in most of these Norwegian companies is characterized by manual or semi-automated production process with a high number of product variants and a small number of produced parts. Often when there is product or variant change a changeover of the production facility is required. Frequent changeovers increase costs that must be covered by the number of produced parts and influence the product price. In order to obtain a better competition situation it is necessary to reduce the changeover cost to zero by means of adequate technology. This enables products to be offered with a lower sales price.
An international wage-level comparison shows that Norway has the highest wage-levels in the world. The great amount of manual work and the high wage-level are competition disadvantages for the Norwegian goods producing economy. Against the competition with low-wage countries, Norway's only chance is using modern technology, delivering high-quality products with a moderate price and further developing production technology.
In future, Norwegian the companies must reduce the amount of manual work and compensate by using modern automated equipment that manufactures faster, at lower cost, and with consistent quality. This means placing the automated devices in the production process at the right place and in the right sequence. The placement of the devices is done during the production development that mostly is based on the product development and its specification. Automated manufacturing differs from manual solutions because automation is limited by constraints, e.g. the handling of parts with a clear geometric shape. These constraints must be identified and adequate solutions for product and production defined or developed during the development process.
Most of the SMEs producing goods in Norway have suitable knowledge in developments for manual assembly but not for automated manufacturing and assembly. Because of strong competition, these companies must keep the risk as low as possible and find the right approach. This requires changes in the development process concerning product and production. The Research Council of Norway would like to support this in companies and provide help to improve the transition from a development style focusing on manual work to developments concerning automated and flexible production.

2.1 Developing the questionnaire

A questionnaire was chosen because this enabled a large amount of companies to be interviewed so that the survey had a more representative character.
The questionnaire focused on the development process and mainly on product and production development. A literature study has been performed related to the topics product and production development and their relationship. In the literature, there is a clear division between product development and production development. Literature about integrated product development and concurrent or simultaneous engineering described the cooperation

between product development and production development. Further literature was reviewed related to the topics of automation, automated production and flexible production.
A list of attributes for the characterization of the development process was worked out based on the paper study and the objectives of the research project. In iteration steps questions related to the attributes were formulated, reformulated until the final form was decided. To test the questionnaire colleagues were asked to fill out the questionnaire and final improvements were based on their feedback.

2.2 Structure of the questionnaire

The main objective of the questionnaire is to get an overview of the current situation of the development process in the Norwegian goods producing industry.
The layout of the questionnaire is a one column text with total of five pages. The first page informs the reader about the intention of the examination, how to mark the close-end questions and answer the open questions, and where the competed questionnaire should be sent back to. On pages two to five the questions are grouped by topics. The first part contains questions concerning the company, product range and variety, working fields, and the interests of the company. The second part focuses on the development process; topics include development process classification, development team, concepts, process control, concurrent engineering, and simulation. In the last part, the topics are related to production, such as production development, type of production and automation. Totally the questionnaire consists of 35 questions in the style of open or close-end questions. The close-ended questions have two variants; the first is only a 'Yes' or 'No' and the second offers different questions related to the response alternatives but not structured in scales, e.g. very good to very bad, and it is allowed to mark multiple. Open questions are used to get the individual response of the company in fields where it is estimated that a broad individuality exists.

2.3 Distribution and response of the questionnaire

The Federation of Norwegian Manufacturing Industries (TBL) distributed the questionnaire to a selected number of companies in their federation. The questionnaire was sent by e-mail as a Word attachment. Totally 70 questionnaires were sent out to companies in different sectors but non-responding companies were not reminded to respond.
A total of 18 companies sent back the completed questionnaire, among them a company that does not suit the questionnaire because of too little activity and experience in product development. That means that 17 companies (24%) completed the questionnaire representing the following manufacturing sectors: automotive supplier, metal working, agricultural machinery, electronic, furniture, sanitary engineering, ships equipment, plastics, and locking systems.

3 Discussion

The questionnaire was sent to 70 Norwegian companies and as 17 companies sent back a completed questionnaire this is equivalent to a response rate of 24% and is the basis for the following discussion.

3.1 Company information about: profile, product range, manuals, interests

The companies divided their profile according to the three alternatives: subcontractor, subcontractor partner, and complete value chain company. Two companies noted that they are 'subcontractors' and have no product development activities. A further two companies are 'subcontractor partners' and develop and produce products related to customer requirements. All the other companies are 'complete value chain company' which develop, produce and sell the products. Totally fifteen companies (88%) are engaged with product and production

development and join the development process with different aspects and with different duration.

All the companies produce several products with different variants and the production volume per product varies from a few hundred to three million parts. A number of production facility changeovers are necessary depending on the production volume and the number of products/variants in the production.

For the certification and auditing it is normally required to have manuals that describe the company's means of performing the work. Only 70% of the companies have a quality manual. After the strong ISO 9000-series and later ISO 14000-series certification movement in the past it is astonishing that still 30% have no quality manual. This is difficult to understand based on the fact that the Norwegian manufacturing industry is an export industry and deals mainly with companies in Europe and North America. Only 41% of the companies have a design or development manual, further only 18% have a production manual and 18% a management manual. Manuals are not only documents for showing key persons how the organization is planed, it is a help that takes away the routine organizational part of work and allows the company to concentrate more on the necessary work activities to achieve the desired goal of work.

Concerning future activities, the interests of a company influence the companies' work directly. Seven interests were formulated according to the product, production, the development, skills, competition, and customers to describe the interests of the company. The interests with the highest acceptance are:

- Follow the customers requirements (long-term contracts)
- Improve current products and production by production concepts
- Setting trends, standards for product of production related to the market and competitors

These company interests reflect a typical forward-looking company. The first point indicates that the companies prefer to have long-term contracts with customers for better planning reliability. But in the future it is not enough to formulate the interests it is more necessary to adapt the structure for the realization of the interests/long-term goals.

3.2 Development process and its control

Most (88%) of the companies have structured the product development process in phases. Compared to the results of company-profile question, all companies with product development have structured the process. Although all the companies produce, only 69% structure the production development process. Over 30% have not structured the production development process and these companies do not purchase services for production development. Based on the questionnaire results it is not possible to identify how these companies organize their production development work. It seems that these companies are not aware of the potential in the production development. Potential must be seen in the following relationship: the production process and facility will be developed only once and affects the costs only one time, whereas production itself is used every time a part is manufactured/assembled and development mistakes must be corrected for every produced part, e.g. additional rework. Development mistakes could be avoided by using a structured development process that improves the development work, the results and helps indirectly to save the cost of reworking.

The companies were asked to specify their structuring of the product-development process, and 82% of the companies answered. The response-results of the open question differ between the term 'Gate Model' and a description of a six-phase development process. A more detailed analysis shows that most of the product-development processes start with the idea level and end with the beginning of Zero-serial production or start of production. The process

in-between can be stated as a sequence of pre-project and detailed-development phase. In a few models the phases are supported by the examination of aspects from marketing & sales, and production. The authors were surprised that not one model that is described is similar to another and concluded that each company has developed its specific model. Further the authors were surprised that the product-development related question is answered with phases about tool-development, product launch, and end of production. This obviously means that different understandings of the term 'product-development' exists, one that is related to the total development including production development, marketing and sales, and the other that is focusing specifically on the product itself.
In 65% of the companies product development work is assisted by purchasing services from specialists concerning design, FEM calculations, etc., whereas only 12% of the companies purchase services related to industrial issues (such as plant development).
The results show an imbalance in disfavour of production development. All questions concerning product development have higher response-rates compared to production development. Also the lower responses according to the purchase of industrial issues support the assumption.
Structuring of the development process is a good organizational help but it does not guarantee that the results will be automatically good. Therefore 88% of the companies control the development process by integrated checkpoints that check the status according to the defined goal. A clear trend can be identified in that 82% of the companies use checkpoints to check the earlier predefined specification according to the current development status. Based on the check-result the project can go on, must be reworked, or is stopped. 12% of the companies use these checkpoints only to compare the current status with the scheduled project timetable. Most of the companies have recognised and mentioned that it is important to control the development process related to the results and not only to the scheduled project timetable.

3.3 Team formation and cooperation

The development process is a complex structure and therefore it is important to know who is involved and what the intended task is. It is normal in smaller companies that each department must take care of several specialized work fields. 15 different names were used to describe for the involved departments and 11 of these names can be grouped according to development, marketing & sales, and production. 73% of the companies mentioned indirectly that the three fields are involved in the development process and this is in agreement with development process literature.
For the development process the companies try to mix the staff if it is possible. This prevents that routines and other mattes will be done without the necessary awareness. In 65% of the companies the development staff joins the whole development project as active or supporting members whereas in 35% of the companies development staff are only working in selected periods.
About half of the companies use computer technology with approved software to have data available in all phases of the development process. This enables the use of previous acquired results without making a new data input for further applications.

3.4 Use of concepts: product and production concept

Concept development, concept phase, and conceptual design are all well-established terms in the development process. The terms concept or conceptual are used for phases there it is necessary to describe ideas without going too much into details; it is more the principle that is formulated to get a better understanding or sketch the overview.
The companies were how they characterized a 'concept'. Only 53% answered the question and the following enumeration cites some the different descriptions:

- New product concept is new main functional principles of the product
- A nearly finished worked-out product
- Describe customers needs/ chances/ advantage, describe the consequence for the own production
- Basic product concept that is able to adapt to various customer specifications
- A defined function reached by a defined method
- Idea, first sketches
- In the concept phase different solutions (principles) /concepts are discussed. For the company the concept represents the basic design of a product
- Superior functionality, superior design/components

The answers show that the companies have different opinions about a concept – from an idea or first sketch to a nearly finished worked-out product. Terms that are often used for the description are 'principle' or 'function'. Other descriptions are more related to a product, its requirements or the consequences for production. This means that the companies use their described concept in their specified development process. Compared to the literature, no common definition is defined and the term concept is used on different levels, e.g. Sänger-Raumgleiter (space orbital glider) as abstract example and as concrete the existing fuel cell concept car NECAR from DaimlerChrysler.

The authors were interested to see how the companies define a concept that is related to a product. 65% of the companies use the term 'product-concept' and the following cites some of the definitions:

- Main functions, principles
- A nearly finished worked-out product
- Range of application
- Functions, user-friendliness, design, safety, etc.
- Customer value, markets advantage
- Finished tested and qualified product, ready for product adaptation/modification
- Function, geometry, manufacturing process
- Function, manner of operation, first shapes
- Function, shape, geometry and international rules/regulations
- Collection of various products into a larger concept

As with 'concept' the companies have different descriptions for a 'product concept' but identical with the 'concept' the 'product-concept' is used to describe very early stages and stages there the product is nearly finished. Based on the answers it can be identified that a product concept includes some characteristics like principle, function, shape, geometry and customer-related aspects.

Finally the companies were asked about their definition of a 'production concept'. 47% of the companies responded to the question and the following list shows the some results:

- A detailed suggestion for production line
- Basis principles for manufacturing
- Line production or batch, manual or automatically handling
- Solutions for component manufacturing and assembly, on superior level
- Often defines the main processes in the production flow

For a 'production concept' the companies have divergent suggestions about the characteristics. It can be identified that the 'production concept' should be a description about the future production process and facility but the level of detail is not clearly defined. A tendency towards a less detailed level that gives more an overview is obvious.

As companies have different opinions about 'what is a concept', which was expected by the authors is not surprising. However, nearly half of the companies can not give a description

about their version of 'concept'. The question about the product concept was more practically relevant than the theoretical definition of 'concept', and this could be the reason why 65% were able to answer that question. The response results concerning 'production concept', was surprisingly only 47% were able to answer this question. As section 3.2 shows the development process is focused mainly on the product and secondary on production. Based on this observation it is logical that fewer companies can define a production concept as a product concept.
As mentioned, a concept describes a more preliminary status. It seems that the companies do not use the possibility to discuss these preliminary situations to get an overview, to identify obstacles or more adequate solutions. It seems that half of the companies start direct into a kind of detailed development work without discussing possible solutions.

3.5 Evaluation during the development process

82% of the companies have implemented an evaluation process in their development process. The evaluation tools and methods used can be divided into the following five categories: development, market, finance, production, and material. According to the category 'development' the following tools and methods were specified: Failure Mode and Effect Analysis (FMEA), Quality for Deployment or Quality Function Deployment (QFD), Design for Manufacturing and Assembly (DFMA), value analysis, and product requirements. Some of these tools are developed for use at later development steps, where more detailed knowledge about shape, geometry, material, and manufacturing method are available. In the category 'market' the used evaluation tools give information about market requirements, the existing market segments, benchmarking, and the forecasted sales price. The analysis of market-related aspects helps the companies to hold the focus on future customer requirements and keeps track of their competitors. For the evaluation related to the 'finance' category, Investment-analysis and Return on Investment (ROI) analysis are used. Companies that mention these methods for evaluation use only these and no additional tools concerning the four other categories. According to category 'production', companies evaluate the friendliness of the production or the production process. Evaluations concerning production take place together with tools for the other mentioned categories. In the category 'material' the selected material is evaluated with the loading, manufacturing abilities and manufacturing costs. On top some companies developed their own evaluation tools to find the best solution.
Based on the individual characteristics of the sectors the used evaluation tools used must cover the development process and the further the production process as whole. Therefore the right mixture and categories must be individually detected. But it can be concluded that most of the companies evaluate fewer categories especially production because all companies produce.
Involved in the evaluation process are different people in different functions in the company. The companies' state that 81% of the development team members are involved in the evaluation process otherwise the top management or manager with specific practical working fields is involved. The objective for the evaluation in the companies is to find the best holistic solution for that company. Therefore over 90% of the companies involve different disciplines in the evaluation process, e.g. quality, sales, marketing, development, economics, and production.

3.6 Structuring of the development work

The questionnaire would like to obtain the working structure between the product and production development department and provide two alternatives for the working structure: sequential and simultaneous development. (The questionnaire makes no differentiation between simultaneous and concurrent development or integrated product development.)

Today 41% of the companies are using the sequential development approach where first the product is developed and based on that the corresponding production development proceeds. None of these companies intend to implement simultaneous development under development in the future. Further, 18% of the companies have not completely implemented simultaneous development but they would like that most of the work is parallel during the development process to avoid additionally iteration steps and reduce the development time. Further 41% have already implemented simultaneous development structure and worked out a detailed plan of procedures, where it is defined which departments are involved and should contact and the point of time.
Most of the companies have recognized that it is important that the product and production departments get in contact early in the development process. Some companies try to have this contact from the first moment of development work, but some try to get in contact in early phases after preparatory work is done by the product development. Some companies mentioned that in their structure is defined so that a very early start of cooperation is desired but in reality it took time to come into contact – that often is evaluated as too late. It is very positive that some companies have recognized that it is important to work parallel as early as possible to improve the development process.

3.7 Help for visualizing and testing during development

Today all the companies use prototyping during development. 12% of the companies use prototyping only to evaluate form and geometry and the remaining 88% use prototyping for the evaluation of function, technology, form, and geometry. It seems that the advantage of prototypes for companies is that the physical object that can be tested.
29% of the companies do not use simulation for the development process. Simulation is mainly used to avoid additionally iteration steps (47%), with respect to product and production (29%), only with respect to the product (29%), and to identify contact problems or avoid building prototypes (respectively 6%). It is astonishing that no companies use simulation to study production concepts.
82% of the companies believe that the use of simulation software will help to develop better products and production facilities with less iteration steps. As mentioned, the simulation software alone will not improve the development, the right implementation into the development environment is important.

3.8 Production and its development

All companies that completed the questionnaire have a functional production plant. For the production of the desired products it is necessary to develop adequate production facilities. 12.5% of the companies do not have a production development department and use external partners instead. The remainder (87.5%) have their own production development department that develops the production process and facility, but 31% of these companies use additionally external partners for the production development. External partners can be generalists or specialists. The generalists have a broader knowledge of production development, perhaps they have worked in different fields, whereas the specialists focus on a limited field and contribute with their knowledge within the given constraints.
In order to get an overview how the production plant is arranged in the companies, four different types were available. The most common production arrangement was the production line that is available in 82% of the companies. The authors suppose that the high production line proportion is not normally associated with SME's. It seems that some companies have different understanding of the characterisation of a production line. The second most used arrangement is the single machine or functional working group in 71% of the companies. This was closely followed by the cell arrangement with 65% and at the end the group arrangement

with 35%. The high amount of production lines and cells indicate that several working steps are necessary for the manufacturing of the products. As known, the investment in production facility is expensive and especially if lines and cells are used with specialized devices. All companies claim that they are using flexible production systems, in which manufacturing equipment is used for manufacturing/assembly of more than one product.
In the last few years, a strong movement towards automation and the increasing used of automatic devices has been recognized. In all the companies semi-automatic production devices are used, which are characterized by cooperation between operator and machine. Further, at least one operation is automated in 65% of the companies. Automated operations for more than one operation are used in 76% of the companies. Already automated devices are used but mostly these are single elements that are placed at various places in a production process.
Automation helps to increase the accuracy, constancy and speed of work but a pre-requisite is the proper operation of the automated device. Production is not only dependent on its development, the chosen process and its devices, but it is also dependent on the operators' knowledge. 53% of the companies believe that there will be no difference between today's operating knowledge and the future. Based on the fact that development workers must be trained in the use of new methods or technology so operators must be trained for work with new automation devices. It is important to organize the training early so that the devices can be operated as required. A perfect device can improve production if it is operated in the right way.

4 Conclusion and hypothesis

In this survey 88% of the companies are engaged with product and production development. These companies have structured their product development process in phases that seem optimal. Although 88% of the companies have their own production development department, only 69% structure the production development process in phases. Additional there is low acceptance of using and defining concepts related to the product (65%) and the production process or facility (47%). Under half of the companies prefer sequential development work because of the increase in time pressure for the development.
The results of the questionnaire give the impression that during the development process the companies mainly focus on the product and secondary on production. Product and production match each other if both are equally taken into account during the development process. This requires the use of the equivalent prepared development processes and very close cooperation between product and production development. For the improvement of the development work in the companies it is necessary to identify the reasons for the imbalance between the product and production development.
Base on the questionnaire response the following two alternatives for the imbalance were hypothesized:

- Lack of knowledge
  The main focus is on the product development and production development; this means that industrial issues are secondary. Given this priority, only basic knowledge about the latter is available.
- Organization flaw
  The organization flaw concerns the structuring and organization of the development process. Additionally, because of the less important role that was identified for production development the cooperation between product- and production development is not as intensive as it should be for the exchange of information.

5 Further research

In the next step, the hypothesis concerning the imbalance between product- and production development should be studied and clarified by a second questionnaire. Based on the results of this a strategy should be worked out to impart knowledge to the SMEs that both equal importance.

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