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DEVELOPMENT OF PRODUCT DESIGN METHODS USING QUALITY ENGINEERING TECHNIQUES

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DEVELOPMENT OF PRODUCT DESIGN METHODS USING QUALITY ENGINEERING TECHNIQUES

Abstract

The dissertation deals with the methodology of designing work that belongs to a special product group and is suitable to use certain tools that are employed in the designing work according to a particular objective function. This research work is confined to typical design steps for manufacturing of garments and takes the resources (time, tool, man) being in connection with early phase of designing work into consideration. Its main objective is to achieve maximal profit during the introduction phase.

The dissertation gives methods for elaboration of the design processes, for estimation of its costs and for its optimization considering the possible risks.

It summarizes the logics and *techniques of risk calculations* and introduces their developments in this work.

Applicability of this design methodology is demonstrated with an example of designing of a certain textile product in factory practice. The thesis integrates the quality engineering techniques into the design process and evaluates the applicability of these techniques through examination of some actual design projects.

DEVELOPMENT OF PRODUCT DESIGN METHODS USING QUALITY ENGINEERING TECHNIQUES

1. FORMULATION OF THE SCIENTIFIC PROBLEM

Methodology of product design, feature and process optimization is very different in various industry sectors, market and production environments. Objective of the present thesis is to develop design methodology from various aspects for a specific part of the light industry sector, for the textile industry.

In the textile industry product and manufacturing (technology) design can not be sharply separated. Design usually handles the aspects of product properties and the possibility of fabrication together. The disadvantage of this is that optimization of properties comes only rarely about, it is characteristic that methodology of design is based on trials and making sample pieces.

Background of the problem can be formulated as follows:

– The level of systematism of realization of design process is lower than desirable. Under framework of regulated steps there is unnecessary large room for uncritical adaptation of proved practice, for the technologist's intuition, for memories of sometimes proved but not really optimal practices.

– Interested parties in the whole supply chain, aspects of environment protection and disposal do not play important role in the methodology of design.

– Market and innovation aspects are usually subjects of momentary interests.

– Conscious and far-sighted innovation and analysis of returns of investments linked to the innovation fall into the background, however this would be very important nowadays when the importance of this industry sector has changed radically.

– Most companies have quality engineering system certified according to MSZ EN ISO 9001:2001. This circumstance offers solution to the standardized requirements of design process but conscious process development offers further important possibilities.

Quality standards (methods and processes having fixed series of steps) can help very much the adaptation of a new regulation system. In addition to these various collections of means and product design methods are developing continuously.

It is necessary to raise the question: how the "best practice" described in standards can turn to technical, aesthetical and economic result in a practice-oriented market environment.

2. OBJECTIVE OF THE RESEARCH WORK

Comprehensive objective of this work is to create methodology for design work that belongs to a special product group and that meets the requirements of quality engineering systems. Partly, it searches for economic optimum of risk bearing formulated exactly according to the system of requirements, it offers, on the other hand, adaptable, process-centric method for attainment of the goal.

The methodology for design work can be realized in various circles of producers and service providers, but the present thesis concentrates on the production processes of garments made from textiles. This work deals with products that represent low risk level from aspect of using, change quickly concerning successfulness (e. g. fashion goods) and can be made profitable in this market environment only by using specific strategies.

Objectives of this thesis are as follows:

1. To elaborate a **flexible general design model** that assures the systematic design process during design of the garment. This model supplies a possible series of steps and is suitable to choose the proper mean from the numerous ones being available for the process in question in order to achieve the objective to be reached.

Our goal is to make the same model applicable for developing of both less and more demanding products, by changing the number and profoundness of the design steps.

2. The main objective of the thesis is to offer logical way of thinking as well as methodology of decision-making for "slim" design methods for *products that are less risky, require quick market entry and are expressly "idea-products".*

The thesis wants to elaborate a design method that is able to take the resources (time, tool, manpower) into consideration being at disposal already in the early period of design and offers the achievement of maximal profit in phase of market entry by deliberation the real risks. It searches for **practical method** for economic optimization of market entry, **taking the requirements of parties concerned into consideration**. For this objective

- the adaptable *risk calculation* logics and *techniques* will be considered and *developed*,
- a routine background-calculation method will be elaborated that can be adapted to the *quality engineering means* of the design process model to calculate their *resource-requirement*. Using this method, the preliminary costs of development, matching to the objectives, can be quickly and simply calculated.

3. *Testing of applicability of the design method* in the development work of a textile product, a fabric which is electrically conductive and has protective effect against electromagnetic radiation; however that is not considered as material of really work protective garments.

4. Objective of this thesis is *to integrate quality engineering techniques into the design process* and to evaluate quality engineering techniques and the applicability of these techniques through examination of some design projects.

Requirements for the model are as follows:

- it must be suitable to realize a regulated, technically and economically effective design process;
- the **supply chain management (SCM) attitude** has to prevail among aspects of product development comparing to the traditional supply chain (which contains only purchasing and the connecting processes performed by the supplier), i. e. all requirements of the supply chain elements must be already taken into consideration at the beginning of the product developing work;
- effectiveness of the design process must be assured by the quality management means that must co-ordinate to the development steps;
- optimization of cost effectiveness of the design process, creation of a design methodology that assures maximal profit during the introduction period of the product;

- integration of risk analysis techniques into the design process in order to achieve save market and technical design results;
- in order to improve the applicability of the model, it has to be a self-learning system using the data of formerly completed designs (it should store, process and analyse the results of previous experiments in self-learning system);
- it should be able to be used within the project compass of design methodology.

3. RESEARCH METHODS AND RESULTS

Aim of the research work is development of the methodology, thus, it uses analysing, exploration means. The thesis explores the features of design processes and models, utilizing the scientific literature on theory of design. It summarizes and evaluates the quality engineering techniques and means applicable in the design process.

Typically, it uses a research methodology the features of which are in this thesis as follows:

- generalizing of practical experiences but, at the same time, analysis of logical co-operation and interaction of elements;
- utilization of methodology of opinion poll by questionnaire and of its evaluation;
- integration of methodology, attitude and knowledge of various professional fields;
- from point of view of scientific tending, it is characterized by attitude to organization, economy and quality engineering;
- analytical evaluation of linking and interaction of methodologies and the economic consequences of effects;
- process-focusing approach, taking the proved practice of quality engineering methods into consideration;
- the developed method uses estimations, and, because of the features of quality engineering, subjective scales for analysis generally used on this specific field.

Algorithm of the research work:

1. Formulation of the problems and marking out of the objectives of research.
2. Definition of the target field, assessment of its state by making interviews and by utilizing of the system-building practice of quality engineering, as well as methods and results of research works and expert activity in the textile industry.
3. Survey and analysis of previous results, formulating of hypotheses.
4. Elaboration of developments by synthesis of various professions (standard requirements in quality engineering, application of conditionality of regulation system, supply chain management attitude, project management attitude, utilization of quality management means). The result is: creation of the general design model.
5. Attaching quality engineering means to the process elements, determination of applicability and costs of using of means (by utilization of quantitative experiences and cost factors of quality engineering means used in previously performed product design works).
6. Determination of design strategies applicable in the textile industry, elaboration of cost models for the various design strategies.

7. Elaboration of risk calculating methodologies linking to the elements of the design model, evaluation of risk of omission of certain means.
8. Verification of the hypotheses on basis of the results of design actions effectuated in the practice.

4. NEW RESULTS OF THE RESEARCH WORK

To lay the foundation for the results of the research work appraisal was made about the methodology of design by questionnaires and interviews. Five medium size companies were drawn into this examination in which the design process, its organization, the applied means and methods were evaluated and that how these companies the aspects of economic efficiency take into consideration. The results of this appraisal are as follows:

Steps of design work follow each other in logical sequence. Among these steps the main design functions could be found: evaluation of the market situation, elaboration of the design concept and process, manufacture of the sample piece, getting up of the documentation, tests of the samples and their approval.

There are, however, some missing elements:

- design is considered as project process but well-ordered project plans are made only in case of processes linking to tenders;
- the costs of developments are roughly estimated but calculation of returns is missing or made only very seldom;
- estimation of risks appearing in design, processing and on the market is made only instinctively.

Chapter 2 of this thesis deals in details with the assessment and comparison of some typical product design and innovation models according to the literature on theory of design.

Hypothesis to Thesis No. 1

The examined design models can be used as foundation of a design model applicable in the textile industry. Speciality of the textile industry is that more and more products have to be offered to the market that serve special applications (technical, protective, etc.), require long lifespan and represent high technical risk level. An other typical group of products is the group of fashion articles that represent low technical risk level but are sensitive to profitability in time of market entry.

In case of design tasks when the design process and market entry has to be carried out on basis of non-average conditions (like fashion goods that are sensitive to the time of stepping-in) the design process has to meet some contradictory aspects. In these cases usual design processes can lead to results that differ from the ideal output. (See comparison of models in Chapter 2.)

Thesis No. 1

Using the elements of examined process-orientated product designs and innovations it is possible to create an original methodological standard that is applicable to design a design process which uses an objective function taking the specific environment of the textile industry into consideration. When planning the process of product design the update collection of means is considered as basis for high level design work, taking their positive and negative effects on the loss into consideration. On this basis an ideal series of steps for

the design process can be created (which can be considered as optimal according to the multicomponent evaluation system).

Hypothesis to Thesis No. 2

It is possible to elaborate a general design model which is able to take the specialities of products of the light industry into consideration and can be used flexibly in the textile industry, assuring the well-ordered, organized work in this design process when used for design of a textile good.

The same model is applicable also for design of fashion goods and goods created by sudden inspiration with reduction of design steps and by choosing means which are less demanding but adapt themselves better to the market environment. In this case this model helps the producer to appear with its product very quickly on the market.

In this work a design process model was elaborated being suitable to treat the complete design process and all processes being in connection with and exerting effect to the design process. This model takes the technical, economic and quality aspects into consideration, from emerging of the idea up to the market entry. Both the phases of marketing and production and the phase of market entry are parts of the design chain.

The design process contains each step being necessary for the design practice in case of a textile product (or of any product made by the light industry in general), including control processes, approval, communication with the customers as well as documentation. This series of design steps can be adapted to the actual market and economic objectives of the company with conscious elimination of certain elements, on basis of risk estimation (see Chapter 5 of the thesis).

Thesis No. 2

A general design process model was elaborated for products made by the light industry (the textile industry), taking the specialities and production processes of these industries into consideration, that makes the design process as a whole designable and traceable. This design model contains the series of steps of systematic design, approval and decision making; it integrates means and risk calculation methods into the design process. The process model establishes the chance to achieve the previously defined objective in case of a certain product design by using variations of development methods.

The elaborated design model is based on attaching of recommended quality engineering, organizing or technical means, techniques to the steps of design process. To each design step belongs means that support the output objective – these are presented in a separate methodology mine.

Statements formulated in Theses No. 1 and 2 are supported by the thesis with elaboration of a design model created especially to the light industry. Most products of the light industry are fashion goods for which time of market entry is precondition for booking an extra profit. Thus, it is paying to think over the time and mean consume of design process. This model consists of a series of systematic steps from which the proper means and methods can be chosen before starting the design process that can be used to estimate the costs. The means to be used depend on the objective of the design process and on the market strategy of the company.

Hypothesis of Thesis No. 3

It can be elaborated a cost calculation model that is adaptable to the practical circumstances and is suitable to determine the total cost balance of the design and launching process with taking the risks and interactions into consideration when some resources, being for certain elements at disposal, are omitted or taken into account only on limited level.

The thesis presents a basis for preparation of the decision concerning the design strategy before starting the design process.

It outlines a dynamic methodology which enables market entry as soon as possible, i. e. to minimize the design project period for very new but short life-cycle products (fashion goods). The calculation methodology concentrates on the critical period of life cycle, i. e. on the period of market entry. It provides a calculation, estimation method to achieve maximal profit, that, as a whole, enables to plan and to trace the design process and its total cost balance. The model works further on much the same way during further periods of the life cycle of the product (however they are less important in case of the products in question).

The total result is derived from the incomes cumulated as function of time (the total quantity of sold pieces in a certain period multiplied by the profit on one piece), reduced by the total costs of innovation and that of the faults:

$$E = \int_0^T [Q(t) \cdot P(t) - H(t) - I(t)]dt \quad \text{[Forints]} \qquad \text{(T.1)}$$

Here

E(t) – total result [Forints]

Q(t) - quantity of sold pieces (estimated demand) as function of time [pieces/unit of time]

P(t) – profit (calculated on one piece or specific cover) [Forints/piece]

H(t) – costs of faults as function of time [Forints/unit of time]

I(t) – costs of innovation as function of time [Forints/unit of time]

According to this method, innovation costs can be determined in advance on basis of the plan for demand on means. Succession course of innovation and fault costs can be defined by estimated data or mathematical functions. The initial total result can be estimated by preliminary summarizing of the functions, providing basis for the decision making on the design strategy to be used (see Chapter 6.3).

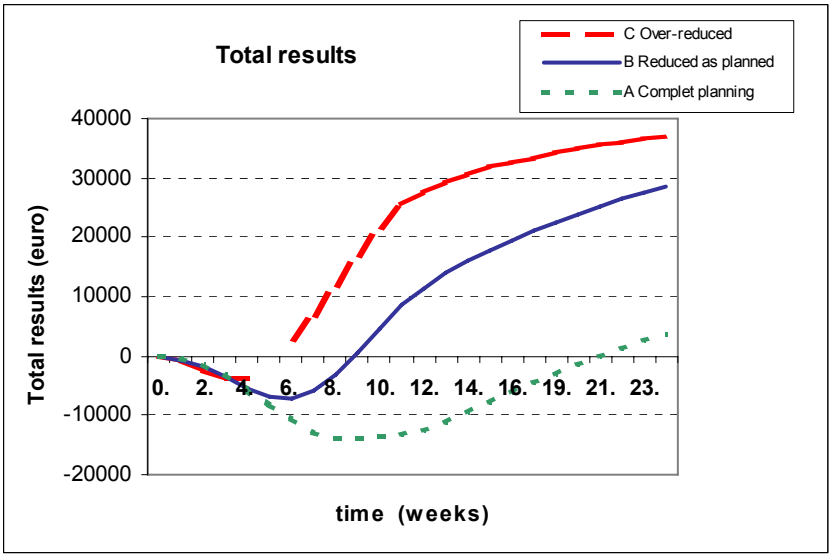

Fig. 1. Total result that can be achieved in the period of market entry as function of various design strategies

Thesis No. 3

A cost calculation method was elaborated on basis of several functions (estimations) that is suitable to determine the expectable economic results for various design strategies. This model respects the sources being at disposal for the individual elements of the design process, the risks and interactions of cases when certain elements are omitted or used only on reduced level. This calculation model is suitable to be preparatory operation for strategic decisions before performing the design process itself.

Hypothesis to Thesis No 4.

Costs of design as substantial elements of returns linking to the product can be planned in a certain environment. This design process enables to evaluate also the consequences beyond the costs of design operations.

The thesis presents a quick estimation and calculation method how the costs of the development/innovation process can be determined in advance, before starting the design process.

These functions describe the change of costs as function of time or some other parameter. In the phase of planning of the design process any parameter can be chosen and on this basis the cost of using of the given mean can be calculated linking to the certain phase of design.

These parametric cost functions can be adapted to the specific features of the company. The database filled up on basis of previous experiences can be used for further designs and the functional dependences can be used as calculation routines (Chapter 6.5.).

Thesis No. 4

Output successfulness of the design process depends on correct choice of the means used. Calculation of time and costs of means of the design work on basis of estimated data are parts of determination of innovation costs. The process of estimation in the practice is helped by time and cost data collected from previous designs. The variable part of design costs can be calculated using the parametric time and cost functions described in the thesis before starting the design project.

Hypothesis to Thesis No 5.

Risk analysis before design has an influence on the reliability of the design and hereby on the efficiency. It is worth to elaborate some risk analyzing methods containing several new elements that take the aspects of market and feasibility at the same time into consideration and are efficiently usable in the factory practice.

Results of the risk analysis can be used in elaboration of planning of the design project.

There are various risk analysis methods in the thesis elaborated on basis of the author's own idea, like these:

- design risk index,
- risk of performance of product functions,
- risk of omission of some steps from the design process,
- estimation of ability to design.

Practical trial of the methods was done on sample project and it could be established that the proper risk handling method by which the hazards of success can be reduced should be chosen in accordance with the design strategy and with knowledge of the inner resources (Chapter 6.6.).

Thesis No. 5

Integration of risk estimation and risk analysis into the product design process improves significantly the efficiency of product design. Estimation of risks of omission or keeping some elements is effective method to choose the proper means of design which suit the company's objectives. For analysing the risk estimation a solution was worked out that is able to quantify the risk elimination effect of the methods and to identify their contact system.

Hypothesis to Thesis No 6

The elaborated profit calculation model is suitable to calculate the total cost balance of the complete design process.

The model was tried out on a sample project at a Hungarian medium size weaving factory. The target system at the company was to develop a new fabric with shielding effect against electromagnetic radiation that can be used as inlay in a garment and provides enough feeling of safety to the wearer who is ready to pay extra price for being under protection against these harmful effects. To achieve this target the fabric must be significantly effective against electromagnetic radiations. At the same time, however, other sanitary or safety expectations or guarantee do not belong to the task of development.

There are calculations presented in this thesis *for three design strategies*: for the traditional (detailed) strategy, for the objective-concentrated (reduced) and for the over-reduced (accelerated) processes. The reachable cost–profit amounts were calculated in case of all these three strategies.

Steps in the design process, means belonging to certain steps as well as their real costs were weighted in teamwork. The team elaborated the risk analysis for application and for omission of each design mean (technique).

Design of the activities, their costs and times needed were made by identification of the means used and by application of costs depending on parameters which were elaborated in proper cost charts.

The management preferred the "accelerated" method because they trusted in the possibility of implementation of short-term economic results but they set the condition that following the quick market entry further development of the product must be carried on in the background using elements of the detailed design, in order to achieve the best quality parameters (Chapter 7).

The project for development of conductive fabrics was carried on with the "accelerated" method and the product was launched on the market in 4 weeks. Comparing to the preliminary estimation the costs of development work were 15 % higher. The reason of this was that, in addition to the results of a previous market research, searching for specific customers and talks with them cost more and, on the other hand, colour fastness values and change of dimensions in washing were insufficient. The company improved these parameters without going beyond the extra cost level defined in the reduced design phase.

The total profit exceeded the value planned previously by the model. Thanks to the quick launch on the market, the company could book extra profit and, improving the product quality, they could go beyond the profit planned

by the reduced design method. Comparing to the plans, 5 % more fabric was sold and 4 % higher price income could be booked as a whole.

Thesis No. 6

In order to make the standardized design method usable a real sample process was implemented by using the results of the former theses. It was proved that the design phases could be used as optimal model. Profit estimation for the phase of launching on the market establishes the plan of design project. Change of detail levels as optimizing input parameters for searching of extremums of the function E(t), defined by us for the market effectiveness of the product, are usable for design of textile fabrics.

Summarizing the above written facts it can be stated that novelty of this work is the *complexity of the design model.* This model takes into consideration, in addition of pure technical aspects, the strategic aspects of the beginning life period of the product, the possibility of calculation of innovation costs that depend on means, the attachment of quality engineering, cost calculation and organization means to the individual design steps as well as paying attention to the aspects of the whole supply chain in phase of the design process.

An additional result of this work is the use of experiences collected from previous designs (elastic bathing suits, comfortable leisurewear made from circular knitted fabrics). Quality engineering methods used in these previous works can help to estimate the costs of design means.

5. POSSIBILITY OF FURTHER DEVELOPMENT OF THIS RESEARCH WORK

The research work can be further developed in various directions:

1. The Author assigns mathematical functions to the subfunctions of the result model. Application spectrum of these functions can be refined and on basis of practical experiences the process functions can be cleansed, it is possible to make proposals on their sector-specific range, applying data collected in continuous work.

2. The solution of the design problem can be generalized, even taking the objective function set for a specific field into consideration; this enables the adaptation of the method of compromise calculation.

Resources assigned to the design (time, cost) can be optimized by a compromise model the input of which are the time, methods and resources devoted to the design, output parameters are the level of most important quality parameters of the product as well as the result parameters of the design and launching processes.

Fig. 2. Optimization model of design process created on basis of principle of compromise

3. Examination of professional an quality engineering methods and that of their interaction from the aspect of output successfulness and substitutability can influence the economic successfulness of the design.

6. SCIENTIFIC PUBLICATIONS LINKING TO THE SUBJECT OF THE THESIS

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