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ERGODESING AS A METHOD FOR THE DESIGN OF THE QUALITY OF PRODUCTS ON THE BASIS OF BENCHMARKING

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Abstract

Of particular importance are the ergonomic and aesthetic indicators that influence the emotional component of the consumer value of the product. Ergonomic design is an extremely important and complex issue that can only be fully solved with the participation of many professionals - engineers, marketers, designers. Such an integrated approach can provide high ergonomic quality indicators. The main aim of this research was to focus on the ergodesign of the product as a mandatory element of the technical proposal, sketch and technical projects where the quality of goods and conditions of effective operation are largely determined by the completeness of ergonomic requirements.

In the complex assessment of the ergonomic level of quality it is recommended to use a comprehensive method of assessing the level of quality based on the comparison of quality indicators on the given values. The starting point of the procedure for assessing the quality of the product is to determine the range of ergonomic indicators. Practical application of quality level modeling is possible with the use of ergodesign. Benchmarking is an effective tool of ergodesign in the field of quality. The study used the method of qualimetric assessment of quality of work in obtaining the final result. Approaches to the formation of product quality based on labor quality and graphoanalytical methods are used as special forecasting methods for the optimal level of product quality. The technology of qualimetric assessment of the quality of work in obtaining the final result - the technical design of the product in the form of a set of design documentation and a test batch of products. To assess the benefits of the criterion of optimizing the level of product quality in the design process used calculation and graphics methods, in particular, graphics. The method of optimizing the level of quality of the designed product, which can be realized by the method of computer graphics and the method of least squares by regression parameters, is given for determining the quality level optimization at maximum profit.

An effective marketing tool is proposed - internal benchmarking, the targeted application of which allows you to create the greatest value for consumers and provide competitive advantages for the company. The method of product design takes into account the requirements, the compromise between the shape of products and their design in accordance with the requirements of efficient and economical production. The application of the qualimetric method of assessing the quality of work allowed to obtain the value of individual quality of work at the levels of the structural unit. Determining the coefficients of significance of the quality of work by type of work and calculating on their basis the individual coefficients of quality of work of performers was the basis for making management decisions in the field of product quality. The method of qualimetric assessment of the quality of work is the basis for increasing the size of wages for participation in the project and improving the quality of work. Computer technology and graph analysis models are also used in addition to the qualimetric assessment of the quality of work of specialists.

The presented method of qualimetric assessment of quality of work in obtaining the final result is effective for optimizing the level of quality of the designed product, which can be implemented by computer graphics and least squares by regression parameters. The author's approach to assessing the quality of goods on the basis of benchmarking, based on ergodesign should be used in production in modern conditions.

***Key words**: Ergonomic design (ergodesign), Marketing researches, Prognostication, Consumer value of goods, Product quality control.*

1. Introduction

Quality formation is considered at all stages of the product life cycle, but fundamentally new qualities are formed at the design stage. The design of a new product in accordance with the requirements of the unified design documentation system (CCS) includes the stages of negotiation of the statement of work and the technical proposal, which propose possible design options, its feasibility study, as well as the development of the project documentation, in which the volume and time of development of a new product of a given quality level is noted.

A large number of technical and economic tasks in which product quality indicators are used define the basic principles of their classification. Product forecasting and quality control at all stages of the product life cycle uses a classification based on the characteristic characteristics of the product: destination, reliability, technological efficiency, resource economy, ergonomics, aesthetics, and patent law.

The nomenclature of indicators should characterize the characteristics of products that define the qualitative expressiveness of an article as a means of satisfying consumer requirements. The existing methodology incorporates unreasonably in the array of qualimetric indicators such parameters of articles, and does not determine their consumer value. The indicators of technological efficiency, labour intensity, standardization, and transportability determine only the production characteristic of a product. The competitiveness of domestic products can be ensured by a higher level of quality and contains characteristics of indicators that determine the consumer value.

Of particular importance are the ergonomic and aesthetic indicators that influence the emotional component of the consumer value of the product. Ergonomic design is an extremely important and complex issue that can only be fully solved with the participation of many professionals - engineers, marketers, designers. Such an integrated approach can provide high ergonomic quality indicators. In Ukraine also according to the Resolution of the Cabinet of Ministers of Ukraine of July 30, 1996 "On the Design Council" was created the Design Council under the Cabinet of Ministers of Ukraine, which was entrusted with the development and implementation of nationwide design and ergonomics problems [13]. Despite some state-wide measures, ergonomic education in Ukraine is in decline, and ergonomics specialists are very few in number.

The main aim of this research was to focus on the ergodesign of the product as a mandatory element of the technical proposal, sketch and technical projects where the quality of goods and conditions of effective operation are largely determined by the completeness of ergonomic requirements.

2. Materials and Methods

The material for work is industrial cold water meters LK-32HT. The study applied a qualimetric estimation method to the design of cold water meters, as well as an assessment of industrial water meters LK-32HT levels of significance for consumers of quality indicators.

Realizing that the market for water meters is sufficiently saturated, where there is serious competition, the decisive factors in winning the market are the technical level and excellent product quality. In recent years, gas and water meters have become widely manufactured.

3. Results and Discussion

An effective design of a product is possible if the object has a performance-based appearance, which in turn satisfies ergonomic requirements. And since design determines the shape of the object being designed, and ergonomics is its content, it is obvious that they are mutually conditioned and that simultaneous use is necessary.

The term "ergonomic design" was first used in the 70s of the twentieth century, in the process of organizing design at Xerox, when 25 designers and 25 ergonomists created a high-quality competitive product that returned the company to the pinnacle of economic success [1]. Ergodesign is seen as a combination of art, aesthetics, engineering thought and technology, in which technology defines the essence of the product, the rationality of form, the integrity of the composition, the perfection of production, and aesthetics - as art and information expressiveness.

The main meaning and peculiarity of the ergodesign process of a system object is the design not only

of the subject matter, but also of the procedural composition of the system. It is regarded as a technical and procedural complex which has a human centric orientation and connections, the structure of which contains the actual project of the subject system and a description of the procedures of interaction with it [2-3].

Ergodesign and information architecture in a highly competitive digital knowledge economy environment are central to users. For example, in order to define their profile, identifying what they are looking for is an important part of the ergodesign process [4]. Agner Luiz presented the results of the study on the innovative visual interface of Amiga and Mac, and noted that the measurement of ergodesign is in the plane of the 3C model: Context (organizational), Contents (informational), Component (two users). In general, marketing tools are often used to develop and increase the efficiency of e-commerce in the context of digitization [5, 6]. An integral part of the application of ergonomic design in information architecture and mechanisms of promotion of goods on the market is modeling of processes in design [7 - 9]. Ergodesign is widely used in the design of ergonomic workplaces to improve production and ensure the safety of workers. Also authors [10], emphasize the importance of software that can help create jobs with human models.

The complex of requirements in the design of the product envisages carrying out the following types of analysis: ergonomic, aesthetic, conformity with requirements of product safety, including ecological and socio-economic efficiency. The peculiarity of ergodesign is that the subjects of its evaluation are those technical aspects that ensure the functioning and operation of the product. Ergodesign product is an obligatory element of technical offer, sketches and technical projects. The quality of the goods and the conditions for their efficient functioning are largely determined by the completeness of the ergonomic requirements.

Human factors and ergonomics and related fields have the ability and responsibility to broadly serve human needs and goals, which encompasses issues of inclusion, equity, and justice [11, 12]. A prime example of this design is the Scottish Dixon Rifle, whose concept has remained unchanged for more than a hundred years, but is in widespread demand on the international (global) market. The British have always been known for their weapons, but the Dixon system has its own constructive feature. It is a German solution, which Dixon called "Run Action", which smoothly passes into the oval head of the bed. The designer took into account peculiarities of ergonomic evaluation and design approach. He/she organically combined the ergonomic features of a powerful mechanism, placing it in a small box, emotional and aesthetic benefits, a bright design that emphasizes the consumer value and quality of the product. The British Standards Institute, which prepares and publishes standards that define sizes, execution methods, ergonomics, Verification and coding techniques for many designs and processes in many industries.

The British Design Council also promotes better designs and technological innovation. It organizes conferences, seminars, publishes relevant literature, showcases at fairs, and offers advisory services. The Council annually awards the best designers engaged in the production of consumer goods, medical equipment, vehicles and others.

Ergonomics plays an important role in the solution of these problems, and it deals with the theoretical and practical problems of optimizing human activity in modern production. In the 21st century, the attitude towards ergonomics of consumer goods has not changed. Ergonomics of a commodity has become almost synonymous with its competitiveness. However, domestic products that exceeded imported products in terms of technical characteristics often lost to them in design and ergonomics. Thus, it is possible to give an example, when Chinese "disposable" goods to win the fight for Ukrainian buyers is enough only beautiful packaging. The survival of the national industry was therefore a major concern.

In practice, it is recommended to use an integrated quality assessment method based on comparisons of quality indicators against the figures [3, 14, and 15]. In the integrated assessment of the ergonomic level of quality, the following tasks are carried out: the structure of the ergonomic quality indicators is established (defined); qualitative and quantitative indicators are established; weighting factors of individual quality indicators are determined.

Thus, the determination of the nomenclature of ergonomic indicators is the starting point of the product quality assessment procedure. A new product under market conditions must be substantially ahead of its consumer value in time, provided by the presence of fundamentally new ideas, inventions and discoveries. I mean, not just a new product, but a new design paradigm. According to the systems approach, an integer is considered as a set of elements whose interaction leads to the presence of a new integrated quality, which is not characteristic of its parts. The practical application of such modelling is possible with ergodesign.

Among the numerous tools, ergodesign has a special place in benchmarking (benchmarking is a reference

point). Benchmarking methodology is known to be linked to the search for best practices in quality work, development paths and opportunities for improvement. Both the quality level, the cost of the process to the manufacturer and the price to the consumer can be taken into account.

In today's competitive environment, domestic enterprises face the challenge of continuing to function effectively. The stable functioning of enterprises on the market is mainly determined by the quality of goods and services. An important work in this direction is the successful use of marketing management tools. A sharply competitive market requires enterprises to increase their domestic capacity and ensure that they have a high market share. In this regard, internal benchmarking is an effective marketing tool, with targeted application that generates the greatest value for consumers and provides a competitive advantage for the enterprise.

Inner benchmarking is a benchmarking process that is carried out internally and consists of comparing the characteristics of business units. The focus of benchmarking is any information that can be used to improve the quality of products, compare them with the quality of competitors' products, predict changes and make sound management decisions. Deviations in information can be positive and negative. In the first case, there is the profit from the improvement of quality, in the other case the loss that threatens the economic security of the enterprise. The strengths of benchmarking are that it can best meet consumer demand through quality, affordable price, quality goods and services by setting new standards and objectives.

Benchmarking is a systematic way to define, understand and develop the best quality products, services, design, equipment, processes and practices in order to improve the real effectiveness of an organization. Benchmarking improves the quality of products, increases the productivity and efficiency of business processes, and creates innovative ideas that enhance the competitiveness of enterprises. The goal of benchmarking is to increase the efficiency of one's own operations and gain competitive advantage. The subject of benchmarking, noted by scientists, is technology, production processes, production and marketing methods, as well as safety.

Stages of benchmarking in the enterprise are following:
1. Definition of benchmarking object. At this stage, the needs of the enterprise for change and improvement are determined; the efficiency of the enterprise's activity is evaluated; the main operations affecting the enterprise's performance are distinguished and studied, as well as the method of quantitative measurement of the characteristics; is determined how deep the benchmarking must be.
2. Choosing a benchmarking partner. It is necessary to establish the type of benchmarking, in this case internal benchmarking; to search for enterprises that are reference enterprises; to establish contacts with these enterprises; to formulate criteria for which the level of quality of products will be evaluated and analysed.
3. Information retrieval. It is necessary to collect information on products, forecast production costs, future cost and price. The information received should be fully verified.
4. Analysis. The information obtained is classified, systematized, the method of analysis chosen, the degree of achievement of the objective and the factors determining the result.
5. Introduction. There is a need to develop an implementation plan, control procedures, and evaluate and analyse the implementation process to achieve high efficiency (profitability).

The use of skilled marketers is necessary to ensure the momentum of research. Ideally, the study should cover the whole market, but it is clear that not all companies are able to do so for different reasons, so information is collected and processed with a focus on only the most important aspects of the study. In order to achieve the next goal of a performance-oriented enterprise in benchmarking, it is necessary to establish an internal strategy for the development of the enterprise, ensures that it is superior to its competitors and that it has a leading position in the relevant area of business, taking into account its potential. It should be noted that this description of the task is somewhat idealized, as not all enterprises that apply benchmarking within their capabilities can achieve leadership and advantage over competitors.

As a reference point can be the design of the product. This is a problem of linking requirements, a compromise between the shape of products and their design, which meets the requirements of efficient and economical production.

The main manufacturers of water meters in Ukraine today are: OJSC "Electrothermometry" Lutsk, SE "Kharkiv Plant of Electrical Equipment", JV "Cenner Ukraine LTD", Kyiv, JV "Invest Premex", Sumy, JV "Aqua Ukraine", Kyiv, JV "Dicom LTD", Lviv. Europe's leading companies are: Apator Powogaz S.A. - Poland, Elin Wasserwerkstechnik Gesellschaft m.b.H. - Austria, Itron Italia S.p.A. - Italy, and ENBRA spol. s.r.o. - Czech Republic.

Therefore, when making the decision on the release of winged water meters (LC-15 LC-20, LC-25 LC-32, LC-40,

LT50), the enterprise carried out an in-depth analysis of the products offered by Ukrainian producers and leading European firms, their constructive characteristics and recent achievements in this field.

The design of the meters took into account the fact that, in order to ensure stability of metrological characteristics over 12 years of operation, the use of materials with stable parameters is an important condition, from which the components of counters are made. For this purpose, the materials of the leading Western European producers with a high reputation only in the first category are used for the production of elements of the counting mechanism.

The most sensitive from the point of view of presence of aggressive impurities in water are the movable parts of the measuring mechanism. Therefore, stable anti-magnetic steel 36NXTYU is used for the manufacture of the impeller axis. The water meter uses seven agate or corundum poles, which provide for a long period of use objective accounting of the water consumed. In order to prevent water from entering the counting mechanism, and as a consequence of pollution and fogging, the counting mechanism is reliably sealed. Enumerators are compiled from parts of their own production, which are subject to strict quality control.

At the design stage, there is no complete technological documentation or standard material and time input, so the new product may be more labour-intensive and less profitable for business. In our opinion, only economic efficiency and a short payback period contribute to the expansion of production of obsolete goods, since such calculations do not take into account the time of design and production. Therefore, there is a need for an organic combination of value and time measures of product quality.

It is proposed to use special predictive methods for optimum product quality based on known data at this stage. Such methods can be product quality approaches based on labour quality and graphological methods.

In view of this, optimizing the quality level of a product on industrial cold water meters LK-32HT was carried out. The water meter LVK 15-01 of JV "Dikom LTD", Lviv is taken as a prototype. Qualimetric assessment of quality of work is carried out after calculation of indicators of quality of counters. To do this, an array of quality indicators of meters is formed, which are more important in terms of utility for the consumer. According to the assessment of industrial water meters LK-32HT levels of significance for consumers of quality indicators are arranged in the order given in Table 1.

Qualimetric evaluation of the quality of work in obtaining the final result - the technical design of the product in the form of a set of design documents (CD) and a prototype batch of products, is carried out as follows. First of all, groups of quality indicators of products with the status of a pilot lot are defined. Their numerical values, defined in comparison with the foreign analogue of this type, are also indicated. Weights are determined by expert judgement (according to the marketing service of a potential producer). The next step is the identification of the best foreign manufacturer's analogue and the calculation of unit quality indicators (qij) and integrated indicators (qi).

The quality level of the product is determined and can be supplemented by a beam diagram of the quality level of the product designed. Next, it is necessary to establish a qualifier unit measure of the quality of individual work and to provide each of them with an appropriate weighting factor in the overall integral quasi-limetric labour indicator. The qualifier, together with the weighting factor, can serve as a measure of individual pay per final result. On the basis of the establishment of a list of types of work for the design of an article, the weighting factors of each type of work are calculated (Table 2).

Table 1. Cold water meter LC-32XT quality indicators to be designed*

Product quality indicators group name	Comprehensive quality indicator of the analogue of LVK 15-01 (Qj)	Coefficient of weight (m_k)	Comprehensive indicator of the quality of the designed product (Q)
Destination indicators	1.0	0.80	1.12
Indicators of reliability and durability	0.90	0.70	1.8
Indicators are ergonomic	1.0	0.55	1.25
Aesthetic indicators	0.80	0.50	1.55
Indicators of rationality of form	1.0	0.60	0.80
Safety indicators	0.90	0.85	1.10

*Source: Authors' results, based on [16].

Table 2. List of types of work for the calculation of work significance coefficients*

Name	Contribution to group quality indicators						Labor quality ratio by type of work
	1	2	3	4	5	6	
Development of the technical task	1.10	1.12	1.8	0.8	1.25	1.55	1.27
Development of a technical proposal	1.10	1.12	1.8	0.8	1.25	1.55	1.27
Development of ergodesign project	1.1	0	1.8	0.8	1.25	1.55	1.08
Technical project development	1.10	1.12	1.8	0.8	0	1.55	1.06
Development of working documentation	1.1	1.12	0	0.8	1.25	1.55	0.97
Design of details	1.1	1.12	1.8	0.8	0	1.55	1.06
Development of text documentation	1.10	1.12	1.8	0	1.25	1.55	1.14
Development of original technological processes	1.10	1.12	1.8	0	1.25	1.55	1.14
Development of typical technological processes	1.1	1.12	1.8	0	0	1.55	0.93
Production of prototypes	1.1	1.12	0	0.8	1.25	1.55	0.97
Testing of prototypes	1.1	1.12	1.8	0	1.25	0	0.88
Adjustment of design documentation	1.1	1.12	1.8	0.8	1.25	0	1.01
Registration of originals of design documentation	1.1	1.12	1.8	0.8	0	1.55	1.06
Work of the selection committee	1.10	1.12	1.8	0	1.25	0	0.88

Based on the list of performers, the coefficients of significance of the work of each of them are calculated by the formula:

$$P_i = \sum_{j=1}^{m} Q_j \quad (1)$$

Where: *n* - the number of weighting factors of complex quality indicators.

Each of the responsible executors is assigned an individual coefficient of quality of work:

$$P_i = \sum_{i=1}^{m} p_{i/n} \quad (2)$$

The list of performers with the calculation of the coefficients of quality of individual labor to wages is presented in Table 3.

Thus, the advantages of a qualimetric method of assessing the quality of work are:

- The possibility of a reliable assessment of the level of quality of production and of organizing the calculation of the individual quality of work at the level of a structural unit or enterprise as a whole;
- The ability to compare the quality of work and the results of the assessment of heterogeneous production in different economic, social and labour indicators of working conditions;
- The possibility of using computer technologies and grapho-analytical models in addition to the qualimetric evaluation of the quality of the work of specialists proposed by the authors.

The proposed methodological approach is based on a quantified evaluation of the project and weighted average indicators of the quality of individual work carried out. The determination of labour-quality coefficients by type of work and the calculation of individual labour-quality coefficients on the basis of these indices are grounds for the correct decision-making in the area of product quality.

The above-mentioned method of qualimetric evaluation of the quality of work is stimulating, since individual quality coefficients of work are also an incentive to increase the wages for participation in the project and to improve the quality of work. This

Table 3. List of performers with calculation of individual work-to-wage coefficients*

Position, profession	Amount	№ works according to the Table 2	Quality factor individual labor
Chief designer	1	1, 2, 3, 4, 11, 14	1.02
Design engineer	1	1, 2, 3, 4, 12	1.078
Design engineer	1	6, 7, 10, 12	1.045
Design engineer	1	6, 12, 13	1.043
Technological engineer	1	5, 6, 8, 9	1.025
Technological engineer	1	8, 9	1.035
Senior Engineer	1	1, 2, 3, 4, 7, 11, 14	1.083
Engineer for the organization and rationing of labor	1	4, 5, 6, 10, 13	1.024

*Source: Authors' results

approach to the assessment of the quality of work and the consequent calculation of wages is one of the effective methods of stimulating the high-quality work of the performers, which is the basis for the creation of high-quality products of the enterprise.

In our view, the optimal indicator of product quality, which ensures the parity of economic interests of the two main market players - the producer and the consumer - can also be considered as a reference point. It bears the content of the criterion of the social and economic feasibility of the product quality level, is achieved by the developer and operates for as long as there is no progressive leap in the scientific and technical concept or technology of manufacture of the product. The quality level of the product in its design does not yet determine the firm market demand and the stable economic position of the manufacturer. The market situation is complicated by changing market conditions, tax policies, competition and other factors. Thus, the maximum consumption of the manufacturer corresponds to a certain optimum level of quality. Its analytical definition is still unknown. In order to fully evaluate the advantages of the considered criterion of optimization of product quality level in the design process, we turn to the method that is widely used by foreign and domestic entrepreneurs. It also belongs to the group of calculation and graphics, so it needs to be illustrated with graphs.

To optimize the level of quality of the designed product, the method of computer graphics can be used. The procedure for its implementation is as follows:

1. Determining the values of the generalized quality indicator Q_i, corresponding to the introduction of one unit of quality indicators in the designed products, their deposition on the abscissa.
2. Determining the increase in the cost of the manufacturer ΔB_{prod} for the introduction of each unit of quality, their deposition on the y-axis according to the values.
3. Perform a graphical approximation of a number of points obtained by performing paragraph 2, some monotonic curve representing the function $\Delta B_{prod}(Q)$.
4. Determining the change in consumer costs $\Delta B_{сп}$ through the introduction into the product of one of the individual indicators of the quality level, their deposition on the y-axis according to the values Q_i.
5. Perform a graphical approximation of a number of points obtained by performing claim 4, another monotonic curve representing the function $\Delta B_{opt}(Q)$.
6. According to item paragraph 3 and 5 construction of the schedule of function $\sum f(Q)$.
7. Finding the point 0 of intersection of the graphs of the functions $\Delta B_{prod}(Q)$ and $\Delta B_{сп}(Q)$ corresponding to the equality $\hat{A}_{ii} = \hat{A}_{prod}$ and the corresponding point 0 of the value Q_0.
8. Finding the minimum point $\sum^{\Sigma} min$ of the function $\sum = f(Q)$ and its corresponding value Q_{min}.

Let's analyze the situation (Figure 1) on the display screen.

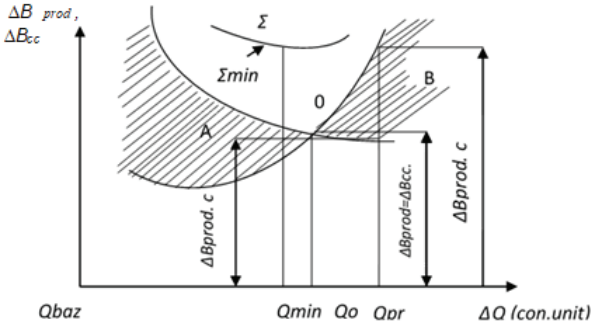

Figure 1. Intermediate stage of quality optimization by computer graphics
($\Delta B_{cc.p.}$ - projected consumer costs; $\Delta B_{prod.c}$ - projected costs of the manufacturer)

If $Q_{min} < Q_0 < Q_{pr}$ (Q_{pr} - a generic quality measure predicted during the design process), then area A (shaded) corresponds to the excess of consumer expenditure over producer expenditure, and area B corresponds to significant producer expenditure. The point 0 is not a point ordinate $\sum^{\Sigma} min$, $Q_0 < Q_{pr}$ which means that the projected quality level of the product is higher than that corresponding to the equality of costs and expenses Q_0 , which in turn exceeds that corresponding to the minimum function $\sum = f(Q)$. Thus, the optimization procedure has proved unsuccessful; the quality level predicted in the project is achieved under conditions that do not take into account their social and economic feasibility. So we need another form of function graphics $\Delta \hat{A}_{prod}(Q)$ with less steepness of growth, that is, with less producer cost for each single generic quality measure. Modifying the form of the function schedule can be achieved in two ways: either by applying cheaper technology for producing parts and assemblies providing quality indicators, or by adopting other unit quality measures that are achieved at a lower cost, while maintaining the projected generic quality indicator. For example, using a 3D printer to produce a prototype.

Take into account the increased costs of the manufacturer in relation to the improvement of quality compared to the base model. The upscale curve of the cost function ΔB (Δq) is shifted to the origin from the increase in the generalized quality indicator Δq is represented by:

$$\Delta B(\Delta g) = Bc.exp(\bar{a}\Delta g - 1) \quad (3)$$

Were: Bc - basic costs of the manufacturer; $\bar{a}$ - regression parameter.

On Figure 2 Function (3) is represented by a theoretical regression line, set for example by the least squares method on a set of empirical data on producer costs.

The increase in market value from the value of Δq is expressed by the following function:

$$\Delta V(\Delta q) = V_{pr}(1 - exp(-в \cdot \Delta q) \quad (4)$$

Where: $V_{pr} = \lim_{\Delta q \to q_{pr}} f(\Delta V)$ - Limit value of market value, corresponds to a limit of technical possibility of increasing the generic quality index Δq_{pr}.

The value of V_{pr} is determined by solving the following system of equations:

$$\left.\begin{aligned} \Delta\bar{V}_1 &= V_{pr}(1 - exp(-в\Delta q_1)) \\ \Delta\bar{V}_2 &= V_{pr}(1 - exp(-в\Delta q_2)) \\ \Delta\bar{V}_3 &= V_{pr}(1 - exp(в \cdot \frac{\Delta q_1 + \Delta q_2}{2})) \end{aligned}\right\}, \quad (5)$$

$$\bar{V}_{pr} = \frac{\Delta\bar{V}_1 \cdot \Delta V_2 - \Delta V_3^2}{\Delta V_1 + \Delta V_2 - 2\Delta V_3} \quad (6)$$

We accept $y = \bar{V}_{pr} - \Delta V$ and linearize:

$$ln\, y = ln\, V_{pr} - в\Delta q \quad (7)$$

The least squares method determines the regression parameter $\hat{a} = \bar{a}$. Thus, all values in the right part of equation (4) are set.

The change in producer profit is represented by the expression:

$$\Delta P(\Delta q) = \Delta V - \Delta B = V_{pr} - \bar{V}_{pr}\, exp(-\bar{в}\Delta q_1) - \bar{B}_\delta\, exp\, \bar{a}\, \Delta q + \bar{B}_\delta \quad (8)$$

The value of Δq_{opt} is now determined:

$$\Delta P'(\Delta q) = \bar{V}_{pr} exp(-\bar{в}\Delta q) + \bar{B}\delta\, exp\, \bar{a}\, \Delta q = 0 \quad (9)$$

$$\Delta q_{opt} = \frac{ln\, \bar{V}_{пр} - ln\, \bar{B}\, \delta}{\bar{a} + \bar{b}} \quad (10)$$

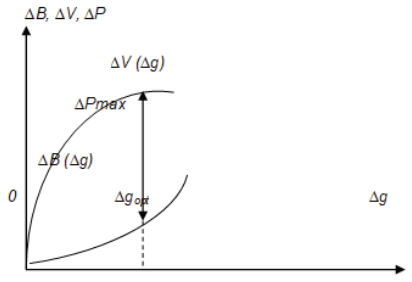

Figure 2. Graphical interpretation of quality level optimization at maximum profit

The curve on the graph shows the function, which reflects the trend of rapid growth of costs of the manufacturer with increase of quality level of the designed product and the function of the predicted price of this product from its quality level $V(Q)$ indicates the fact that the quality level is achieved by means of modernization of the basic sample.

4. Conclusions

- This method of optimizing the quality level of a product, especially of high technical complexity and durability, does not take into account the consumer's costs of operating the product because it is a durable product with high reliability.
- The presented method of qualimetric assessment of quality of work in obtaining the final result is effective for optimizing the level of quality of the designed product, which can be implemented by computer graphics and least squares by regression parameters. The author's approach to assessing the quality of goods on the basis of benchmarking, based on ergodesign should be used in production in modern conditions.

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