3rd Research/Expert Conference with International Participations
„QUALITY" 2003, Zenica, B&H, 13 and 14 November, 2003.

STATISTICAL METHODS IN PRODUCT DESIGNING AND PROCESS PLANNING

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Keywords: quality, product designing, process planning, statistical process control, enterprise

ABSTRACT
The methodics of estimation of construction in aspect of functional quality and of technology of production worked out and used by the team has been presented in the paper. On base of ISO 9000 standards with reference to concurrent engineering method the general course of conduct in estimation of construction and of manufacturing technology at estimation of quality has been discussed. Some probabilistic methods have been used in troubleshooting and forecasting of quality of project of construction and of technology. Aspects of concurrent estimation of quality are necessary from regard on simultaneous designing of construction and of process planning. Stages of conduct at estimation of quality have been presented. For chosen stages one worked out statistical methodics of many criterial estimation with 15 groups of different criterions. Each criterion one supplemented with characterization and manner of realization of this characterizations in manner rozmyty crediting to them descriptive values. For every from criterions one credited with weight – his importance. One marked, that in dependences from kind of construction and her destinations values of weight can surrender to not large changes. One fixed rule of admiting of points for each characteristics. One used two kinds of scale point: 6 gradual and 11 gradual.

1. INTRODUCTION

The condition of success of enterprise in terms of strong competition is stable and systematically perfected quality. New situation creates general introducing of quality management systems based on ISO 9000.
One of most important spheres of activity of enterprise, in considerable degree conditioning his efficiency of activity is manner of solving problems of product construction and of process planning. Technical preparation of production is important factor in development and competitiveness of enterprise on market.
Recommendations from ISO 9000 refer to whole activity of enterprise, also to product designing and to process planning with special regard of quality inspection, connected compactly with technological process. Specifying manners of realization of this inspection and steering her on process control across elaboration, possibly in detail, methodicses of process realization, influences on enlargement of reliability and stabilities of technological process. The aim is such a process planning, so technological process reach minimum cost and labour consumption of production. Regarding of quality inspection demands progressive in leading enterprises integration of process of planning and of manufacturing in accordance

with rules of modern methods of product creation, which became recognized as most important for further quick industrial development [4].

2. PRESENT METHODS OF PRODUCT DESIGNING

Present product designing methods were developed to give parameters of efficiency in technical departments in enterprises, mostly construction and technology. They make possible shortening to minimum of time of product designing and technology planning, equipments of machine tools in suitable tools and instrumentation and other productive helps, and of also oneself manufacturing process, with simultaneous lowering to minimum of costs of this work and with increasing of product quality. One of this methods, lately widely propagated, is concurrent engineering.

Name: „concurrent engineering" (CE) appeared in 1986 r in United States for qualifications of such methods of organization of production planning, in which all the works are almost simultaneous. Each stages of designing, realization, researches of prototype, corrections and then of construction and manufacturing of instrumentation, are executed simultaneously with delivering of information about obtained results. This method, in opposite to classic, treats creation of product as one whole. In former methods every stage creates separate whole, delivered to further elaboration. Process of quality inspection in such system lean on checking of concordance degree of stage with foundations. Statistical method of estimation of quality of technological processes introduced many years ago by authors relating more qualities of work of designer, than of process, was in essence passive method. Present methodics one can define as follows: its integrated product planning and process planning, taking into account all units of cycle of product creation. Integrated product planning should take into account quality of article, cost, prducibility of machining and assembly, reliability, easy service, easy disassembly, reparation etc [2].

In distinction to sequential engineering (SE), where each acts at product planning, executes oneself in turn, and in general without synchronization, frequently with their repetition. In CE base of activity is team solving of problems.

Conccurency of works realization is introduced on stage of product design. From regard on narrow specialization of constructors practical is nowadays also diffuse designing, how as team designing of more complicated products. Utilization of modern informatics technology makes possible concurrent designing through connection of each constructor (whether of constructional studio) with speed, wide communication net. Each constructor has given definite areas and circumstances, in which should be situated team and connections with other teams. These data could change during designing basing on suitable co-ordinations and decisions of leading constructor. Net connections give possibility of immediate view in partial constructions by CAD systems. System of communication assures controlled access of each constructor to system CAD. Large part performs here full integration of product model assuring cohesion and replaceability of data. Such a system will demand however completely other methods of quality inspection of documentation. This should be active inspection, with continuous estimation of work concordance with starting circumstances. The simultaneous estimation of many activities in range product and technology planning should be possible.

Essential for such a method of inspection is computer aid, which makes possible simultaneous investigation of designed and manufactured product. This methodics gives shortening of time of starting of production, which obtains oneself across elimination of executing of physical prototypes on eg analysises of computer designed prototypes and of simulation investigation [6]. This permits on detection of defects of project in early stage of works, and on avoidance of constructional changes during production. Parametrical

modelling makes possible immediate introducing of constructional and technological changes, resulting from e volution of idea of project or from detected during the simulation or of animation inaccuracy or defects.
It permits also on optimization of shape of produst and regard requirements of technology and initial estimation of production costs.

3. PROBABILITY METHODS IN TECHNOLOGY INSPECTION

In this understanding of parallel inspection wider disseminations will demand necessity of utilization of methods of probability and mathematical statistics in solving problems of quality control of process planning of production. Part of events in planning of product and technology comes into being on the ground of deterministic mechanisms. Results of observation and analysis of results of investigations permit to present extremely probable argument, that greater part of events being found in area of designing and process planning has random character [2]. Probabilistic methods assure correct description of this type of events and of processes. Additional factor, underlining meaning and necessity of usage of these methods, is prognostic character of designing and planning.
Statistical methods refer in similar degree to following kinds of activities of system of planning [3, 7]:

1. project, qualifying postulated quality of product in future.
2. diagnostics, qualifying quality of product in presents or in past,
3. prognostics, qualifying quality of product in future,

Domination of events and of random processes causes, that diagnostics, prognostics or projected qualities of product characterizes inhomogeneity and variable uncertainty, independently from this, whether are they controlled variables, whether are not. Aim of usage of probabilistic methods is identifying and explanation of this not homogeneities and uncertainties.
Central category of calculus of probability and mathematical statisticses is notion of probability referred to variable events and random variables.
With this notion binds directly problem of inequivalence and uncertainty in qualifying of random events. Process of designing of construction, how as methods of manufacturing, is connected with taking of decision in area of inequivalence and variable uncertainty [5]. In statistical analysis of random variables measures of central tendency (position) and dispersing (scattering, concentration) are applied. Mostly practical measures of position are arithmetical mean, median and modal value.
As a principle features of quality are random variables, related with inequivalence and with uncertainty of decisions, with related correlational dependences. This permits to favour following situations of project decisions:

1. deterministic, characterized with uniqueness and with certainty of diagnozed, prognozed or postulated states of product quality.
2. random with well-known distributions and values of probability, in which states of product quality can be described by waited values and of standard deviations of well-known distributions of random features.
3. random with unknown distributions and values of probability, in which steps out lack of premises to estimations of probability of states of features and of states of product quality.

These situations are connected with decisions relating to object of designing. To undertaking of decision in circumstances of well-known or unnknown risks serve suitable statistical

decision models and criterions of choice. Postulate of minimization of number of decision situation with unknown level of risk does not wake doubt, at regard of balance of advantage and of losses of costs of such operation. Projecting system has considerable freedom in classifying of product features on deterministic features or random features. Difficulties connected with statistical investigation induce designers to treat considerable numbers of random features as deterministic features. Such tendency could not be accepted even in well-founded situations.
Rules of probabilistic refer not only to object of designing, his internal structures, but also external structures of object of projecting and of diagnostic and prognostic activities. Complexity of so understood project problemses causes, that steps out unrestricted number of assignments, in which reaches it is necessary of profiting from calculus of probability and mathematical statistics. Here become only signalled selected types of project assignments, which refers to rules of probabilistics.
Base of elaboration of project ideas determines marketing in aspect of diagnosis and prognozis of qualitative external structur of product, projected with regard of cycle of his existences. On entrance indispensable is realizing of statistical marketing investigations. Following statistical researches refer to definite characterizations of foreseen areas of exploitation of product. Knowledge of distribution of probability of features of environment of product exploitation is important at projecting his qualities, variety, kinds. Analogous meaning has acquaintance of distributions of probability of features of productive base, foreseen to productions of product [2].
Usage of probabilistics in researches of qualitative external structure of product of designing depends to complex elaborations of statistical characterizations of this structure. So worked out characterization of structure determines the base of realization of project assignments, relating directly to designed product and makes possible estimation of their realization.
Usage of probabilistics with reference to object of projecting relies on marking of definite features of designde products as random variables. It means that distribution of these features are decision variables, conditioned partly through random variables. Designing system for random features qualifies basic characterizations of their distribution - form of distribution, value waited, standard deviation - or probability of each states of features.
In process planning of manufacturing statistical ability to attaining of states of random features in borders of planned tolerances of realization and to maintenance of required homogeneities of qualitative of product batch [6]. Efficiency of technological processes could be measured by size of waited deviations of obtained states of random features in relation to provided states.
Examples of typical probabilistic assignments in product designing are following:

- marking of reliability both parts, how as product, having to warrant definite probability of failure-free working in definite circumstances and in accepted period of time,
- qualifying of tolerance in fittings and chains of dimension and replaceability of product parts,
- making selection of machine tools, process plans, tools and workshop help possible,
- permitting on planning and realization of project-investigative methods, relating to select constructional solutions, prototypes and batches of product.

Indispensable project-assignment is estimation of probability and of sizes of acceptance of designed project on market. Knowledge about stepping out here risks determines principle premise in undertaking of decision about starting of production.
In constructional and technological works different statistical methods are used. Authors of this elaborations limit oneself to analysises of methodics of statistical estimations of project solutions.

4. METHODICS OF STATISTICAL ESTIMATION OF PROJECT SOLUTIONS

Estimation of solutions and choice of method of this estimation is complicated assignment. Its difficult to demarcate clearly constructional, technological and economic properties, being criterions of estimation. Its profitable to estimate each part of construction, and even single parts. In this manner one can easily find weak points of every part already in phase of designing and to eliminate it. After estimation of each part follows estimation summing up entire idea. Applied are point measures of quality.
Creature of point technics relies on qualifying and to taking into account of requirements, which has to realize product at choice of numerical estimation of each criterion [3, 7]. Procedure of conduct consists from following acts:

1. composition of objects of investigation,
2. settlement of criterions of choice,
3. qualification of importance of criterions,
4. delimitation of partial estimations,
5. calculation of points,
6. delimitation of area of investigation.

Criterions of estimation embrace all features essential for elaboration of product construction. Example of such criterions [1] one gave in table 1.
Settled criterions possess different importance - from point of view of choice of object of investigation. Degree of their importances is called weight of criterion (W_k).
Most often uses oneself following sections of weights:

$$0 < W_k \leq 1 \text{ or } 1 \leq W_k \leq 10 \qquad (1)$$

Settlement of partial estimations has in view qualification of degree of participation of each feature of object in criterion of choice. For making execution of estimation possible, one should rated features (accepted as criterions) bring to equal scale (eg vitality one can qualify in hours, supply or demand in units, rentability in one zloty coins etc).
Partial estimation one can pass by means of valuation, through settlement of participation of feature of investigated elaborations of product in suitable criterion.
Estimation of importance of every from hauled objects passes basing on example:

$$W_{OB} = \sum_{i=1}^{n} W_{ki} * a_{ij} \qquad (2)$$

Where:

W_{OB} - importance of object expressed in points,
W_{ki} - weight of criterion qualifying stage of importance,
a_{ij} - estimation of partial state for product „i" and criterion „j"; (i=1, 2,... n, j=1, 2,... n)

As results from practical experiences, utilization eg. in analysis of presented technicses of choice of area of investigations in very large degree enlarges effectivity of passed analysises.

TABLE 1 EXAMPLE - CRITERIONS OF ESTIMATION

No	Criterion	Weight constr.	Variant A			Variant B	Weight techn.*
			constr.	W_k / W_t	techn.*	W_k / W_t	
1	functional	0,056	4,2	0,235 / 0,235	4,2	0,276 / 0,28	0,056
2	eksploational	0,054	3,1	0,167 / 0,178	3,3	0,18 / 0,17	0,054
3	constructional	0,13	3,5	0,455 / 0,35	3,5	0,55 / 0,45	0,10
4	technical	0,05	3,1	0,155 / 0,192	3,2	0,23 / 0,21	0,06
5	technological	0,12	0,2	0,024 / 0,03	0,2	0,3 / 0,33	0,15
6	ergonomical	0,055	3,2	0,176 / 0,084	1,4	0,18 / 0,16	0,06
7	productive	0,12	0,3	0,036 / 0,014	0,1	0,3 / 0,34	0,14
8	economical	0,12	3,2	0,384 / 0,364	3,3	0,36 / 0,35	0,11
9	trade	0,05	0,3	0,175 / 0,105	3,5	0,2 / 0,22	0,03
10	legal	0,045	3,1	0,139 / 0,062	3,1	0,14 / 0,066	0,02
11	aesthetical	0,027	3,3	0,089 / 0,066	3,3	0,1 / 0,12	0,02
12	control&acceptance	0,0055	2,3	0,126 / 0,14	2,0	0,25 / 0,18	0,07
13	organizational	0,052	3,4	0,177 / 0,098	1,4	0,18 / 0,12	0,07
14	safety	0,028	3,3	0,092 / 0,098	3,5	0,2 / 0,21	0,028
15	ecological	0,028	4,5	0,126 / 0,09	4,5	0,126 / 0,09	0,02

* technological weight in constructional documentation

Procedure of conduct consists from following acts:

1. Composition of variants of elaboration surrendered to estimation.
2. Settlement of criterions of estimation.
3. Qualification of importance of each criterion (W_k) as in example (1).
4. Qualification of degree of participation of each feature of hauled variant in criterion of choice - delimitation of partial estimations „aij" for variant „i" and criterion „j"
$$0 \le a_{ij} \le 1 \qquad (3)$$
5. Estimation of importance of every criterion of object of investigation as in example (2).
6. Calculation of cost of relative variant of object of investigation:
$$K_j = \frac{\text{cost of proposed solution } (K_i)}{\text{cost of solution at present step of work } (K_a)} \qquad (4)$$

7. Calculation of coefficient of value of rated variant of process

$$\frac{W_p}{K_j} \tag{5}$$

8. Settlement of order of realization of process variant.

Constructional project limits often wide fan of technological possibility, among other things on account:

- unsuitable, from regard on realized functions, of selection of geometrical features, mechanical features, etc.,
- not taking into account possibilities of existence of random deviations from some nominal constructional features.

Unsuitable selection of features, for example: bad producability of construction or badly chosen material causes height of costs of production resulting from excessive waste material, labour consumption and material consuming of process, wastes of tools, etc.
Absence of definition of borders of admissible states, resulting from their random distribution, is often reason of excess sharpened requirements. Sharper requirements cause always greater costs of production without full compensations in product quality.
Qualitative features one can designate much in dependences from point of view. On example taking under attention only proprieties of physical proprieties of product one can among other things to take into account following features:

- length, width, height, volume, etc.,
- weight, specific weight, etc.,
- mechanical proprieties, durability, resistance on knocks,
- electric proprieties,
- thermal proprieties, thermal expansibility, heat resistance etc.

Dimension of qualitative feature is number credited to feature, having definite meaning, resulting from manner of measurement. In practice of designing general quality is gathering of certain features, sometimes even mutually from oneself dependent on and often measured in different units.
At usage of analysis of features one examines:

- basic features, which mostly protect correct and safe working of product, eg shape, dimension, durability, etc.,
- secondary features, helping influence of basic features on working of product, eg exactitude, heat resistance, plasticity, thermal capacity, etc.,
- useless features, which do not have influence on realized functions how much are not negative features, how as eg. fragility, thermal expansibility (rails, iron - bridges), etc.

Measure of estimation of technical quality of every construction of product from gathering of admissible solutions is so sum of points in definite numerical scale (tabl. 2), the same for all gathering of criterions of estimation. Value of construction from point of view of selected criterion of estimation is assigned to solutions from not satisfying (0 points) to excelent, ideal (5 or 10 points). Scale of estimations from 0 to 5 points is used usually to phase of idea, while 10-point scale to phase of construction and of technology. Often 2-point scale: 1-good, 0-bad, is used, what considerably simplifies estimation.
Example system of criterions of estimation together with aggregate of weights is introduced in table 1. For every investigated product one should work out proper aggregate of criterions of estimation and to assign to them adequate weight.

TABLE 2 RATING OF TECHNICAL QUALITY IN 6 POINT SCALE AND 11 POINT SCALE

6 point scale		11 point scale	
Solution	Number of points	Solution	Number of points
Excelent	5	ideal	10
Very good	4	superb	9
		very good	8
Good	3	good	7
		good with lacks	6
Sufficient	2	satisfactory	5
		sufficient	4
Acceptable	1	acceptable	3
		defective	2
Bad	0	insufficient	1
		bad	0

In table 1 one took into account possibly large number of criterions, to present necessary area of estimation of quality of concrete elaboration, introducing two his variants: variant A - first and variant B - after verification. Constructional and technological weight were examined in constructional elaboration. Essential unit of estimation examined in aspect of quality, is fact of necessity of separate treatments of project of construction and of projects of technology.
To analysises received values one can use methods of statistical reception, how as statistical supervisory charts.

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