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QUALITY MANAGEMENT IN THE PROCESS OF SELECTION OF MATERIAL FOR DUMP TRUCK ELEMENTS

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Abstract: The article presents the problem of quality management in the process of material selection for structural elements of a car dump truck. The study took into account the classical management pyramid and there was used the optimization method (generalized objective function). The center that manages the process of production / assembly of the dump truck should be the level of organization that has the highest degree of processing of required information and making strategic decisions in this respect. The design process of structural elements is carried out primarily in terms of the ability to provide adequate physical and mechanical properties in the process. There is a very strong tendency to reduce the own weight of the semi-trailers by increasing the weight of the load. This is an important criterion from the point of view of the economics of operation of technical facilities of this type. The article presents the results of the application of a generalized objective function in the field of material selection for construction elements of a dump truck. The analysis includes structural elements made of S355 steel and Hardox 400 and 450 fine-grain steel.

Keywords: quality management, material selection, objective function, dump truck

1. INTRODUCTION

Quality management is planning, organizing, motivating and controlling all activities in such a way that in their result is formed a product that satisfies the client's needs. Quality is created not only during the production process, but also "is created" in the pre-production and post-production spheres. Quality management is all management activities that determine quality policy, objectives and responsibilities, as well as their implementation within the quality system through such measures as quality planning, quality control, quality assurance and quality improvement (Skotnicka-Zasadzien et al., 2017). The issues of material selection are included in the pre-production zone of the product, which mainly includes the collection and processing of content-differentiated information, which should enable the product design to meet in possibly highest degree the expectations of those who will use the manufactured product. In our case, a car dump truck, where the important criterion is not only the price but above all the quality under which the user understands reliability during operation and the ratio of net weight to load weight (Zhuravskaya et al., 2016, Ingaldi and Dziuba, 2016). Analyzing the pre-production zone, we can define among other elements:

- information system about product quality,
- examining the quality of new design solutions, new materials and their technologies,
- product competitiveness on the market,
- verification of the quality control system.

With a large number of factors, there is the problem of quality assurance and quality control using various parametric variables (Pacana et al., 2012). One of the solutions is the application of benchmarks and unification of the scale of measurable values by means of the meteorization method. Figure 1 presents the links between processes related to the implementation of the product, taking into account the place of application of the objective function and criterion standards.

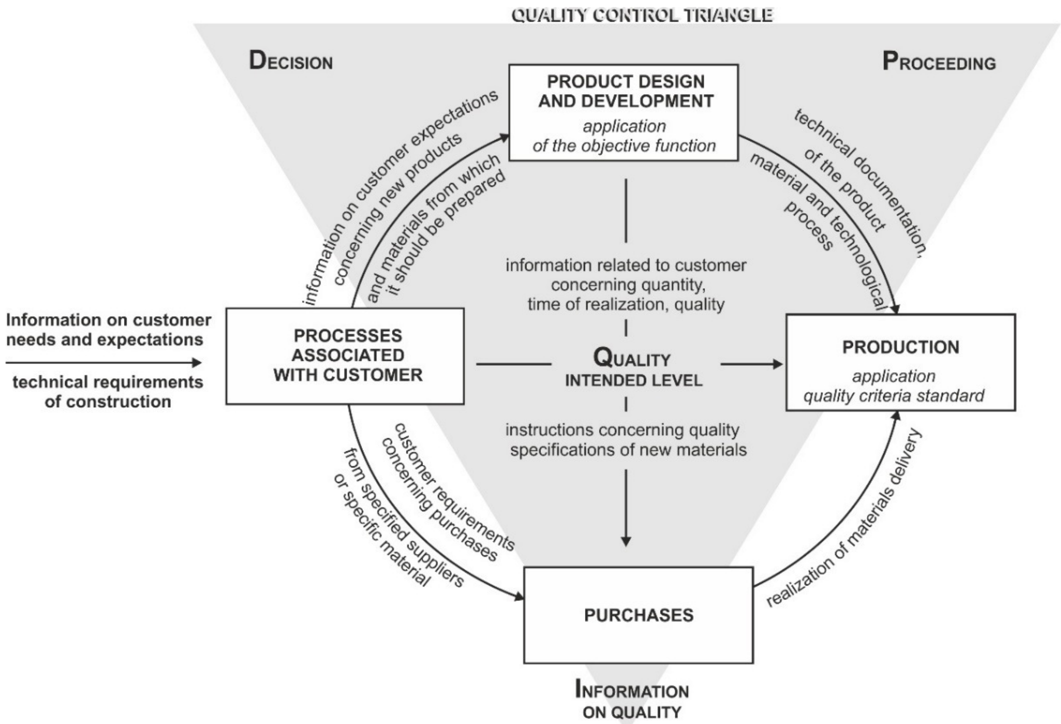

Fig. 1. Relationship between the product realization processes in terms of quality assurance

2. QUALITY MANAGEMENT

Modernity and quality are the basic attributes of all products and one of the key issues is the modern construction and technology of manufactured products (Ulewicz et al., 2013). In the company at the highest level of management there are formulated quality goals, team tasks and plans, as well as the place of providing the infrastructure and resources necessary to implement these developed plans (Salek and Klimecka-Tatar, 2016).

Figure 2 presents a modern management in which quality management should be implemented hierarchically:

- at the operational level by carrying out basic processes to obtain a finished product and by regulating quality,
- at the tactical level through coordination programs, i.e. proper use of information from the customer and suppliers of materials and components to the production process,
- at the strategic level – defined as the management center by developing a strategy and setting goals.

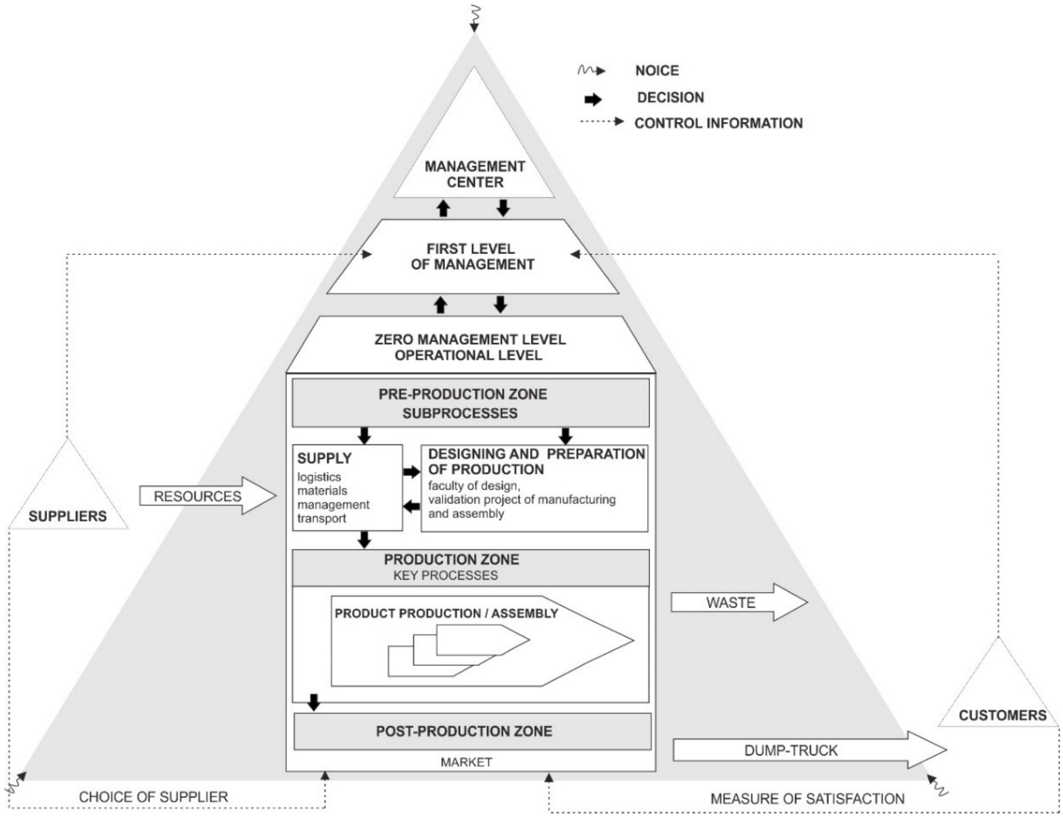

Fig. 2. Pyramid of management

The management center should be the system level with the highest degree of processing of required information and making strategic decisions in this respect (Zasadzień, 2016). The management center is to formulate long-term business plans and manage aggregated sizes of resources. The management model includes:

- processes in the pre-production, production and post-production spheres, that is, the execution zone together with the flow of information, decisions and necessary resources,
- procurement management process, design and preparation of production, design and assembly of car semi-trailers, sales and measurement of customer satisfaction,
- development of the company's strategy, new constructions and improvement of the organization's activities.

3. DETERMINATION OF THE DESTINATION FUNCTION

Analyzing the impact of many factors on the properties of the designed semi trailers (dump trucks), we encounter difficulties in their assessment, because they are generally incomparable and uncountable. Material standards provide recommendations on the values of appropriate sizes specifying the properties of materials or acceptable intervals in which the controlled states of appropriate sizes should be located (Schaeffler, 2017). Interpretation is often used in the interpretation of audit results (Leal, U.A.S. et al., 2015, Bober, 2017, Ulewicz et al., 2014):

- good if the value found is within the range of acceptable variability,
- bad when the value exceeds the admissible volatility band.

Such an evaluation method is insufficient because it does not contain the correlation of technical parameters of the material with technological or operational properties or economic factors. If we want to include these incomparable and uncountable factors in the assessment, we can apply the generalized objective function in this case.

At the beginning values scope of individual input parameters y_1, y_2, ..., y_n should be transformed into dimensionless selection scale d with values within the interval (0÷1). This scale expresses relationship between input parameters values y_1, y_2, ..., y_n and corresponding with them values of d_1, d_2, ..., dn. Value of $d_i = 0$ corresponds to such value of input parameter y_i, which is absolutely unacceptable. Value of $d_i = 1$ corresponds to the best value of input parameter y_i, while further its improvement is impossible or inadvisable. Indirect selection scale values are shown in Table 1.

Table 1
Value range of selection scale

Value marking (quality)	Interval of product scale values
very good	0.80÷1.00
good	0.63÷0.80
sufficient	0.37÷0.63
wrong	0.20÷0.37
very wrong	0.00÷0.20

In most practical optimization cases we have to do with single specification limit of input parameters of $y \le y_{max}$ or $y \ge y_{min}$ type. In such case, conversions of input value y into d are done according to the following exponential relationship:

$$d_i = \exp[-\exp(-z_i)] \quad (1)$$

where:

$$z_i = \mathrm{b}_0 + b_1 \cdot y_i \quad (2)$$

After conversion and bilateral finding the logarithm of (1) equation there is received:

$$z_i = -\ln(ln\frac{1}{d_i} \quad (3)$$

Coefficients b_0 and b_1 can be determined from equations:

$$z_{i1} = \mathrm{b}_0 + b_1 \cdot y_{i1} \quad (4)$$

$$z_{i2} = \mathrm{b}_0 + b_1 \cdot y_{i2} \quad (5)$$

which are determined for two different input values of y_i parameter with given for them appropriate selection values d_i. When solving given system of equations (4) and (5) there are obtained:

$$b_i = \frac{z_{i1} \cdot y_{i2} - z_{i2} \cdot y_{i1}}{y_{i2} - y_{i1}} \quad (6)$$

$$b_0 = \frac{z_{i2} - z_{i1}}{y_{i2} - y_{i1}} \quad (7)$$

In described way there are carried out conversions of value of each input parameter y_i into dimensionless scale d_i. Having determined selection values d_i for all input parameters, there is calculated general quality function D as geometric mean of special partial functions.

$$D = \sqrt[n]{d_1 \cdot d_2 \cdot \dots \cdot d_n} \quad (8)$$

The values of D function belong to the interval 0 ÷ 1.

3. RESULTS AND DISCUSSION

Quality control is a conscious implementation of projects leading to the intended purpose. In the case of quality control at the stage of material selection is to obtain and maintain an economically justified level of product quality, as well as to ensure adequate fatigue properties, which directly affect the safety of the operation of car semi trailers (Ulewicz and Mazur, 2013;

Mazur and Mikova, 2016). In the case of construction elements of dump truck, three types of steel S355, Hardox 400 and Hardox 450 were tested.

To characterize the utility of a given type of steel for structural components criteria were adopted:

- mechanical properties with fatigue properties,
- technological properties,
- economical.

For the components of the adopted criteria the following were included:

- strength in the longitudinal direction and transverse direction,
- toughness,
- wear resistance, hardness (structural elements of tippers),
- fatigue properties,
- ease of machining processes,
- weldability,
- a price per ton.

A special selection function has been defined for each material. For example, for the hardness parameter, a special selection function was defined assuming the following assumptions:

- steel hardness equal to the nominal value was estimated as *d* = 0.80 (lower limit of very good grade),
- steel hardness equal to 80% of nominal strength was rated as *d* = 0.10 (very bad grade). In line with the adopted assumptions for Hardox 450 steel, the hardness ranges from 450-475 HB, we assumed a nominal value of 450, and in this case we obtain:

$$y_1 = 450 \; and \; d_1{=}0.80 \tag{9}$$

$$y_2 = 320 \; and \; d_2{=}0.10 \tag{10}$$

When substituting values d_1 and d_2 to the equation (3), we get:

$$z_1 = 1.499 \tag{11}$$

$$z_2 = -0.834 \tag{12}$$

In next step we determine coefficients b_0 and b_1 by using equations (4 ÷ 7):

$$b_0 = -6.576 \tag{13}$$

$$b_1 = 0.017 \tag{14}$$

Thus, the special selection function for steel with an assumed hardness of 400 HB has the form:

$$d = \exp[-\exp(6.576 - 0.017 \cdot y)] \tag{15}$$

where *y* is the actual hardness of steel.

By analogy to the other steel grades and other criterion components, further detailed functions of the dump truck are obtained.

After performing all the detailed calculations for all the steel grades tested, it was possible to compare the general selection function *D* for individual steel grades as well as their components d_i, representing the values of the detailed selection functions. Table 2 presents the specification of the specific value of the selection function d for the three tested steel grades.

Table 2
List of calculation results of the generalized selection function for Hardox 400,450 and S355 steel

Partial value	Characterizing parameter	Hardox 400	Hardox 450	S355
d_1	Fatigue resistance	0.71	0.85	0.59
d_2	Impact resistance	0.68	0.69	0.55
d_3	Hardness	0.78	0.85	0.53
d_4	Weldability	0.75	0.75	0.82
d_5	Technological properties	0.75	0.74	0.79
d_6	Price sheet	0.75	0.71	0.85
General objective function *D*		**0.74**	**0.80**	**0.69**

Based on the calculations made, it is possible to compare individual grades of steel used for structural components of dump trucks. Based on the results we can conclude that the best parameters has Hardox 450 steel, however, the price as well as problems with machining and welding technology cause that the use of this steel is expensive. However, the fatigue strength and general operational properties of the finished dump truck compensate for higher purchase costs.

3. CONCLUSION

The paper presents the practical use of the generalized objective function as an element ensuring the quality of the selection of the most optimal material for the construction elements of the dump truck. The presented method proved to be an effective solution in the presented example and ensured the most optimal choice of material with regard to quality, technological and operational parameters. The condition of the objective function usage is the knowledge of the edge proprieties (such as endurance, hardness) of a material for a given usage. Every needed propriety can be described by separate detailed function, which enables to take into consideration different factors as one objective function regardless if they are connected with mechanical proprieties or they are the economic factors. The shown way of material choice is used in Wielton company for the production of specialist trailers. The information obtained makes it easier for the management center to make the right decisions in the pre-production as well as the production zone.

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