Advanced morphological approach for systems value engineering

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Abstract. The value engineering is widely used in the design of innovative engineering systems. The paper discusses the combination of morphological approaches for the development of value engineering methods. Increasing the efficiency of searching and analyzing new engineering solutions leads to the increase and refinement of information about the system under consideration. One of the defining criteria is adaptation at all stages of the life cycle. The purpose of the paper is to briefly analyze the application of the advanced morphological approach for detailed analysis. This paper describes the concept and results of using the methodology. As a result, the engineering system is analyzed and suggestions for further improvement of the approach are made. The advanced morphological analysis use in VE can be considered as a continuous process of increasing engineering and economic indicators of synthesized systems and technological processes, organizational structures.

1 Introduction

Since the 60s of the last centuries, functional value engineering (VE) has appeared and started to be actively used in engineering practice [1,2]. The reason for its emergence and development is the fact that when analyzing engineering systems (ES) and technological processes, due to the lack and uncertainty of information, some decisions parts are made intuitively, based on experience, which may be outdated. Quite often there is no effective feedback between designers, technologists and manufacturers. Designers do not fully take into account the peculiarities and cost of using technological processes and processing methods, and usually focus on achieving a high technical level and performance characteristics of synthesized engineering solutions. When developing new technical solutions, there is a lack of new ideas necessary for making rational decisions under conditions of uncertainty and constant increase in the rate of scientific and technological progress. It is very important to consider the processes of engineering and design comprehensively, taking into account their complex relationships [3].

VE is used for system analysis of the research object. The main objective of VE is to reduce costs in the design and creation of the object under study. Cost reduction should be performed without losing the quality of the object for the end user.

VE contains a number of fundamental provisions:
- As a rule, the ES has hidden reserves and, consequently, opportunities for modernization.
- Analysis and cost reduction should be carried out at the design stage.
- It is easier to improve individual subsystems than the ES as a whole.

VE is considered throughout the product life cycle and includes the following main stages: costs, materials, manufacturing, operation and utilization. The following main stages of VE can be considered:
- Selection of the object to be investigated.
- Analysis of information.
- Decomposition and selection of elements of the engineering system.
- Analysis and determination of the functions of the elements of the ES parts.
- Construction of the functional scheme of the ES.
- Development of the structural scheme of the technical solution.
- Convergence.
- Analysis of the obtained solutions and performance evaluation.

The VE use is expedient for solving a wide range of practical engineering problems in various technical and technological fields. With the help of this approach, it is possible to significantly improve the understanding of problems in the design and development of engineering systems. Also, the use will lead to an increase in the efficiency of functioning of systems at various stages of the life cycle.

Fig.1. Stages of the system life cycle.

The use of VE is most appropriate at the first stages of engineering systems development (Fig. 1). At the initial stages of the life cycle the analysis and synthesis of some set of
engineering solutions of the future system is carried out. At this stage, the structure of the synthesized system is determined.

2 Morphological methods

Morphological methods can be used at some stages of VE [4,5]. The methods are based on the creation of a morphological matrix (MM) (Fig. 2). Morphological approaches are successfully used in knowledge-based engineering systems (KBE- Knowledge-Based Engineering) [6, 7]. For example, KBE systems are defined as: "A rule-based expert system contains a knowledge base, inference engine, knowledge retrieval, explanation tools, and user interface" [8, 9].

Fig. 2. MM (left) and one of the solutions (right).

Classical methods of morphological analysis have a number of drawbacks. In particular, it is relatively easy to generate a set of potential ESs, but there remains the problem of selecting from this set a number of really best ones. In order to address this and several other drawbacks, the advanced morphological approach (AMA) has been proposed. AMA is a development of the classical morphological analysis of Fritz Zwicky. The developed method is based on the methods of cluster and system analysis, set theory and expert judgment.

The proposed approach decomposes the system into functional attributes, each of which can be realized by corresponding sets of options that make up a morphological matrix. The options are further obtained by qualitative evaluation of the options by experts and a number of sequential operations are performed [10].

- Generation of some set of solutions (Fig.3).
- Clustering of scanned solutions based on top-down agglomerative grouping (Fig.4).
- Synthesizing the solution space with clusters (Fig.5).
- Analysis of clusters and individual solutions (Fig.6-8).
- Based on the provisions of the methodology, the software Okkam was developed (Fig.9) [11].
Fig. 3. Generation of a solutions set

Fig. 4. Clustering of solutions (389 generated variants (left), 3890 (center) and 38900 generated solutions(right)
Fig. 5. Synthesis of the solution space with clusters (2 and 5 clusters)

Fig. 6. Solutions space with 6 clusters (left) and cluster arrangement (right)

Fig. 7. Solutions space (left) and location of reference solutions (right)
3 Results

When searching for new technical solutions in VE, the issues of optimal and rational use of resources and materials, as well as operational characteristics of ES and technological processes are investigated.

On the basis of the approach additive manufacturing processes are analyzed. At the beginning, a number of typical technological processes are analyzed and a morphological matrix is generated [12-16]. The sequence of attributes is arranged as technological operations are performed (Fig. 10) [17].
Discussion

The use of joint creative efforts and discussions of specialists of different specialties allows to achieve a wide synthesis of a spectrum of valuable ideas in the VE. Creation of working groups consisting of specialists of different specialties is one of the main conditions for successful analysis.

The advanced morphological analysis use in VE can be considered as a continuous process of increasing engineering and economic indicators of synthesized systems and technological processes, organizational structures.

The VE use and morphological approach is expedient for solving a wide range of practical engineering problems in various engineering and technological fields.

References

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