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QUALITY FORMATION IN THE DESIGN PROCESS BASED ON THE EXAMPLE OF A SELECTED MACHINE COMPONENT

Key words

Quality, design process, elastic joint, TRIZ.

Abstract

The article presents the methods used in the analysis of the possibilities of a modernisation of a metal-elastomer joint construction regarding the quality of the element. The solution proposed makes use of TRIZ (also known as TIPS) guidelines, which allow a wide range of factors related to the application and production to be taken into consideration. The analysed joint is used in many branches of industry. Its variety of applications in different conditions and environments necessitates improvement in its construction with regard to quality and reliability. The aim of the analysis is to define the possibilities of modernisation of the joint, taking into account trends in the development of technical systems. The analysis conducted specified areas in which changes in construction may be introduced to improve the joint and its operational and maintenance characteristics.

Introduction

Some of the most important criteria in the process of machine component designing that influence quality include reliability, durability, and safety. These criteria are often the basis on which a technical component is chosen by the user. The designer, constructor, and manufacturer, in compliance with applicable procedures and norms, often adapt the proposed solutions, improving and modernising them to suit their current requirements and conditions of use, taking into account ongoing technological development. During modernisation works, it is important not only to apply selected criteria for choice, but also to apply methods that increase the effectiveness of task completion, and therefore, improve the quality of the object. Modernisation should be carried out comprehensively, and its verification in practice should be conducted at the prototype stage.

In this article, an attempt is made to formulate directions and methods for the modernisation of a selected technical component (a metal-elastomer joint) used in industrial machinery and devices. The proposed solution makes use of the principles and criteria of the Theory of Solving Invention-related Tasks (TRIZ, also known as the Theory of Inventive Problem Solving, TIPS), which allow the analysed component to be modernised, simultaneously improving the quality of the device of which it is a part.

1. Characteristics of the component analysed

The construction of the joint under consideration in this article is based on a patent registered by Hermann Neidhart [5], and it is the most commonly found variation of its construction. The joint consists of two groups of parts, steel profiles of a square cross-section and elastomer working elements (Fig. 1). The larger, external profile plays the part of the casing, and the second, internal body, is the shaft. The shaft is rotated relative to the casing by 45° angle. In the space between the exterior corners of the casing and the sidewalls of the second profile, the working elements are inserted. These are cylinders made of rubber. The diameter of the elastomer elements ensures their deformation during the assembly of the joint. The resultant elastic reaction on the walls of the profiles may then be interpreted as a measure of preload of the joint.

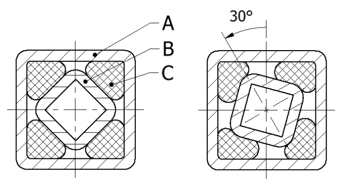

Fig. 1. Construction and principles of operation of a metal-elastomer joint: A – casing, B – shaft, C – elastomer working element

The joint has one degree of freedom, which is the rotation of the shaft with regard to the casing. For this reason, it can only be used as a damper for torsional vibration. The load torque applied to the shaft causes it to rotate around an axis proportionally to the load. The rotation of the shaft results in additional deformation of the elastomer elements, thus increasing the strength of the elastic reaction resisting this motion. Due to the mechanical properties of the rubber, the relation between the angle of rotation and the applied torque has a non-linear character. When taking into consideration the geometry of the joint, it should be assumed that the rotation angle should not exceed approximately 30°, as greater angles may cause the elastomer element to slip out of the casing, damaging the joint.

Metal-elastomer joints are most often used in various types of tension systems of chains, transmission belts, rollers, etc. They are also used in the construction of troughing sets in conveyor belts and in baffle plates.

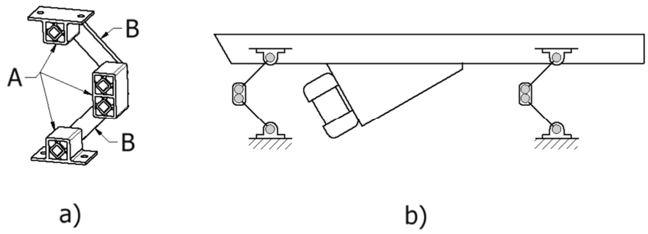

Fig. 2. Jointed shock absorber (a) and an example of its use in a vibrating feeder (b): A – joint, B – connector

Joints may be connected in more complex systems consisting of two or more elements. This means that vibration can also be damped in linear motion, and this significantly expands the possibilities for the application of this type of solution. One example is a four-joint shock absorber (Fig. 2a) used in vibrating machines such as tables, conveyors (Fig. 2b), and screening units [6]. Moreover, double-jointed anti-vibrational supports are used in compressors and generators.

The types of objects analysed, due to the variety of their applications, require individual construction solutions related to the specific nature of their use, the conditions in which they are used, and their production technologies. In the example under consideration, the use of TRIZ should allow one to raise the quality of the object during the process of its construction modernisation.

2. Characteristics of the methods used in searching for an innovative solution

The Theory of Inventive Problem Solving (TRIZ), formulated by Genrich Altshuller, is a theory which assists inventors and designers in the search for new solutions [1, 2, 3, 7], including those in the so-called “technosphere.” It is applied in many countries and in numerous enterprises leading in the development of technology. It provides methods and tools that increase the effectiveness and productivity of the work of inventors. TRIZ proposes laws of the development of technical systems which, when understood, allow the inventor to work effectively in the search for new solutions, based on the assumption that all technical systems develop in accordance with formulated principles [3, 4].

The analysis of opportunities for the modernisation of technical systems (in German, Evolutionspotenzial-Analyse – literally: the Analysis of Evolutionary Potential [4]) is associated with TRIZ. It is one of the more modern methods of an analysis of directions that (in accordance with general principles) the development of a given technical system should follow. The result of the analysis is a set of values which show to what degree particular directions in the modernisation of the studied object have already been exploited at the current stage of development of its construction, and thus simultaneously indicate which modernisation possibilities are still available and justified [4]. The procedure for conducting such an analysis is shown in Figure 3 (cf. [4]).

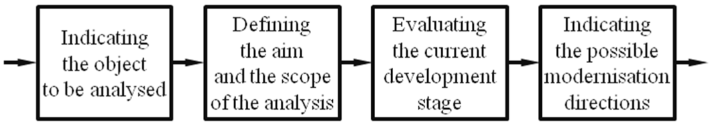

Fig. 3. Procedure for conduct of analysis (cf. [4])

One example of the use of the analysis of opportunities for the modernisation of a technical system is presented in the following chapter of this article.

3. Modernisation of an object aiming to improve its quality using the selected methodology

The management of an analysis of modernisation opportunities involves the comprehensive assessment of the current solution with the application of a set of 25 characteristics typical for the selected method. Each of these criteria (related to the relevant trend of development of technical systems) allows the level of development of the construction solution under consideration to be assessed with regard to the given criterion. The effect of this assessment according to each criterion is a ranking of current levels of development and the application of a numerical indicator w (from 1 to 10), which reflects the level of the development of the construction solution (cf. [4]).

The areas of modernisation and the results of assessment conducted on the joint under consideration (with a justification for the chosen indicator values) are presented below.

Table 1. Assessment of the level of development of a technical system based on individual criteria

Item	Criterion	*w*	Justification
1	Number of elements of the system and the level of their mechanical flexibility	5	Two rigid elements joined by a rubber connector
2	Level of ‘dynamics’ of the substance	1	Uniform solid bodies
3	Level of ‘dynamics’ of the field	1	Invariability of the mechanical field [2] due to control of its parameters
4	Level of coordination of frequencies	6, 7	The system may reduce resonance effects
5	Level of coordination of tasks	5	Frequency of system operation adjusted to frequency of force
6	Nature of the task	1	Uniform reaction to force
7	Level of adaptability of the form	6, 7	Rubber elements adjust to the steel profiles
8	Level of linear development of system geometry	2, 5	System includes primarily elements which can be represented in linear form
9	Level of volume development of system geometry	2, 5	Cubic forms
10	Level of symmetry	10	Arrangement of system elements always symmetrical
11	Level of asymmetry	1	Asymmetry not applicable
12	Level of adaptation of the field to the substance	10	Under the influence of mechanical force, the substance behaves predictably
13	Level of limitation of energy loss	1	Energy subject to dissipation is irretrievably lost
14	Level of segmentation of the object	2, 4	System consists of elements which are separate parts
15	Level of segmentation of the surface	1	Smooth surface
16	Level of porosity (amount of empty space within the given volume)	1	Solid elements
17	Level of controllability of the operation of the system	1	No control system
18	Level of susceptibility to control of the fields used	1	Used fields controlled directly
19	Level of transparency of the system	5	Interior elements are partially visible
20	Level of use of sensors / engagement of human senses	1	Not applicable
21	Level of automations	1	No automation present
22	Level of limitation of human involvement	10	Human involvement not necessary for the normal operation of the system, but necessary for changes in its parameters
23	Level of connectivity with other systems and superior systems	5, 6	Connection of rubber and steel components
24	Level of complexity of the system	1	Single object
25	Level of connectivity and transfer of functions of system elements	1	Each element performs one defined function

The assessment criteria indicated in Table 1 take into account the selected factors that have a vital impact on the modernisation of the construction of the object, which influences its production technology as well as operation and maintenance processes, with regard to technological advancement.

The results of the analysis conducted are presented in the form of a radar graph [4] (Fig. 4).

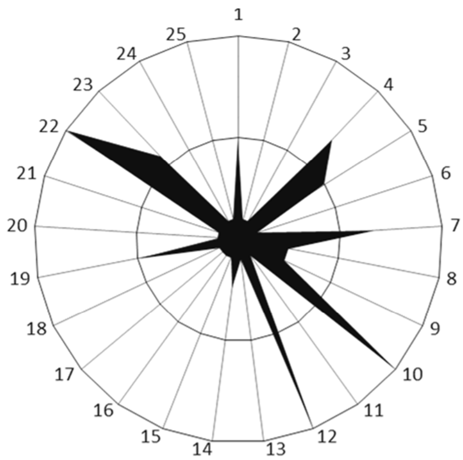

Fig. 4. Results of the analysis. The labels on the graph reflect the order of criteria presented in Table 1

The radially placed elements of the graph that are not covering its surface indicate the directions for development, which represent the greatest opportunities for the modernisation of the analysed construction [4].

Conclusions

The proposed solution allows the improvement of the quality of the analysed component at the design stage, taking into account a series of criteria and limitations related to its application and the resultant conditions of its operation and maintenance.

The areas for the future development of the analysed joint indicate directions in which modernisation should be carried out in order to increase the effectiveness of such technical systems in a given application as well as to suggest its applicability in completely new areas. An example of one such direction is the possibility of controlling the operation of a joint (criterion 17).

Assessment of the object (with regard to the analysis conducted) according to strictly defined criteria is, in and of itself, of a subjective nature; this, however, should not negatively affect the search for new solutions.

Improvement of a technical system by using the proposed method indicates directions and potential decisions that could be taken both by the designer and by the manufacturer. At the same time, it is conducive to the organisation of designing works, particularly regarding invention.

At this stage of the modernisation of construction, the analysis presented in this article has given the basis for several new solutions, which will be subject to patent applications.

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Kształtowanie jakości w procesie projektowania na przykładzie wybranego zespołu maszynowego

Słowa kluczowe

Jakość, proces projektowania, przegub elastyczny, TRIZ.

Streszczenie

W artykule przedstawiono metodykę analizy możliwości modernizacji konstrukcji przegubu metalowo-elastomerowego w aspekcie jakościowym. W proponowanym rozwiązaniu skorzystano z wytycznych TRIZ, które pozwalają na uwzględnienie szerokiego aspektu czynników związanych z przeznaczeniem oraz wytwarzaniem. Analizowany przegub znajduje zastosowanie w wielu gałęziach przemysłu. Różnorodność jego zastosowań dla różnych warunków eksploatacji wymusza konieczność doskonalenia konstrukcji z uwagi na wymaganą jakość i niezawodność. Celem analizy jest określenie

kierunków modernizacji analizowanego przegubu przy uwzględnieniu trendów rozwoju systemów technicznych. Przeprowadzona analiza pozwoliła na sprecyzowanie obszarów, w których wprowadzane mogą być zmiany konstrukcyjne doskonalące obiekt oraz proces jego eksploatacji.