Features of Structural Analysis of the System “Wheel Pair - Top of the Railtrack Structure”

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Abstract. The paper presents evidence of the possibility of changing the mobility of structural elements in mechanical systems when changing the configuration of the force field during of their work, which requires consideration of steelworks as systems with the potential mobility, is greater than zero.

An algorithm for the normalization of relations and the structure of the force field in the system «railroad - projected object».

1. Introduction

The multifaceted nature of the design process implies, already at the very beginning, to represent how fully the object being developed will fulfill its function. The task is even more complicated if a system with a previously unknown functional purpose is designed, that is, when analogues and prototypes are unknown [1,2,3]. It should be added that the mistakes made in the synthesis of the schemes of machines and mechanisms, and in particular the structural ones, cannot be corrected by any technological and structural improvements, and the synthesis of structural schemes is the first step in the design system.

The synthesis of the structural scheme in general, includes three main stages: setting input parameters, determining a set of output parameters, determining the degree of mobility and excess connections [1,2].

2. Results and discussions

However, the synthesis of a rational structural scheme lends itself little to formalization and, in practice, is carried out using a heuristic approach. If at the same time analogues and prototypes are unknown, then the description of the input and output parameters will be reduced to the formulation of the functional purpose. As for the third stage, the difficulties will not lie in how to calculate the number of redundant bonds, but in how to determine the class of kinematic pairs and which of them are required, to replace to obtain a rational structure, i.e. a statically determinable mechanism.

The versatility of the design process implies that, when creating a mechanical system, it is necessary to predict how it will behave in real conditions, since all mechanical systems change during operation and these changes are subject to certain laws [1,2,3], and in particular the principle of functional adaptability. In mechanical systems, functional adaptability is realized, in particular, through the self-installation effect [1], which is associated with deformation of links, selection of gaps,
and friction forces in kinematic pairs. Given these movements, all trusses (foundations, supports) are varieties of mechanisms, i.e. systems with the number of degrees of freedom greater than zero [4-6]. Thus, when considering schemes, it is necessary to take into account that any support and fixed connection are equivalent to kinematic pairs and under certain conditions can acquire mobility.

So, the synthesis of new structural schemes is carried out using heuristic methods based on the experience and intuition of the designer. However, the multivariance of such problems and the difficulties associated with their solution, even with a high level of individual design features, make the search for a rational solution time-consuming and unpredictable. Therefore, any reduction in the variability of solutions can increase the efficiency of design, reducing the complexity and improving the quality of the results. It is not possible to propose universal methods for solving problems of this level, since they are associated with the individual features of the designer and the task itself, but the implementation of such approaches for special cases and their generalization for certain classes of technical systems in search design can be very promising.

For example, in mechanical engineering, functional tasks are not uncommon when one object must constructively adapt to the position and/or unchanged geometric shape of another object [7-11]. The solution to such problems is reduced, first of all, to the formation of such a conjugation between objects in which one object (permanent structure) does not change shape and position, and the other one itself being developed (variable structure) adapts to it while retaining its functional purpose. The governing factor in this case is the reaction in the places formed conjugations. Using this factor, structural elements are introduced that ensure the force field is brought to the desired configuration [12-20].

To obtain practical results, we formulate the main provisions of the procedure for solving functional problems with this approach:

1. The selection of the object position and structure, which should remain constant and determining the configuration of the force field in which it works is a normal field.
2. Determining the influence of the structure of the projected object (variable structure) on the change in the configuration of the force field is an anomalous field.
3. Harmonization of constant and variable structures in order to restore the normal configuration of the force field.

Based on the principle of constant and variable structure, we study the system “wheelset - top of the railtrack structure”, taking into account the intermediate structures attached to it. The top of the railtrack structure in the conventional sense is a support, that is, a fixed connection or truss. Denoting the degree of mobility of the top of the railtrack structure (constant structure) through \( W_1 \), and the mobility of the variable structure taking into account the wheelset through \( W_2 \), we obtain the total mobility \( W \)

\[
W = W_1 + W_2 \tag{1}
\]

After that, we determine the mobility of the top of the railtrack structure in a changing force field, which arises under the influence of a variable structure. The results of the study are summarized in table 1.

So, the top of the railtrack structure consists (Table 1) of rails 1 connected to sleepers 2 through track pads 3 by rail fasteners 4. A vertical force \( F \) arises from the axle load of the rolling stock in contact with the wheel pair. Under the influence of this force, sleepers sag due to uneven shrinkage of the ballast, and after unloading due to the elasticity of the rails, they return to their original position, forming a progressive kinematic pair A with one degree of mobility with sleeper box 5, i.e. a pair of fifth grade (p5).

The mobile link \( n \) in this case is the rails connected to the sleepers, therefore, for mechanisms with lower pairs according to the Chebyshev formula

\[
W = 3n - 2p5, \tag{2}
\]
the mobility of the system is $W = 1$, and the acting force field will be considered normal, and the position of the rails relative to the sleepers will remain constant.

Consider the operation of the top of the railtrack structure in an anomalous force field, for this we apply the transverse moment $M$ to the rail (Table 2) under the influence of which conditions will be violated communication elements of rail fastening 4; with the base of the rail, as a result of which a fifth-class rotational pair B is formed between it and the gasket. The number of movable links in this case is two $n = 2$, (rail and railroad tie), kinematic pairs $p_5 = 2$ and, therefore, $W = 2$. If (table 3) apply such moments to both rails, then $n = 3$, $p_5 = 3$, $W = 3$.

**Table 1.** Scheme of changes in top of the railtrack structure depending on changes in the force field of the system.

| Design scheme along the cross section of the system | $n'$ | $p_5'$ | $W_1$ | Force field |
|----------------------------------------------------|------|--------|-------|-------------|
| 1st case                                           | 1    | 1      | 1     | normal      |
| Calculation formula $W = (3 \sum_{n=1}^{n} n - \sum_{p=1}^{p} p_5) + (3 n - 2 p_5 - p_4)$ |
| 2nd case                                           | 2    | 2      | 2     | abnormal    |
| Calculation formula $W = (3 \sum_{n=2}^{n} n - \sum_{p=2}^{p} p_5) + (3 n - 2 p_5 - p_4)$ |
| 3rd case                                           | 3    | 3      | 3     | abnormal    |
| Calculation formula $W = (3 \sum_{n=3}^{n} n - \sum_{p=3}^{p} p_5) + (3 n - 2 p_5 - p_4)$ |

Since at this stage it is not possible to imagine how it will change, the structure of the designed system, we will use the Chebyshev formula of general form to determine its mobility and then the total
mobility of the top of the railtrack structure and the designed system, taking into account the results obtained, will be, where \( p_i \) is the kinematic pair of the fourth class.

\[
W = W_1 + W_2 = (3\sum_{n=1}^{n-1} n - \sum_{n=1}^{n-1} p_3) + (3n - 2p_3 - p_4)
\]  

formula (3) for each case is given in the table.

3. Conclusions
The following main results are obtained in the article;

- based on theoretical studies, the position on the possibility of a change in mobility in the structural elements of mechanical systems with a change in the configuration of the force field is confirmed;
- justified the need to consider farms as potential systems with mobility above zero;
- presents a method for determining the mobility of elements in the system "top of the railtrack structure - projected object" is being with the "top of the railtrack structure" in kinematic connection.

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