DOI:10.22337/2587-9618-2025-21-4-240-257

ABOUT DEVELOPMENT OF COMPUTATIONAL SCHEMES OF ADDITIONAL DEVICE ON A STRUCTURE, THAT ALLOWS FOR TARGETED CHANGES OF NATURAL FREQUENCIES TO PRESET VALUES

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Abstract: For some elastic systems with a finite number of degrees of freedom of masses, in which the directions of mass movement are parallel, methods have been developed for creating additional constraints, the introduction of each of which specifically increases the value of only one natural frequency to a given value, without changing any of the other natural frequencies and any of the forms of natural vibrations. Methods have also been developed for creating additional kinematic devices, the introduction of each of which specifically reduces the value of only one natural frequency to a given value, without changing any of the other natural frequencies or any of the forms of natural vibrations. If it is necessary to aim at increasing the values of some natural frequencies and reducing the values of some others, then these requirements can be implemented by creating appropriate separate targeted constraints and separate targeted kinematic devices. If the operating conditions of the facility allow, then these individual targeted devices can be independently installed in the source system. The distinctive paper proposes a method for development of integrated (complex, unified) group targeted device that increases some intended natural frequencies to preset values and reduces other intended frequencies to preset values, without changing any of the other natural frequencies and any of the forms of natural vibrations. An algorithm for the creation of such a single targeted group device is proposed. It is shown that the group targeted device created in this way can be used in special cases both as a group targeted kinematic device and as a group targeted constraint. The initial probation (testing) of the algorithm was implemented with the use of the software products "SCAD" and "Lira". Some special cases of development of computational schemes of such devices are considered.

Keywords: natural oscillation frequency, natural oscillation shape, separate aiming kinematic device, coefficients of additional inertial forces, separate aiming coupling, coefficients of additional stiffness, aiming control of the natural oscillation frequency spectrum, group aiming device, building structures, elastic systems

О ФОРМИРОВАНИИ РАСЧЕТНОЙ СХЕМЫ ДОПОЛНИТЕЛЬНОГО УСТРОЙСТВА НА СООРУЖЕНИИ, ПОЗВОЛЯЮЩЕГО ПРИЦЕЛЬНО ИЗМЕНЯТЬ ДО ЗАДАННЫХ ЗНАЧЕНИЙ ЧАСТОТЫ СОБСТВЕННЫХ КОЛЕБАНИЙ

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Аннотация: Для некоторых упругих систем с конечным числом степеней свободы масс, у которых направления движения масс параллельны, разработаны методы создания дополнительных связей, введение каждой из которых прицельно увеличивает величину только одной собственной частоты до заданного значения, не изменяя при этом ни одну из остальных собственных частот и ни одну из форм собственных колебаний. Также разработаны методы создания дополнительных кинематических устройств, введение каждой из которых прицельно уменьшает величину только одной собственной частоты до заданного значения, не изменяя при этом ни одну из остальных собственных частот и ни одну из форм собственных колебаний. Если необходимо прицельно увеличить величины некоторых собственных частот и уменьшить величины некоторых других, то эти требования можно реализовать созданием соответствующих отдельных прицельных связей и отдельных прицельных кинематических устройств. Если условия эксплуатации сооружения позволяют, то эти отдельные прицельные устройства могут автономно устанавливаться в исходной системе. В данной статье предлагается способ формирования комплексного (единого) группового прицельного устройства, которое увеличивает одни намеченные собственные частоты до заданных значений и уменьшает до заданных значений другие намеченные частоты, не изменяя при этом ни одну из остальных собственных частот и ни одну из форм собственных колебаний. Предложен алгоритм формирования такого комплексного единого прицельного группового устройства. Показано, что сформированное таким образом комплексное групповое прицельное устройство в частных случаях может использоваться и как групповое прицельное кинематическое устройство и как групповая прицельная связь. Первичная пробация (тестирование) алгоритма была реализована с использованием программных продуктов “SCAD” и «Лира». Рассмотрены некоторые частные случаи формирования расчётных схем таких устройств.

Ключевые слова: частота собственных колебаний, форма собственных колебаний, отдельное прицельное кинематическое устройство, коэффициенты дополнительных инерционных сил, отдельная прицельная связь, коэффициенты дополнительных жесткостей, прицельное регулирование спектра частот собственных колебаний, групповое прицельное устройство, строительные конструкции, упругие системы

1. INTRODUCTION

In [1-7, 16-22], theoretical approaches were formulated and methods for development of computational schemes for targeted constraints and targeted kinematic devices were proposed for elastic systems with a finite number of degrees of freedom of the masses, in which the directions of mass motion are parallel. Each targeted constraint increases, and each targeted kinematic device decreases, the value of only one natural frequency of oscillations to a specified value, without changing any of the other natural frequencies or any of the natural oscillation modes. If it is necessary to specifically increase the values of some natural frequencies and decrease the values of others, then these requirements can be achieved by creating appropriate individual targeted constraints and individual targeted kinematic devices and autonomously placing them on the original system. In [8], a method for development of computational scheme for a single group targeted constraint based on individual targeted constraints is considered, which increases all the intended frequencies to specified values.

The distinctive paper is devote to continuation of research works, presented in papers [1-8, 16-22]. It is devoted to method for development of integrated (complex, unified) group targeted device that increases some intended natural frequencies to specified values and decreases other intended frequencies to specified values, without changing any of the remaining natural frequencies or any of the natural oscillation modes. In specific cases, the integrated group targeted device created in this manner can be used both as a group kinematic targeted device and as a group targeted constraint.

2. ALGORITHM FOR CREATION OF COMPUTATIONAL SCHEME OF A GROUP TARGETED CONSTRAINT

The following algorithm for creation of computational scheme for a group targeted constraint is used:

1) In accordance with the considering particular case individual targeted devices (individual targeted constraints, individual targeted kinematic devices) are formed, each of which changes only one of the intended natural frequencies to a given value, while all actions are performed [2], in which the lengths of all the main posts will be of the same sign.

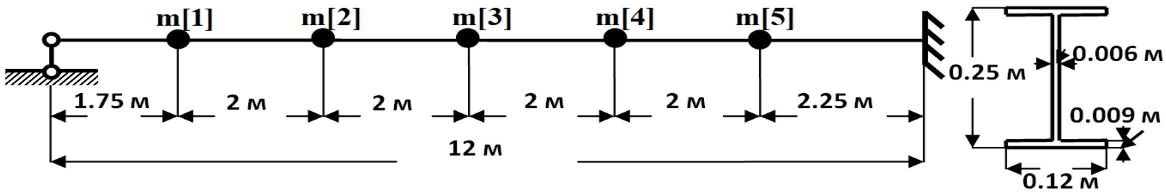

Figure 1. Considering structure (numerical example)

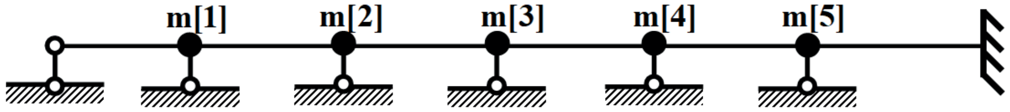

Figure 2. The basic system of the displacement method (numerical example)

2) All individual targeted devices are placed in the nodes of the structure;
3) In areas where several posts are combined, only one is left.
4) Hinges are introduced at the intersections of the rods.

When implementing the first step of the algorithm, the frequency spectrum of the natural oscillations of the original system with n degrees of freedom is considered,

$$\omega[1],\ \omega[2],\ ...,\ \omega[q],\ ..,\ \omega[q+j],\ \omega[q+(j+1)],\ ...,\ \omega[n].$$

It is necessary to specifically free the frequency interval $\omega[q]$, .., $\omega[q+j]$ from j frequencies, reducing some of them to values smaller than $\omega[q]$ and increasing the remaining frequencies from this interval to values greater than $\omega[q+j]$.

3. NUMERICAL EXAMPLE OF IMPLEMENTING OF ALGORITHM OF CREATION OF COMPUTATIONAL SCHEME OF GROUP TARGETED KINEMATIC DEVICE

Let us demonstrate the implementation of the algorithm described in the previous paragraph using the example of a system with five degrees of freedom from [2]. The beam section is a composite I-beam (Figure 1). The modulus of elasticity of the system material is $E = 206000\,\text{MPa}$. The mass values are equal to

$$m[1] = m[5] = 400\,\text{kg};$$
$$m[2] = m[4] = 800\,\text{kg};\ m[3] = 1200\,\text{kg}.$$

The frequencies and modes of the natural oscillations of the original system are determined by the displacement method, in which the unknowns are the displacements in the direction of mass motion. The basic system of the displacement method is shown in Figure 2.

The coefficients of the displacement method equations and the values of the nodal masses form matrices

$$A = \|a[i,\ k]\|;\quad M = \|m[i]\|. \tag{1}$$

The roots of the equation

$$\left|A - \omega^2 M\right| = 0 \tag{2}$$

define the frequency spectrum of the system's natural oscillations. The frequencies and modes of natural oscillations of the original system are presented in Table 1.

In order to form individual targeted kinematic devices, it is necessary to determine the forces that should appear in the device's posts [1-8, 16-22]

$$R_0[i,\ j] = m[i]v[i,\ j], \tag{3}$$

where i, j are the numbers of the components of the j-th mode of natural oscillations, respectively.

Table 1. Frequencies and modes of natural oscillations of the original system

Number k	Natural vibration modes					$m[k]$
	for frequency 14.07953	for frequency 53.0752	for frequency 109.5337	for frequency 195.0757	for frequency 226.8870	
0	0.0000	0.0000	0.0000	0.0000	0.0000	0
1	-0.315087	-0.502865	-0.594382	-0.73793	-0.369613	400
2	-0.565080	-0.520103	-0.174580	0.370387	-0.264938	800
3	-0.606213	0.103822	0.432120	-0.086169	0.212601	1200
4	-0.432097	0.574986	-0.359747	-0.137055	-0.383591	800
5	-0.164932	0.367738	-0.547801	0.540420	0.775147	400
6	0.0000	0.0000	0.0000	0.0000	0.0000	0

Table 2. Values of $R_0[i,\ k]$

i	1	2	3	4	5
$R_0[i,\ 1]$	63.04	226.24	364.32	173.28	33.08
$R_0[i,\ 2]$	-101.52	-210	62.88	232.16	74.24

If in the considering example it is required to reduce the value of the first natural oscillation frequency from 14.0715 sec^{-1} to 10 sec^{-1}, and the second natural oscillation frequency from 53.0769 sec^{-1} to 11 sec^{-1}, then

$$R_0[i,\ 1] = m[i]v[i,\ 1]; \quad R_0[i,\ 2] = m[i]v[i,\ 2].$$

The values $R_0[i,\ k]$ are given in Table 2.

In order to construct a computational model for a kinematic targeted device that reduces $\omega[q]$ to $\omega[s]$, a matrix of additional inertial forces is formed:

$$M_0 = M_{m0}M_m; \tag{4}$$

$$M_m = \left\| m_0[i,k] \right\|_{i,k=1}^{n}; \tag{5}$$

$$m_0[i,\ k] = m[i]m[k]v_\omega[i,\ q]v_\omega[k,\ q] \quad \text{or}$$

$$m_0[i,\ k] = R_0[i,\ q]R_0[k,\ q]; \tag{6}$$

$$M_{m0} = \\ = \frac{\sum_{i=1}^{n}\sum_{k=1}^{n}(a[i,\ k]-(\omega[s])^2 m[i,\ k])v_\omega[i,\ q]v_\omega[k,\ q]}{\sum_{i=1}^{n}\sum_{k=1}^{n}(\omega[s])^2 m_0[i,\ k]v_\omega[i,\ q]v_\omega[k,\ q]}. \tag{7}$$

After forming the matrix, the following equation is solved:

$$\left| A - \omega^2 (M + M_{m0}M_m) \right| = 0. \tag{8}$$

The solution results determine the frequency spectrum and natural oscillation modes of the modified system.

For systems in which the directions of mass motion during natural oscillations lie in the same plane, the method of creation of computational model is based on the properties of a rope polygon constructed from the forces $R_0[i,\ k]$. For the initial system considered in the distinctive paper, such an approach is given, for example, in [2]. There we have $R_0[i,\ 1] = m[i]v[i,\ 1]$ and corresponding kinematic targeted device is formed, that reduces the first natural oscillation frequency from 14.0715 sec^{-1} to 10 sec^{-1}.

Table 3. Frequencies and modes of natural oscillations of the modified system

Number k	Natural vibration modes					$m[k]$
	for frequency 10.0095	for frequency 53.0752	for frequency 109.5337	for frequency 195.0757	for frequency 226.8870	
0	0.0000	0.0000	0.0000	0.0000	0.0000	0
1	0.315087	-0.502865	-0.594382	-0.73793	-0.369613	400
2	0.565080	-0.520103	-0.174580	0.370387	-0.264938	800
3	0.606213	0.103822	0.432120	-0.086169	0.212601	1200
4	0.432097	0.574986	-0.359747	-0.137055	-0.383591	800
5	0.164932	0.367738	-0.547801	0.540420	0.775147	400
6	0.0000	0.0000	0.0000	0.0000	0.0000	0

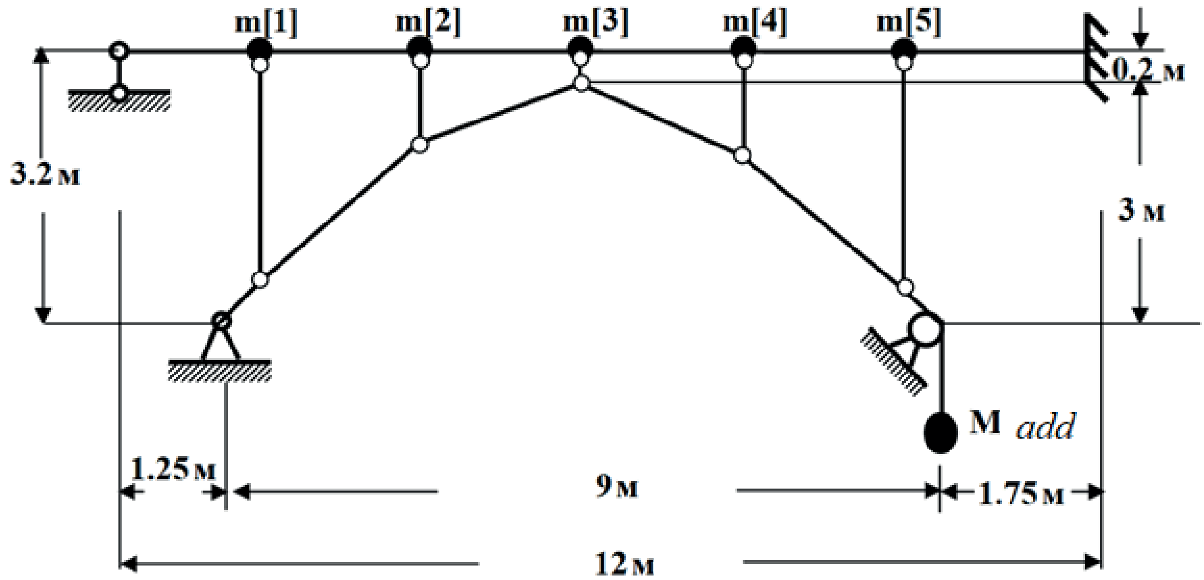

Figure 3. The general view of computational scheme of targeted kinematic device

The frequencies and forms of natural oscillations of the modified system are presented in Table 3. The general view of this kinematic targeted device is shown in Figure 3. We have the following lengths of posts:

$$l_p[1] = 2.6934\,\text{m}; \quad l_p[2] = 0.9406\,\text{m};$$
$$l_p[3] = 0.2000\,\text{m}; \quad l_p[4] = 1.0879\,\text{m};$$
$$l_p[5] = 2.7498\,\text{m}.$$

The magnitude of the additional mass is determined by the relationship (see, for example, [2])

$$M_{add} = M_{mo}(N[n])^2, \tag{9}$$

where $N[n]$ is the force in the outermost post of the device's belt, to which the additional mass is attached.

The additional mass for the formed device is equal to $M_{add} = 1586.5229\,\text{kg}$. The cross-sectional areas of the kinematic device rods are identical; their values can be chosen arbitrarily. A cable runs from the lower hinge of fifth post through the block to the ground.

In [3, 4, 18, 19, 22] it is shown that changing the lengths of all the targeted device posts by the same amount does not affect the spectrum of natural frequencies and vibration modes.

Figure 4 shows a kinematic device formed from the one shown in Figure 3, by lengthening all the posts by 2 m.

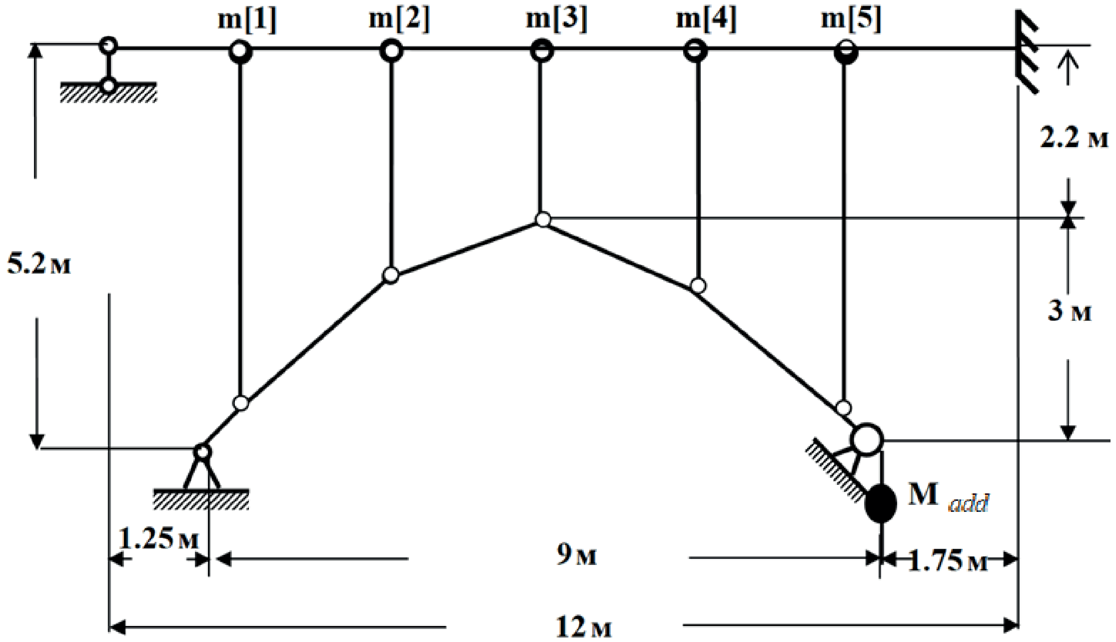

Figure 4. The general view of computational scheme of targeted kinematic device

Table 4. Coordinates of the belt nodes

Number of node	0	1	2	3	4	5	6
Coordinate of node	4.0557	2.9725	1.6217	6.4406	9.4115	5.5631	4.0557

Table 5. Frequencies and modes of natural oscillations of the modified system

Number k	Natural vibration modes					$m[k]$
	for frequency 11.0062	for frequency 14.07953	for frequency 109.5337	for frequency 195.0757	for frequency 226.8870	
0	0.0000	0.0000	0.0000	0.0000	0.0000	0
1	-0.502865	-0.315087	-0.594382	-0.73793	-0.369613	400
2	-0.520103	-0.565080	-0.174580	0.370387	-0.264938	800
3	0.103822	-0.606213	0.432120	-0.086169	0.212601	1200
4	0.574986	-0.432097	-0.359747	-0.137055	-0.383591	800
5	0.367738	-0.164932	-0.547801	0.540420	0.775147	400
6	0.0000	0.0000	0.0000	0.0000	0.0000	0

Similarly we have $R_0[i, 2] = m[i]v[i, 2]$ and a matrix of additional inertial forces is formed based on the forces, reducing the second natural frequency from 53.0769 sec^{-1} to 11 sec^{-1}, and a corresponding computational model for the targeted kinematic device is created. A general view of the computational model for this targeted kinematic device is shown in Figure 4.

The additional mass is equal to

$$M_{add} = 6301.7206915414\,\text{kg}.$$

The frequencies and modes of natural vibrations of this modified system are presented in Table 5.

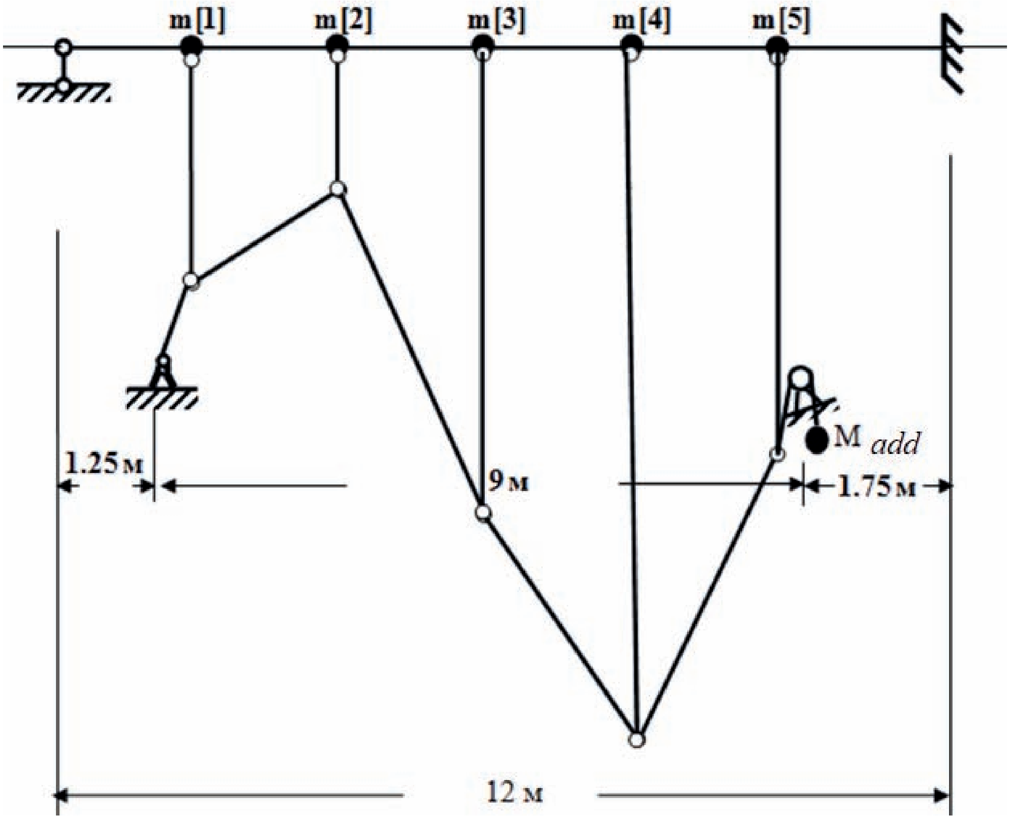

Figure 5. The general view of computational scheme of targeted kinematic device

Table 6. Coordinates of the belt nodes.

Number of node	0	1	2	3	4	5	6
Node coordinate (upper chord)	3.2000	2.6934	0.9406	0.2000	1.0879	2.7498	3.2000
Node coordinate (lower chord)	4.0557	2.9725	1.6217	6.4406	9.4115	5.5631	4.0557

After creation of individual kinematic targeted devices necessary for solving the problem, a group matrix of additional inertial force coefficients can be formed. In order to do this it is required simply sum the coefficients of the additional inertial force matrices of the individual kinematic devices.

By implementing the second step of the algorithm described above, we form a group targeted kinematic device. In order to do this, the generated computational schemes for the individual targeted kinematic devices are placed at the nodes of the original system. The general view of this device is shown in Figure 6.

We have the following additional masses:

$$M_{add1} = 1586.5229\,\text{kg}, \quad M_{add2} = 6301.72069\,\text{kg}.$$

In this version of the group targeted kinematic device, both additional masses are attached to the rightmost links of the individual kinematic devices' belts.

In some cases, it may be necessary to attach additional masses to different sides of the group targeted kinematic device. Implementing this requirement does not complicate the procedure of creation of the group targeted device. In this case, in the individual kinematic devices used, the corresponding numbers j of the outermost belt links are selected when determining the values (9).

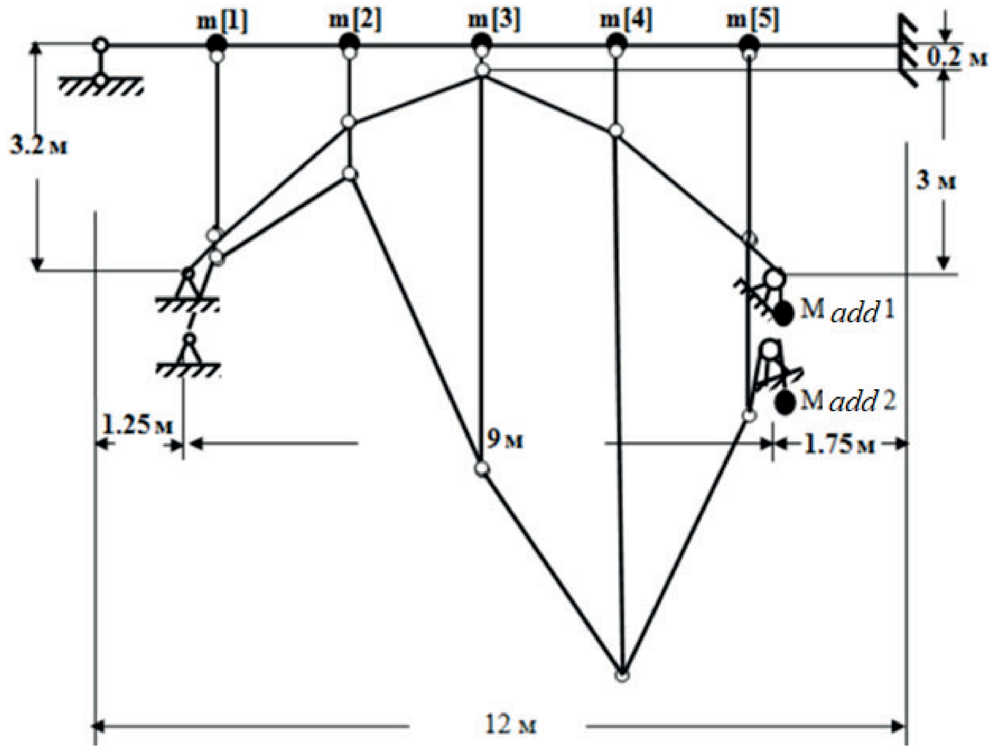

Figure 6. The general view of the device

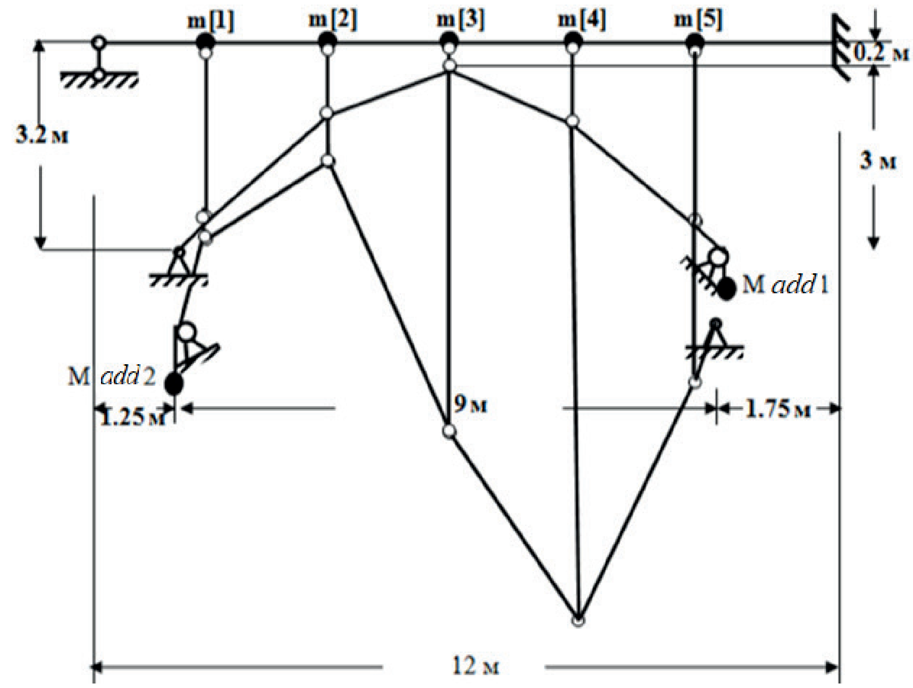

Figure 7. The variant of group targeted kinematic device

Table 7. Frequencies and modes of oscillation of both variants of the group targeted kinematic device

Number k	Natural vibration modes					$m[k]$
	for frequency 11.0062	for frequency 14.07953	for frequency 109.5337	for frequency 195.0757	for frequency 226.8870	
0	0.0000	0.0000	0.0000	0.0000	0.0000	0
1	-0.502865	-0.315087	-0.594382	-0.73793	-0.369613	400
2	-0.520103	-0.565080	-0.174580	0.370387	-0.264938	800
3	0.103822	-0.606213	0.432120	-0.086169	0.212601	1200
4	0.574986	-0.432097	-0.359747	-0.137055	-0.383591	800
5	0.367738	-0.164932	-0.547801	0.540420	0.775147	400
6	0.0000	0.0000	0.0000	0.0000	0.0000	0

Table 8. Comparison of the natural frequencies of the original system with the results of testing using the "SCAD" and "LIRA" software products

	$\omega[1]$	$\omega[2]$	$\omega[3]$	$\omega[4]$	$\omega[5]$
Proposed pproach	14.0715	53.0769	109.5339	195.0757	226.8873
"SCAD" and "LIRA" software packages	14,0820	53,4030	111,5070	201,4150	237,1590

A version of the group sighting kinematic device in which the additional masses are attached to different sides is shown in Figure 7.

The frequencies and modes of natural oscillations of both variants of the group targeted kinematic device are identical and are presented in Table 7.

The posts of the individual targeted kinematic devices, mounted at the mass application nodes and directed along their trajectory, are aligned. Forces $R_0[i,\ k] = m[i]v[i,\ k]$ arise in the aligned posts, each of which determines one of the individual targeted kinematic devices.

The absence of mutual influence between the forces determining the various individual kinematic devices is justified by the properties of the forces $R_0[i,\ k]$. The forces $R_0[i,\ k_1]$ determining the targeted device, which reduces the natural frequency $\omega[k_1]$, do not perform work on the displacements of the natural oscillation mode of any other natural frequency, that is,

$$\text{if } k_1 \neq k_2 \text{ we get } \sum_{i=1}^{n} R_0[i,\ k_1]v[i,\ k_2] = 0. \quad (10)$$

Relationship (10) determines the absence of mutual influence between the forces $R_0[i,\ k]$ arising in the posts of the group targeted device.

The results presented in Table 7 confirm that the introduction of the group targeted kinematic device reduces only the first two selected natural oscillation frequencies to the intended values and does not lead to a change in the natural modes and values of the remaining frequencies. The results presented in Tables 1, 2, 3, 5, 7 were obtained by the finite element method (FEM) [18] by dividing (discretizing) the length of the original beam into 24 sections. A comparison of the natural vibration frequencies of the original system with the test results of the "SCAD" and "LIRA" software products [9-15] is presented in Table 8. Considering the difference in the calculation method for Tables 1, 2, 3, 5, 7 between the "SCAD" and "LIRA" software products, the agreement between the results can be considered fairly close, confirming the reliability of the original data.

We will now test the group targeted kinematic device using the "SCAD" and "LIRA" software products. The results are presented in Table 9.

Table 9. Testing the group targeted kinematic device

	$\omega[1]$	$\omega[2]$	$\omega[3]$	$\omega[4]$	$\omega[5]$
Initial	14,0820	53,4030	111,5070	201,4150	237,1590
Group	10,8000	11,1400	111,5200	201,4200	237,1600

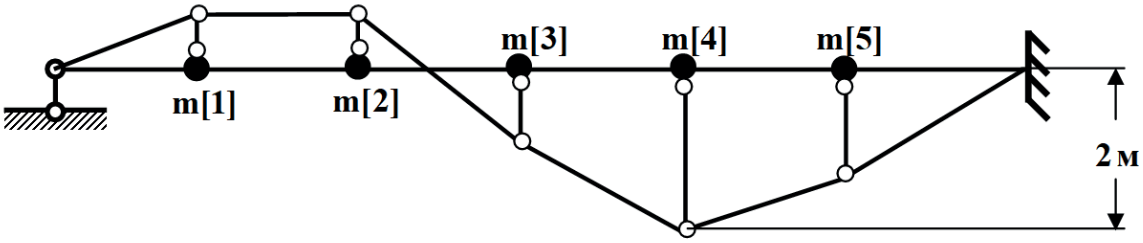

Figure 8. The general view of the device

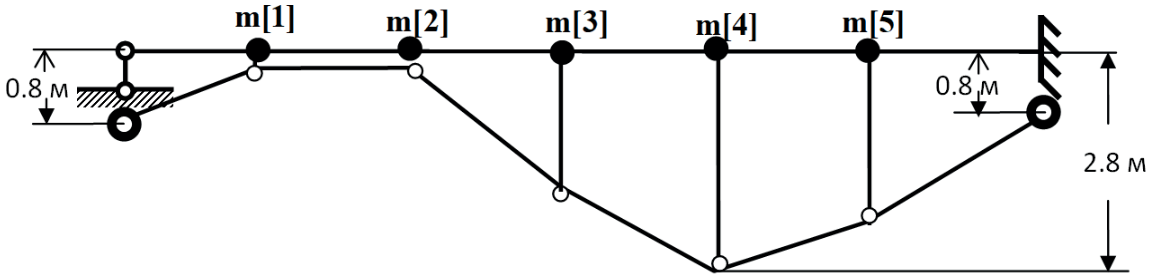

Figure 9. The general view of the modified device

The data presented in Table 9 prove that the testing performed convincingly demonstrates a reduction exclusively in those frequencies targeted by the group kinematic device, while the other natural oscillation frequencies remained unchanged.

If for the initial system (Figure 1) it is required to reduce the value of the first natural frequency from 14.0820 sec^{-1} to 10 sec^{-1} and to increase the value of the second frequency from 53.4030 sec^{-1} to $\omega_{S2} = 110$ sec^{-1}, then one of the separate targeted kinematic devices shown in Figure 3 and Figure 4 can be used to reduce the first frequency. In order to increase the value of the second frequency, a separate targeted constraint, created in [58], can be used.

For this purpose, a matrix of additional stiffness coefficients is formed based on the forces

$$A_0 = A_{S0} A_S ; \quad (11)$$

$$A_S = \left\| a_0 [i,k] \right\|_{i,k=1}^{n} ; \quad (12)$$

$$a_0[i,\ k] = R_0[i] R_0[k] ; \quad (13)$$

$$A_{SO} = \\ = \frac{-\sum_{i=1}^{n}\sum_{k=1}^{n}(a[i,\ k] - \omega_{S2}^2 m[i,\ k]) v_\omega[i,2] v_\omega[k,2]}{\sum_{i=1}^{n}\sum_{k=1}^{n} a_0[i,k] v_\omega[i,2] v_\omega[k,2]} . \quad (14)$$

In accordance with [2], a separate targeted constraint is formed. The general appearance of this device is shown in Figure 8.

The lengths of the posts of this device are of different signs. To avoid the complications associated with this circumstance, we will increase the lengths of all legs by 0.8 m.

The general appearance of this modified device is shown in Figure 9.

We have the following lengths of posts:

$$l_p[1] = 0.1264\,\text{m}; \quad l_p[2] = 0.1212\,\text{m};$$

Table 10. Frequencies and modes of oscillation of the separate targeted constraint

Number k	Natural vibration modes					$m[k]$
	for frequency 14.07953	for frequency 109.5337	for frequency 109.9983	for frequency 195.0757	for frequency 226.8870	
0	0.0000	0.0000	0.0000	0.0000	0.0000	0
1	-0.315087	-0.594382	-0.502865	-0.73793	-0.369613	400
2	-0.565080	-0.174580	-0.520103	0.370387	-0.264938	800
3	-0.606213	0.432120	0.103822	-0.086169	0.212601	1200
4	-0.432097	-0.359747	0.574986	-0.137055	-0.383591	800
5	-0.164932	-0.547801	0.367738	0.540420	0.775147	400
6	0.0000	0.0000	0.0000	0.0000	0.0000	0

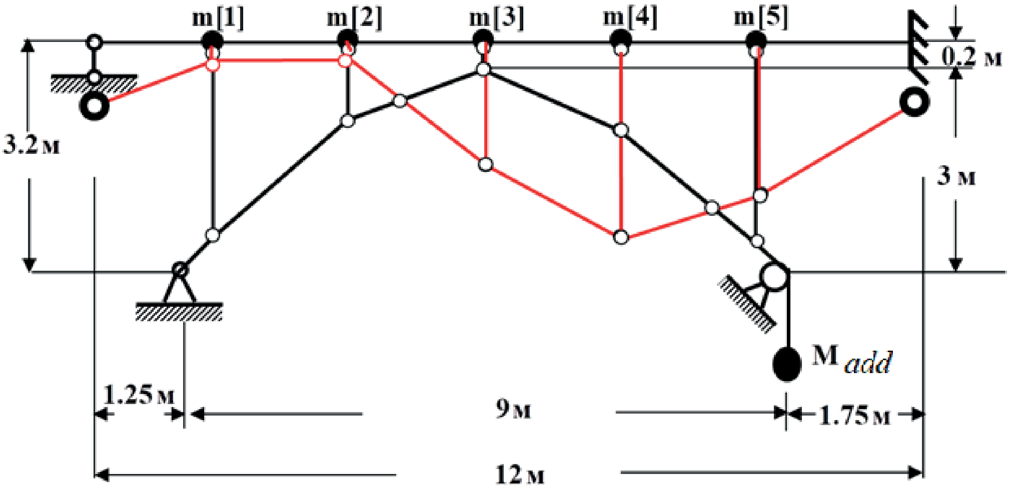

Figure 10. The general view of the considering variant of integrated group targeted device

$$l_p[3] = 1.6981\,\text{m}; \quad l_p[4] = 2.8000\,\text{m};$$
$$l_p[5] = 2.1555\,\text{m}.$$

The cross-sectional areas of the belt rods and the posts are, respectively, equal to:

$$F_b = 0.0003538\,\text{m}^2; \quad F_p = 0.0007075\,\text{m}^2.$$

The diameters of the belt rods and the posts are, respectively, equal to:

$$D_b = 0.02122\,\text{m}; \quad D_p = 0.0007075\,\text{m}.$$

The frequencies and modes of natural vibrations of this individual targeted constraint are presented in Table 10. They are determined by the roots of the equation

$$\left|(A + A_{SO}A_S) - \omega^2 M\right| = 0. \qquad (15)$$

By implementing the second step of the above algorithm, we create an integrated group targeted device. Let us first consider the variant in which the integrated targeted device is created based on the individual targeted constraint shown in Figure 9 and the individual targeted kinematic device shown in Figure 3.

In order to achieve this, the selected computational schemes for individual targeted devices are placed within the nodes of the original system.

The general view of this version of the integrated group targeted device is shown in Figure 10.

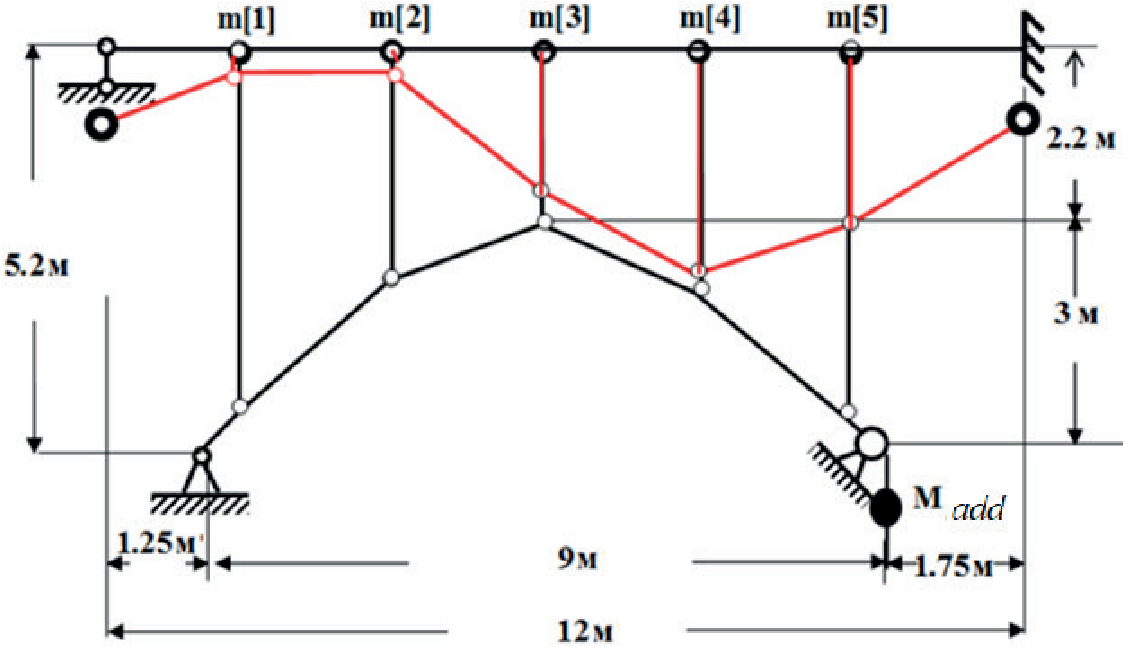

Figure 10. The general view of the considering variant of integrated group targeted device

It should be clarified that the symbol  denotes a fixed flat hinge, with a cable running from the fifth post to the block and down.

The additional mass is equal to

$$M_{add} = 1586.5229125936\,\text{kg}.$$

The cross-sectional areas of the red belt rods are equal to

$$F_b = 0.0003538\,\text{m}^2.$$

The cross-sectional areas of the red posts are equal to

$$F_p = 0.0007075\,\text{m}^2.$$

The diameter of the belt rods is equal to

$$D_b = 0.02122\,\text{m}.$$

The diameter of the belt rods is equal to

$$D_b = 0.03001\,\text{m}.$$

The cross-sections of the black rods are the same. Where posts overlap, the cross-sections are not doubled.

In the considered computational scheme for the integrated group targeted device, the belt of separate targeted constraint and belt of separate targeted kinematic device intersect.

Let us now consider a variant in which the integrated targeted device is created based on the separate targeted constraint shown in Figure 9 and the separate targeted kinematic device shown in Figure 4.

The general view of this variant of the integrated group targeted device is shown in Figure 11. In this computational scheme, the belt of separate targeted constraint and belt of separate targeted kinematic device do not intersect.

The posts of the separate targeted devices are superimposed. Forces

$$R_0[i,\ k] = m[i]v[i,\ k]$$

arise in the combined posts, each of which determines one of the individual targeted devices.

Table 12. Frequencies and modes of oscillation of both variants of computational schemes

Number k	Natural vibration modes					$m[k]$
	for frequency 10.07953	for frequency 109.5337	for frequency 109.9983	for frequency 195.0757	for frequency 226.8870	
0	0.0000	0.0000	0.0000	0.0000	0.0000	0
1	-0.502865	-0.315087	-0.594382	-0.73793	-0.369613	400
2	-0.520103	-0.565080	-0.174580	0.370387	-0.264938	800
3	0.103822	-0.606213	0.432120	-0.086169	0.212601	1200
4	0.574986	-0.432097	-0.359747	-0.137055	-0.383591	800
5	0.367738	-0.164932	-0.547801	0.540420	0.775147	400
6	0.0000	0.0000	0.0000	0.0000	0.0000	0

Table 13. Test of group targeted device

	$\omega[1]$	$\omega[2]$	$\omega[3]$	$\omega[4]$	$\omega[5]$
Table 12	10.0095	11.0062	109.5337	195.0757	226.8870
Test	10,8000	11.1400	111.5200	201.4200	237.1600

The absence of mutual influence between the forces determining the different individual targeted devices is explained by the properties of the forces $R_0[i,\ k]$, which are represented by the relationship (10).

The frequencies and modes of natural vibrations of both variants of the computational schemes are the same. They are determined by the roots of the equation

$$\left|(A + A_{SO}A_S) - \omega^2\left(M + M_{m0}M_m\right)\right| = 0. \quad (16)$$

Equation (16) is formed from equation (2) by adding the matrix of additional stiffness coefficients (11), (12) to matrix A (1) and the matrix of additional inertial forces (4) to matrix (1).

The frequencies and coordinates of the natural oscillation modes presented in Table 12 were obtained as the roots of Equation (16) before the computational model of the integrated group sighting device was created.

Table 2.3.12 shows that the intended changes in the natural oscillation frequencies occurred with sufficient accuracy. Only the first natural oscillation frequency decreased, and only the second increased. The remaining frequencies and all natural oscillation modes remained unchanged.

We will now test the group targeted device with the use of "SCAD" and "LIRA" software products [9-15]. The results are presented in Table 13. The data presented in Table 13 demonstrate that the testing of the computational model convincingly demonstrates the closeness of the test results to the roots of equation (16) and confirms the change in only those frequencies targeted by the integrated group targeted device, while the remaining natural oscillation frequencies remained unchanged.

Thus, the distinctive paper proposes an algorithm for generating an integrated group targeted device that increases some targeted natural frequencies to specified values and decreases other targeted frequencies to specified values, without changing any of the remaining natural frequencies or any of the natural oscillation modes. A method for generating a matrix defining an equation whose roots determine the frequencies and natural oscillation modes of the integrated group targeted device is considered. A justification is provided for the absence of mutual influence between the forces $R_0[i,\ k]$ arising in the posts of the integrated group targeted device. The proposed algorithm was tested with the use of "SCAD" and "LIRA" software products [9-15].

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