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MINIMISE OF VIBRATION OF SOME SELECTED POINTS OF THE DISCRETE — CONTINUOUS SYSTEMS BY MEANS OF THE STRUCTURE SYNTHESIS OF THE RECEPTANCES

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Summary: *The paper the synthesis of the receptance by using the block diagrams. This method has some advantages. Each sub-system is described by its receptance and occurs in the in the formulas separately. If the sub-system is so complicated the receptance can be obtained by experiments. In this paper the problem of vibration reduction by this method was solved.*

1. The model of the system

The aim of this work is minimization of vibration of the selected construction points e.g. a engine room, a building construction, a ship deck etc. An example of this task is presented below – Fig. 1.

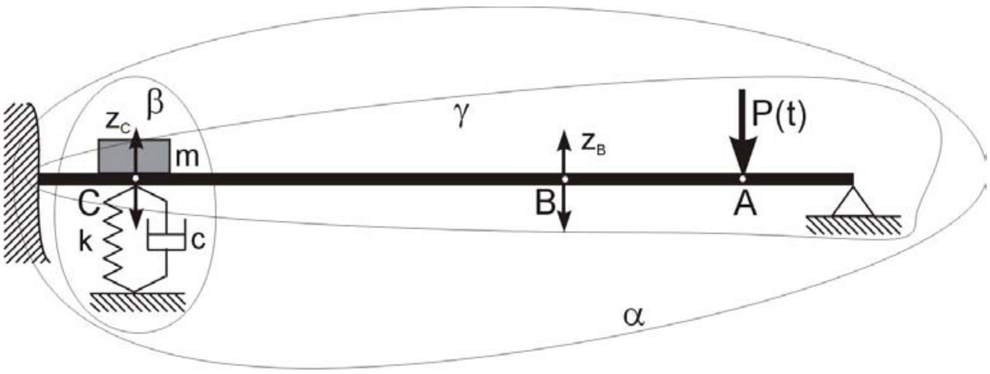

Fig. 1. The model of the system

In the point A of analysed system the input force $P(t)$ is acted. On point C we have to add such mass m, or spring k, or damper c in order to vibrations in the point . B would be near zero. The all system has two subsystems: continues subsystem γ and discrete subsystem β .

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Receptances of continuous system in individual points are denoted by γ_{ij}, where $i, j = A, B, C$. Because the continuous sub–system is very difficult for analytical description the unknown data of receptances were determined experimentally.

In this paper for description of this model the method of structural connection will be used [1]. After connection we obtain the structural diagram of this model.

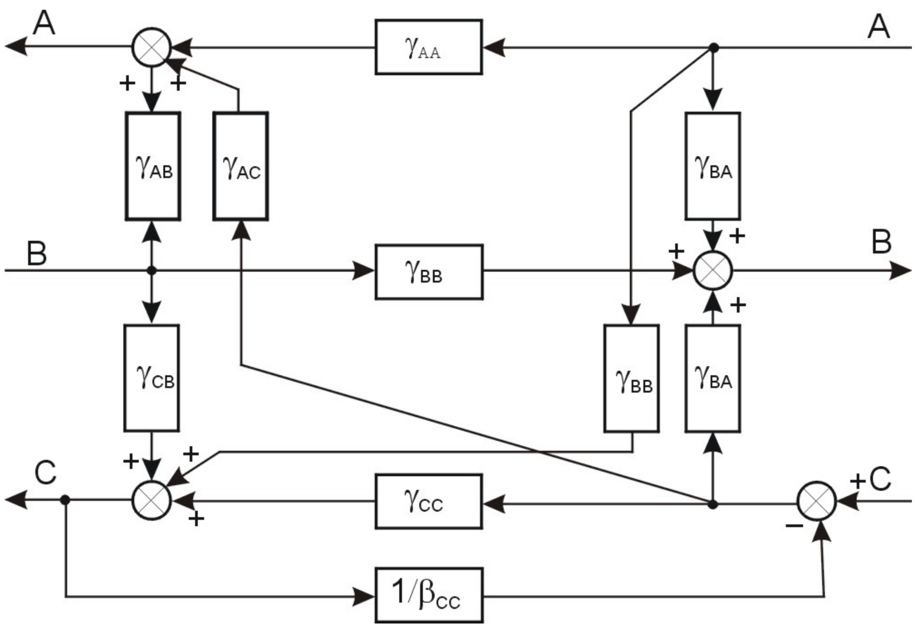

Fig.2. Structural diagram of dynamic system receptances

From above structure we can obtain the receptance α after connection. Receptance α has the form:

$$\alpha(i\omega) = \begin{bmatrix} \alpha_{AA} & \alpha_{AB} & \alpha_{AC} \\ \alpha_{BA} & \alpha_{BB} & \alpha_{BC} \\ \alpha_{CA} & \alpha_{CB} & \alpha_{CC} \end{bmatrix} \tag{1}$$

System response is obtained from the equation

$$\begin{bmatrix} z_A \\ z_B \\ z_C \end{bmatrix} = \begin{bmatrix} \alpha_{AA} & \alpha_{AB} & \alpha_{AC} \\ \alpha_{BA} & \alpha_{BB} & \alpha_{BC} \\ \alpha_{CA} & \alpha_{CB} & \alpha_{CC} \end{bmatrix} \begin{bmatrix} P(t) \\ 0 \\ 0 \end{bmatrix} \tag{2}$$

or in shorten notation

$$\mathbf{Z} = \boldsymbol{\alpha}\mathbf{P} \tag{3}$$

where: $\mathbf{Z}$ is column vector including outputs: z_A, z_B, and z_C $\boldsymbol{\alpha}$ is matrix of receptances of the whole system after synthesis the subsystems, and $\mathbf{P}$ is column vector of input forces.

According to equation (2) or (3) w can write:

$$z_B(i\omega) = \alpha_{BA} P(t) \tag{4}$$

where α_{BA} is the receptance between points A and B.

As we can see coordinate z_B is function α_{BA}. The receptance α_{BA} we obtain from above presented structural diagram (Fig. 2).

2. Mathematical analyses of model

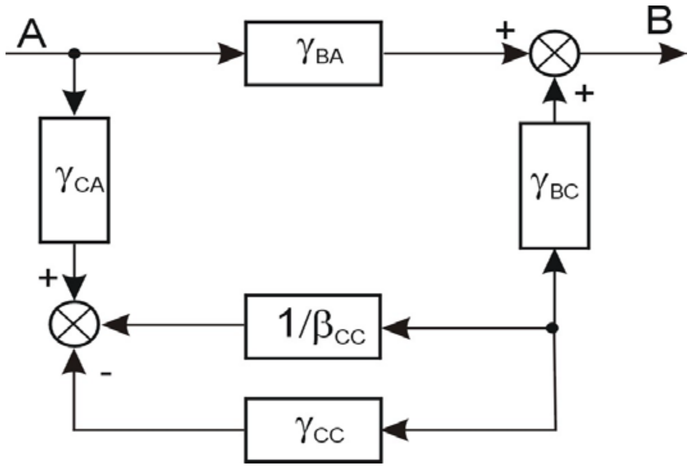

Fig. 3. Simplified structural diagram

The structural diagram of the receptance α_{BA} is presented on Fig. 3.

Solving diagram shown on Fig.3 we obtain:

$$\alpha_{BA} = \frac{\gamma_{BA}(\gamma_{CC} + \beta_{CC}) - \gamma_{BC}\gamma_{CA}}{\gamma_{CC} + \beta_{CC}} = \frac{L_{BA}(i\omega)}{M(i\omega)} \tag{5}$$

The coordinate z_B is zero when $\alpha_{BA} = 0$, that is mean when $L_{BA} = 0$, so

$$\gamma_{BA}(\gamma_{CC} + \beta_{CC}) - \gamma_{BC}\gamma_{CA} = 0 \tag{6}$$

and, at the and

$$\beta_{CC} = \frac{\gamma_{BC}\gamma_{CA} - \gamma_{BA}\gamma_{CC}}{\gamma_{BA}} \tag{7}$$

The receptance β_{CC} can get the following forms:

a) mass $\beta_{CC} = -\dfrac{1}{m \cdot \omega^2}$ (8)

b) damper $\beta_{CC} = \dfrac{1}{i\omega c} = -i\dfrac{1}{\omega c}$ (9)

c) spring $\beta_{CC} = \dfrac{1}{k}$ (10)

Substituting equations (8), (9), and (10) to (7) we can we can calculate properly mass m, damping c, and stiffness k in point B respectivly.

$$m(\omega)=\frac{\gamma_{BA}}{\gamma_{BA}\gamma_{CC}-\gamma_{BC}\gamma_{CA}} \tag{11}$$

$$c(\omega)=i\frac{\gamma_{BA}}{\omega(\gamma_{BC}\gamma_{CA}-\gamma_{BA}\gamma_{CC})} \tag{12}$$

$$k(\omega)=\frac{\gamma_{BA}}{\gamma_{BC}\gamma_{CA}-\gamma_{BA}\gamma_{CC}} \tag{13}$$

3. Solution

In our case the continuous subsystem is very difficult for analytical description, therefore this subsystem was experimentally described (Tab. 1), and graphically presented on Fig. 4 [2].

Table 1. The experimentally determined receptances

ω	50	60	70	80	90	100	110
γ_{BC}	0,000010	0,000014	0,000020	0,000026	0,000033	0,000041	0,000050
γ_{CA}	0,000050	0,000060	0,000066	0,000072	0,000076	0,000080	0,000083
γ_{BA}	0,000050	0,000060	0,000066	0,000072	0,000076	0,000080	0,000083
γ_{CC}	0,000070	0,000082	0,000089	0,000095	0,000100	0,000120	0,000130
ω	120	130	140	150	160	170	180
γ_{BC}	0,000058	0,000067	0,000078	0,000088	0,000100	0,000113	0,000120
γ_{CA}	0,000085	0,000086	0,000087	0,000087	0,000087	0,000086	0,000085
γ_{BA}	0,000085	0,000086	0,000085	0,000080	0,000073	0,000064	0,000055
γ_{CC}	0,000150	0,000150	0,000155	0,000150	0,000140	0,000130	0,000120

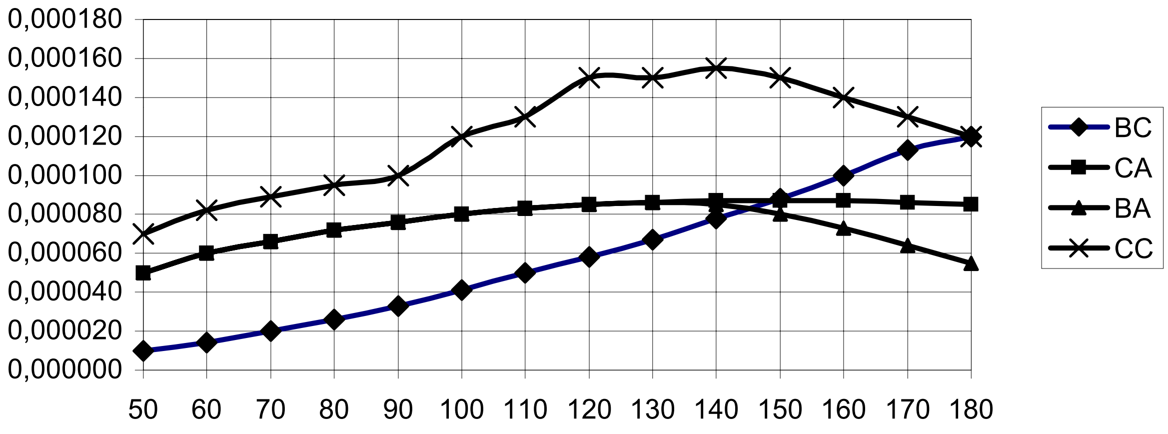

Fig. 4. The receptances of sub-systems γ

Substituting the values of the receptances γ_{BC}, γ_{CA}, γ_{BA}, γ_{CC} from table 1 to equation 11 the mass of subsystem β is obtained, Fig. 5.

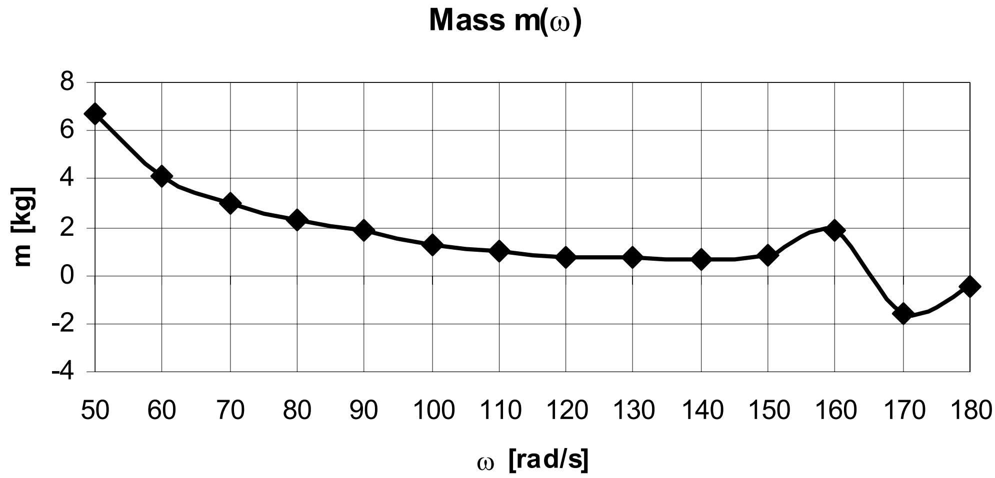

Fig. 5. The mass m of the subsystem β

Fig. 5 is designed for chosen of added mass m for selected frequency ω. Now we can check the result of calculation. For frequency $\omega = 60$ and $\omega = 100$ we have mass $m(60) = 6{,}7\ \text{kg}$, and $m(100) = 1{,}27\ \text{kg}$ respectively.

If the calculation is correctly done the recptance α_{BA} should be zero for above masses, Fig. 6 and Fig 7.

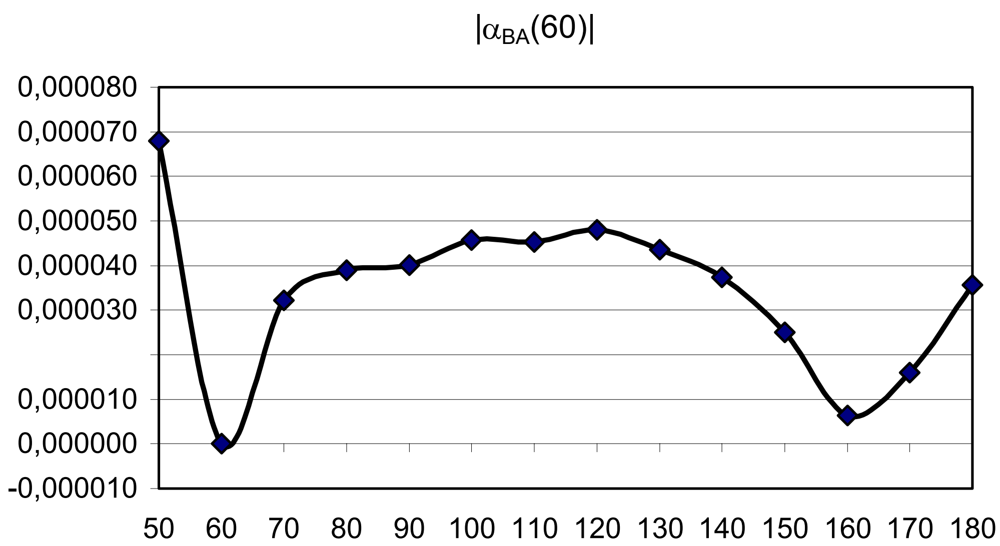

Fig. 6. The receptance α_{BA} for $m(60)$

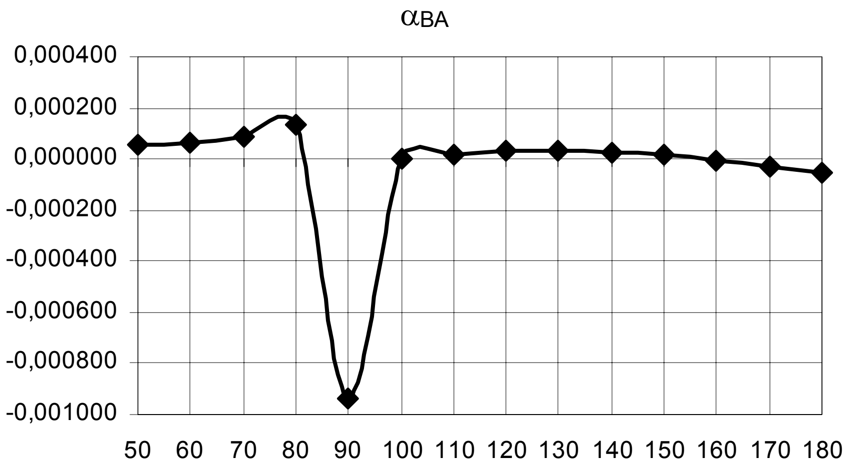

Fig. 7 The receptance α_{BA} for $m(100)$

From presented diagrams (Fig. 6 and Fig. 7) we can see that really for $\omega = 60$ and $\omega = 100$ the receptance $\alpha_{BA} = 0$, that means $z_B(i\omega)$ is zero too (see equation 4).

3. Results

In this paper three possibilities of vibration reduction were presented: by changing mass, stiffness, and damping.

If the frequency is changing there is another method of vibration reduction by using active control for changing mass, stiffness, and damping.

4. References

[1] Holka H.: *Receptance synthesis by Means of Block Diagrams*, 7th World Congress of IFToMM, Sevilla 1987

[2] Holka H.: *Układy dyskretne ciągłe jako wielowymiarowe obiekty sterowania*, Zeszyty Naukowe ATR, Mechanika nr 37, Bydgoszcz, 1995