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MACHINE VIBRATIONS ON A FLEXIBLE ROOF

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Abstract

The paper presents the synthesis of the receptance by using the block diagrams. The presented method is also very useful when the machine or a group of machines is mounted on a flexible roof which is hard to describe analytically. Such a case occurred while analyzing vibrations of a group of pumps installed on a floor of an assembly hall. Pumps, apart from excitations generated by the operation, are subjected to kinematic excitations from a vibrating foundation. A synthesis of the pump connection with a flexible base has been presented in this paper.

Keywords: *pump, vibrations, structural synthesis, flexible foundation*

1. Introduction

In paper [3] vibrations of a mixed flow pump rotor shaft seated with neighboring machines on a susceptible floor. The vibrating shaft generated the pump vibrations which through the susceptible roof were transferred onto the neighboring machines causing a kinematic excitation, Figure 1.

Fig. 1. A group of pumps installed on the first floor of an assembly hall

Thus, there was crated a dynamic system consisting of the pump and roof for which, due to an unknown flexible continuous system, the analytic description is difficult. A interesting method of analysis discrete and flexible systems is structural synthesis of their receptance, [1, 2]. The simplification of a description is based on the idea that the unknown and difficult for fully identification flexible sub-system is replaced by its receptance, obtained by experiments, only in the points of connection.

A structural scheme of connection built this way can be treated as the object of control and is completely ready for the analysis which are used in the control engineering by means of the matrix transfer function [4]. The method will be illustrated using the example.

2. The synthesis of the receptance

Let us consider the system presented in Fig. 2.

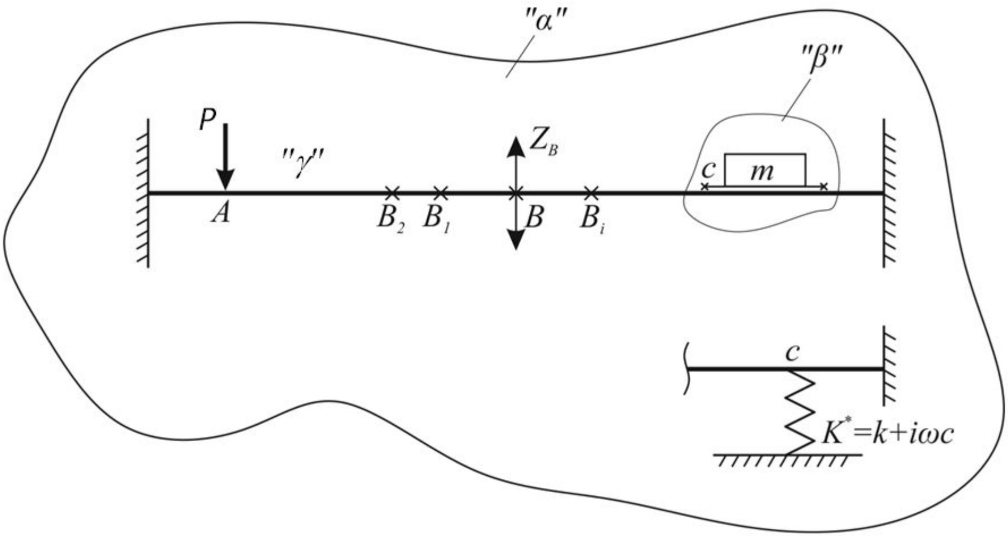

Fig. 2. The model of the system

In the point A of analyzed system the input force P(t) is acted. On point C there is the mass m or spring k. The aim of this work is minimization of vibration of the point B.

This model consists of the flexible sub-system "γ" and discrete "β". Because the continuous sub-system γ is very difficult for analytical description ,the unknown data of this receptances were determined experimentally.

The matrix receptance γ has the form

$$\gamma(i\omega) = \begin{bmatrix} \gamma_{AA} & \gamma_{AB} & \gamma_{AC} \\ \gamma_{BA} & \gamma_{BB} & \gamma_{BC} \\ \gamma_{CA} & \gamma_{CB} & \gamma_{CC} \end{bmatrix}, \quad (1)$$

where: $\gamma_{ij} = \gamma_{ji}$.

After connection the block diagram can be drawn (Fig. 3).

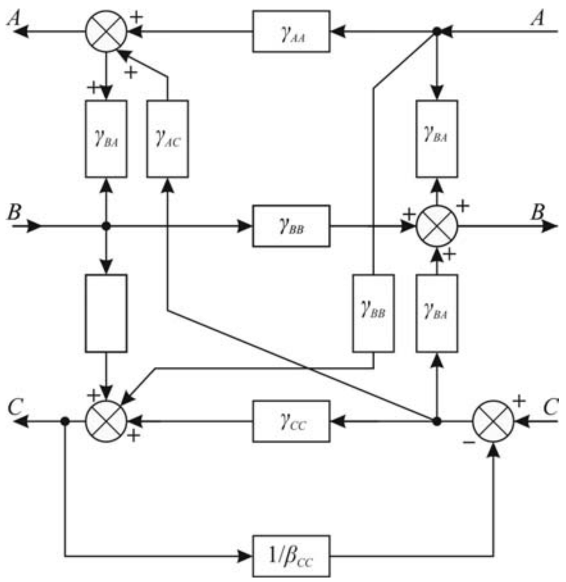

Fig. 3. Synthesis of the receptances

From above structure the receptance α after connection has the form:

$$\alpha(i\omega)=\begin{bmatrix}\alpha_{AA} & \alpha_{AB} & \alpha_{AC}\\ \alpha_{BA} & \alpha_{BB} & \alpha_{BC}\\ \alpha_{CA} & \alpha_{CB} & \alpha_{CC}\end{bmatrix}. \tag{2}$$

System response is obtained from the equation

$$\begin{bmatrix}Z_A\\ Z_B\\ Z_C\end{bmatrix}=\begin{bmatrix}\alpha_{AA} & \alpha_{AB} & \alpha_{AC}\\ \alpha_{BA} & \alpha_{BB} & \alpha_{BC}\\ \alpha_{CA} & \alpha_{CB} & \alpha_{CC}\end{bmatrix}\begin{bmatrix}P(t)\\ 0\\ 0\end{bmatrix}, \tag{3}$$

or in shorten notation

$$\boldsymbol{Z} = \boldsymbol{\alpha}\,\mathbf{P}\,, \tag{4}$$

where: **Z** is column vector including outputs z_A , z_B, z_C ,
α is the matrix of receptances of the whole system after connection,
P is the column vector of input forces.

From equation (4) one can write:

$$z_B(i\omega) = \alpha_{BA}P(t)\,, \tag{5}$$

where: α_{BA} is the receptance between points B and A.
The receptance α_{BA} is obtained from above general presented diagram - Fig. 4.

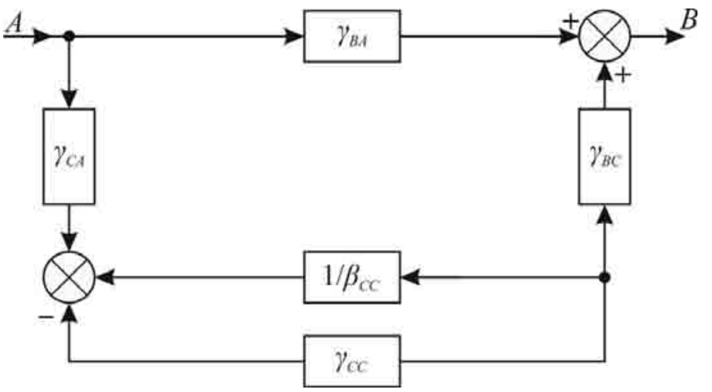

Fig. 4. The block diagram of the α_{BA}

Solving above diagram we have:

$$\alpha_{BA} = \frac{\gamma_{BA}(\gamma_{CC} + \beta_{CC}) - \gamma_{BC}\gamma_{CA}}{\gamma_{CC} + \beta_{CC}} = \frac{L_{BA}(i\omega)}{M(i\omega)} . \tag{6}$$

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

$$\gamma_{BA}(\gamma_{CC} + \beta_{CC}) - \gamma_{BC}\gamma_{CA} = 0 , \tag{7}$$

now

$$\beta_{CC} = \frac{\gamma_{BC}\gamma_{CA} - \gamma_{BA}\gamma_{CC}}{\gamma_{BA}} . \tag{8}$$

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

$$\text{mass } \beta_{CC} = -\frac{1}{m \cdot \omega^2} , \tag{9}$$

$$\text{spring } \beta_{CC} = \frac{1}{k} . \tag{10}$$

Substituting equations (9) and (10) to (8) we can calculate mass the m or stiffness k:

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

$$\boldsymbol{k(\omega)} = \frac{\boldsymbol{\gamma_{BA}}}{\boldsymbol{\gamma_{BC}\gamma_{CA} - \gamma_{BA}\gamma_{CC}}} . \tag{12}$$

3. Calculation

The sub system γ was experimentally described (Tab. 1) and graphically presented in Fig. 5.

Tab. 1. The experimentally determined receptances γ

ω	γ_{BC}	γ_{CA}	γ_{BA}	γ_{CC}
50	10^{-6}	50^{-6}	50^{-6}	70^{-6}
60	14^{-6}	60^{-6}	60^{-6}	82^{-6}

70	20^{-6}	66^{-6}	66^{-1}	89^{-6}
80	26^{-6}	72^{-6}	72^{-6}	95^{-6}
90	33^{-6}	76^{-6}	76^{-6}	100^{-6}
100	41^{-6}	80^{-6}	80^{-6}	110^{-6}
110	50^{-6}	83^{-6}	83^{-6}	120^{-6}
120	58^{-6}	85^{-6}	85^{-6}	135^{-6}
130	67^{-6}	86^{-6}	86^{-6}	140^{-6}
140	78^{-6}	87^{-6}	85^{-6}	148^{-6}
150	88^{-6}	87^{-6}	80^{-6}	150^{-6}
160	100^{-6}	87^{-6}	73^{-6}	140^{-6}
170	113^{-6}	86^{-6}	64^{-6}	130^{-6}
180	110^{-6}	85^{-6}	55^{-6}	120^{-6}

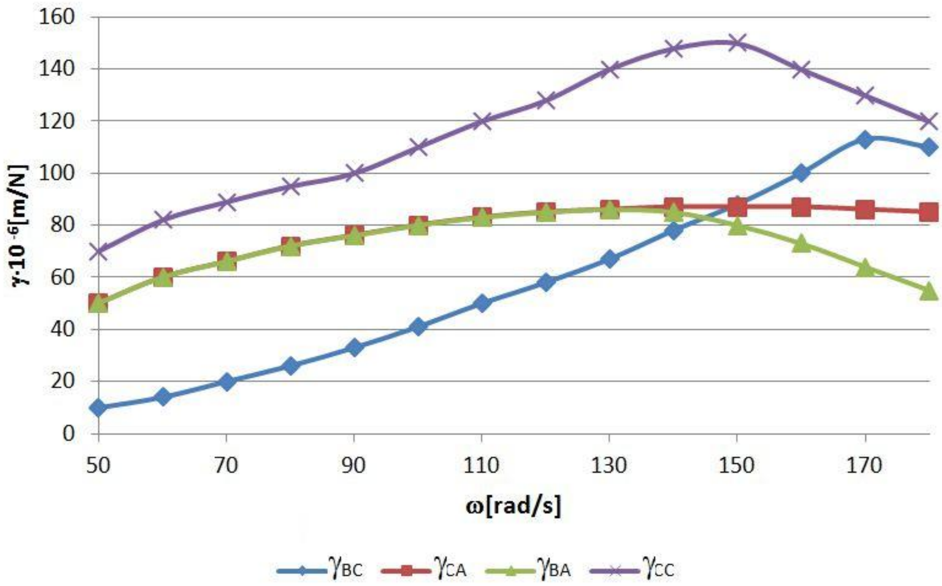

Fig. 5. The receptances of sub-system γ

Substituting the values of the receptances γ_{BC} , γ_{CA} , γ_{BA} anad γ_{CC} from Tab. 1 to equation 11 the mass of subsystem β is obtained, Fig. 6.

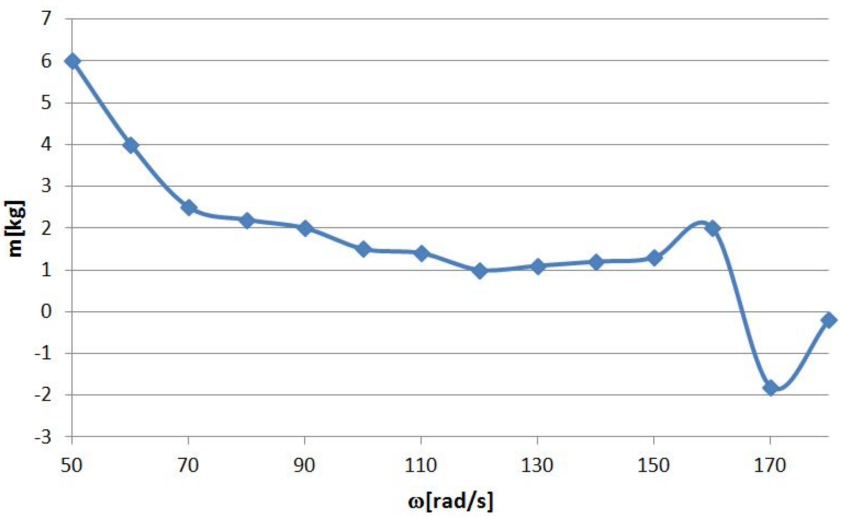

Fig. 6. The mass of the subsystem β

Now one can check the result of calculation, for ω=60 rad/s and 100 rad/s, m(60)=4 kg and m(100) =1,5 kg .

If the calculation is correctly done, the receptance α_{BA} (equ. 6) should be zero for above masses, Fig. 7.

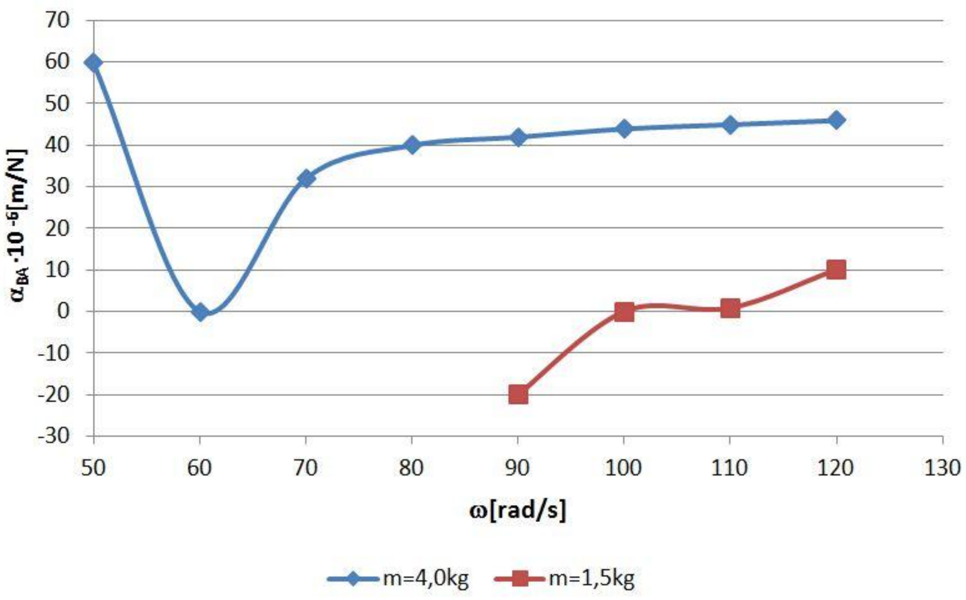

Fig. 7. The receptance α_{BA} for m=4 kg and m=1,5 kg

From presented diagrams (Fig. 7) one can see that really for ω=60 rad/s and ω=100 rad/s the receptance $\alpha_{BA} = 0$, that means $z_B = 0$.

4. Conclusion

As the result of the above work the following conclusion have been drawn:

1. As it has been demonstrated the method is very useful for systems in which the continuous system is difficult to describe analytically. In such a case the continuous system can be described by the experiment only in the points of connection with the discrete system.
2. On the basis of this example, it can be said that reduction of vibrations in selected points of the continuous system is possible and it is even possible to seat the machines in such a way that vibrations can reduce each other.
3. For large roofs the equipment for taking dynamic characteristics is expensive and, above all, needs to have relatively high power. It is usually used in construction engineering.

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