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Hydraulic elements in reduction of vibrations in mechanical systems

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Abstract. This work presents non-classical method of design of mechanic systems with subsystem reducing vibrations. The purpose of this paper is also introduces synthesis of mechanic system with reducing vibrations understand as design of this type of systems. The synthesis may be applied to modify the already existing systems in order to achieve a desired result. Elements which reduce vibrations can be constructed with passive, semi-active or active components. These considerations systems have selected active items. A hallmark of active elements it is possible to change the parameters on time of these elements and their power from an external source. The implementation of active elements is very broad. These elements can be implemented through the use of components of electrical, pneumatic, hydraulic, etc. The system was consisted from mechanical and hydraulic elements. Hydraulic elements were used as subsystem reducing unwanted vibration of mechanical system. Hydraulic elements can be realized in the form of hydraulic cylinder. In the case of an active vibration reduction in the form of hydraulic cylinder it is very important to find the corresponding values of hydraulic components. The values of these elements affect the frequency of vibrations of this sub-system which is related to the effective vibration reduction [7,11].

1. Introduction

Vibration belongs to one of the most common daily-life phenomena. The phenomenon of vibration is understood as periodical movement of a particle or system. Such movement is caused by external factors. Vibration occurs when the system, or part of it, becomes unbalanced i.e. loses its state of equilibrium. The system whose state of equilibrium has been disturbed tends to return to its original state. In case of mechanical systems, this process is caused by elastic or gravitational forces.

The majority of vibration occurring in devices and machines is harmful and has a disadvantageous effect on their condition. Harmful impact of vibration is caused by the occurrence of increased stresses and the loss of energy, which results in faster wear machinery. Vibration, particularly low-frequency vibration, also has a negative influence on the human organism. For this reason many scientists in various research centres conduct research aimed at the reduction or total elimination of vibration. There are many methods of reducing vibration. Most common methods of vibration are divided into passive, semi-active and active methods. Characteristic for active methods is that the parameters of these elements can change over time. The example presented here is made up of mechanical and hydraulic elements. By using the hydraulic subsystem, it is possible to change the power generated by this subsystem. Using a non-classical method as a design can also be used as a modification of existing systems [1-6].

2. Research problem and method

A solution to the inverse problem of dynamics is obtaining the structure of a system and the determination of its parameters (only inertial elements – *m* and elastic elements – *c*) depending on the required spectrum of frequency. Mechanical systems can be described by means of dynamic characteristic in the form of dynamic slowness *U(s)* (2). If we want to use passive elements to reduction vibrations we could use damper elements [1-4].

Values of individual frequencies (1):

$$\begin{cases} \omega_1 = 5\dfrac{rad}{s},\ \omega_3 = 15\dfrac{rad}{s} - \text{resonant frequencies,} \\ \omega_0 = 0\dfrac{rad}{s},\ \omega_2 = 10\dfrac{rad}{s} - \text{anti-resonant frequencies.} \end{cases} \tag{1}$$

As a result of the synthesis by means of the decomposition into a continued fraction one receives systems of the cascade structure.

$$U(s) = \frac{(s^2+\omega_1^2)(s^2+\omega_3^2)}{s(s^2+\omega_2^2)} = \frac{c_1}{s} + m_1 s + \cfrac{1}{\cfrac{s}{c_2} + \cfrac{1}{m_2 s}} = \frac{56}{s} + 1s + \cfrac{1}{\cfrac{s}{94} + \cfrac{1}{0.94s}} \tag{2}$$

The next step requires the assumption related to the external influence exerted on the system. In the case under discussion it was ascertained that the system was affected by the dynamic excitation, $F(t) = 1.5\sin\omega t\,[kN]$, on inert element 2 (Fig. 1). In order to reduce the system vibration caused by forces acting on the system it was chosen to use active elements. The method of active reduction of vibration is characterised by the fact that vibration is compensated by vibration from additional external sources. The system with active elements is presented in Fig. 2 [1-4].

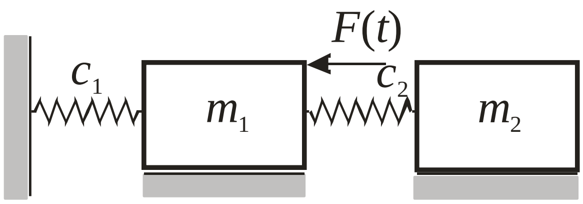

Figure1. System of two degrees of freedom.

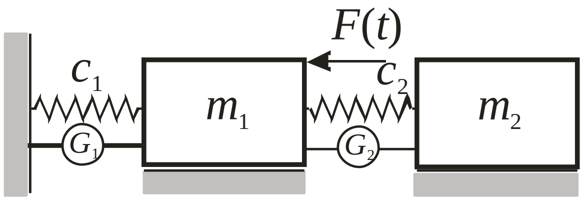

Figure 2. System of two degrees of freedom with active elements.

The work is limited to using only active elements. In the case of passive components, viscose dampers could be used.

In order to determine values of forces G_1 and G_2 generated by active elements, it is necessary to solve the system of equations (3), in the matrix form.

$$G = D \cdot A - F \tag{3}$$

where:
G – matrix of excitations generated by active elements,
D – matrix of dynamic stiffness,
A– matrix of amplitudes (approaching zero),
F – matrix of dynamic excitations.

Table 1. The values of active elements

No.	Frequency	The value of amplitude of force generated by active element [k*N*]
1	ω = 5 *rad/s*	$G_1 = 1.49$
2		$G_2 = 0.01$
3	ω = 15 *rad/s*	$G_1 = 1.5$
4		$G_2 = 0.06$

The hydraulic cylinder piston to be able to move freely in the body must remain slack, and that to achieve the movement it is necessary to pressure difference in the chambers between the piston body. For this purpose, the piston seals are located which allow the creation of a pressure difference, and thus, movement of the piston in one direction. The liquid under pressure is fed via connecting wires through the holes. To calculate the pressure that is needed to achieve the predetermined force is necessary to know the surface area of the piston side of the piston and of the rod. According to Pascal's Law, which says that the pressure exerted on the liquid spreads evenly in all directions, and therefore the pressure inside the body is exerted with the same force on each of its wall. That is, at the same pressure on both sides of the piston will remain at rest and will travel with a uniform motion, because the force is dependent on the surface that runs, and the surface of the rod is reduced by the cross sectional area of the piston rod [8].

Typical actuator consists of: cylindrical body, stuffing box (front cover), foot (rear cover), piston and piston rod with seals and piston and piston guide elements. Cylinders are designed for use at a variety of nominal pressure values - in industrial applications up to 210 bar (continuous) and up to 350 bars in presses and steel rolling mills.

The simplest construction is a single-acting actuator, in which the hydraulic oil is supplied only to one side of the piston, producing force and movement in one direction only. Gravity or external return

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springs move the piston into its initial position and the oil is back in the tank. In double-acting cylinders, hydraulic oil is applied to both sides of the piston, producing both force and movement when retracting and retracting the piston rod. Seals between the outer diameter of the piston and the inner diameter of the actuator body must ensure tightness when the piston moves in both directions. A variant of the two-stroke actuators is the two-piston rod actuator in which one piston rod passes through the front and the other through the rear cover.

If you need maximum force to reduce vibration is 2.0kN, it is necessary to the selection of the actuator with higher performance, so as to ensure the safety and does not strain the actuator during operation, which may lead to faster wear. With a diameter of 35 mm and 10 mm. The nominal working pressure for the cylinder is up to 20bar. With such parameters, the actuator is an active area of 9.621 cm^2, and 0.785mm^2. With such input data can be calculated and the selection of the parameters of pressure which should be obtained by the system to obtain the desired strength. From the formula (4) shown below, you can calculate the force that will be obtained [8-10].

$$G = P \cdot S \tag{4}$$

where:
P – pressure,
S – surface area.

Figures (3-6) present the comparative analysis of the system with and without vibration reduction. The analysis and synthesis were supported by the *Mathcad* programme used for determining the values of forces generated by active elements and for preparing the diagrams of amplitude-frequency functions.

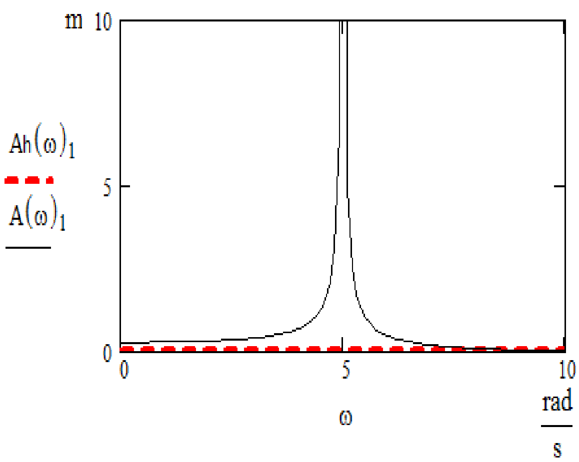

Figure 3. Diagram of A_1 amplitude (Fig.1) and Ah_1 displacement of a system with hydraulic elements (Fig. 2) at $\omega = \omega_1 = 5$ rad/s.

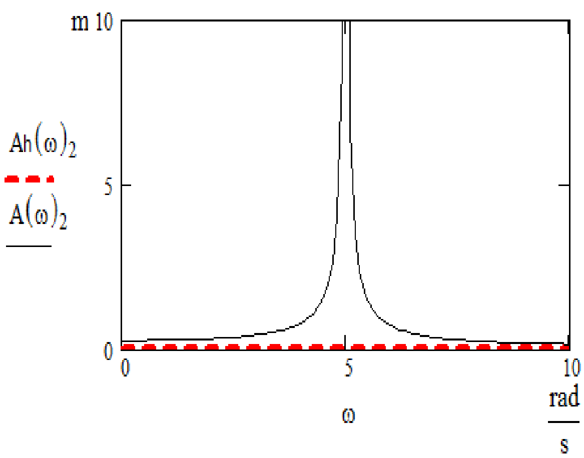

Figure 4. Diagram of A_2 amplitude (Fig.1) and Ah_2 displacement of a system with hydraulic elements (Fig. 2) at $\omega = \omega_1 = 5$ rad/s.

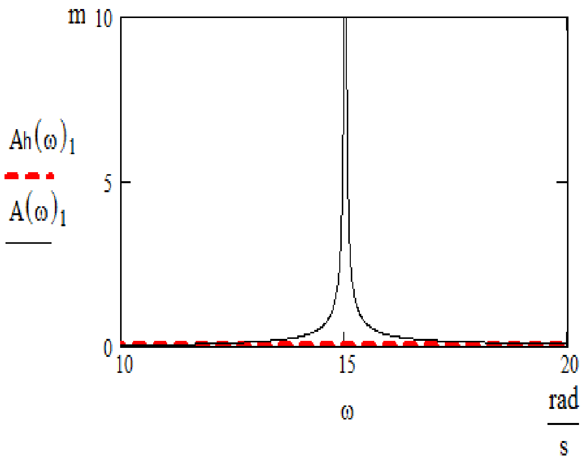

Figure 5. Diagram of A_1 amplitude (Fig.1) and Ah_1 displacement of a system with hydraulic elements (Fig. 2) at $\omega = \omega_3 = 15$ rad/s.

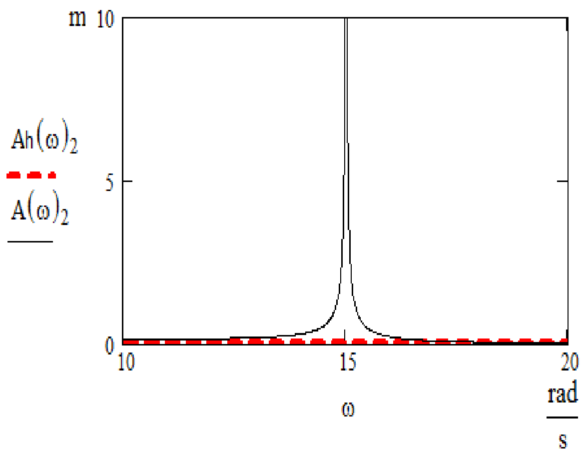

Figure 6. Diagram of A_2 amplitude (Fig.1) and Ah_2 displacement of a system with hydraulic elements (Fig. 2) at $\omega = \omega_3 = 15$ rad/s.

3. Conclusion

The working approach to the design of this type of system is a non-classical design method. The selection of hydraulic components was selected on the basis of folders companies producing hydraulic cylinders. However, it is the selection of the theoretical values meeting the desired requirements. Used data subject actuators unilateral action. In further consideration should examine the real possibility of implementing actuators that meet the specified parameters.

Hydraulic cylinders for industrial applications can be equipped with a position sensor (feedback) and electrohydraulic servo-valve, which allows the speed and position of the piston rod and the load to be controlled - and not just shifting the load to the full stroke distance. The scope of application of hydraulic cylinders is very wide - from the machine tool industry and the work of moving various objects (manipulation work) to drive the rolling mill in the metallurgical industry, control of equipment in nuclear power plants and in passenger and freight elevators.

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