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On the effect of the direction of external load application upon the change in stiffening behavior of rubber vibration isolators

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Abstract. The paper represents experimental results concerning determination of stiffening behavior of rubber vibration isolators depending upon the direction of external load application as well as fastening conditions. Paying attention to the fastening technique makes it possible not only to widen the area of application for vibration isolators, but to reduce the range of the ones being manufactured.

Introduction

Key point of vibratory transportation equipment is as follows: in the context of the drive, used in it, oscillatory movement, amplitude, and geometry of the operating member trajectory are determined only by following factors – force action (impact force), number, and mass of moving components as well as the amount, arrangement, and characteristics of elastic elements [1].

Currently, structures of vibratory transportation machines include elastic couplings in the form of either steel springs or rubber and rubber-metal parts. Elastic couplings of vibratory transportation machines differ in the types of deformation effecting the elastic components; those deformations are subdivided into compression, bending, and shearing ones. In the majority of cases, steel springs work in torsion, bending, and compression while rubber and rubber-metal parts work in compression, shearing, and shearing with compression [2].

Depending upon the material as well as deformation type and mode, each of the listed variety of elastic couplings has its own peculiar elastic properties with corresponding influencing upon the selection and calculation of stiffness parameters.

Determination of effective stiffening behaviour of elastic coupling is the important problem for the following calculation since the correct solution effects considerably the operation of a vibratory transportation machine and its performance in terms of the specified technological process.

Modulus of elasticity is one of the basic parameters to design rubber parts operating both in static and dynamic modes. In terms of such calculations, value of the elasticity modulus should not belong to rubber as to the material but it should belong to the whole

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component part since the component part geometry and fastening conditions change significantly the characteristics of a rubber component.

Nowadays, elastic couplings in the form of cylindrical rubber components with complex shape of free surface are rather wide spread [3]. Such components have considerable differences between compression stiffness and shearing stiffness due to the differences in elasticity moduli in those directions. Comparing to cylindrical ones, such components are characterized by the increased area of heat removal that makes it possible to use them in terms of intense modes of loading in screens, mixing machines, conveyors, and separators. Wider application of cylindrical rubber components with complex shape of free surface requires us to know their stiffening behaviour depending upon the direction of the external load action.

Purpose of the paper is to determine experimentally the changes in stiffening behavior of full-scale specimens of rubber components depending on the direction of external load action and conditions of their fastening.

Methodology

Two types of rubber vibration isolators have been tested: V-100 (diameter is 100 mm; height is 80 mm), V-101 (diameter is 100 mm; height is 127 mm), and V-103 (diameter is 20 mm; height is 150 mm). All the vibration isolators were made of the rubber from one batch. Each vibration isolator was pre-tested for axial stiffness in terms of quasi-static and dynamic loading modes. To carry out further tests, one pair of vibration isolators of each type with similar quasi-static stiffness were selected.

Quasi-static tests were performed in terms of special-purpose screw press with a self-braking device. Value of the generated load was recorded by means of reference dynamometer; movements due to the loading action were recorded with the help of dial indicator. Loading was generated gradually with five-minute delay at each stage. The delay was followed by the record of loading and movement readings.

Dynamic tests were carried out on a special-purpose stand where vibration insulator was effected by dynamic loading according to sinusoidal law with 1000±5 rpm frequency and 0.005 m amplitude. Dynamic loads were recorded by means of a measuring strain-gage bush.

In terms of all the test types, vibration isolators were fixed on the butt ends with the help of cups. Cups of 9 mm depth were used for vibration isolators V-100 and V-101; cups of 20 mm depth were used for vibration isolators V-103.

Each pair of vibration isolators of one standard size was fixed in special facilities which schemes are represented in Figure 1. Figure 1, a represents a scheme of compression loading of a vibration isolator with shearing at the angle of $\varphi = 30°$ and $\varphi = 60°$. Figure 1, b shows shearing angle $\varphi = 90°$, i.e. pure shear. Quasi-static shearing stiffness was measured in the context of the previously developed axial precompression by 10 % of the height of vibration isolators being tested. Figure 2 shows a device to test vibration isolators of V-100 type at an angle $\varphi = 30°$.

According to the measuring results, Figure 3 represents dependences of changes in quasi-static stiffness of C_∞ of vibration isolators upon φ angle of external loading application.

Figure 4 shows a stand with a device for dynamic tests at an angle $\varphi = 30°$.

Table 1 shows the results of determining values of quasi-static and dynamic stiffness of vibration isolators at different φ angles of external loading application.

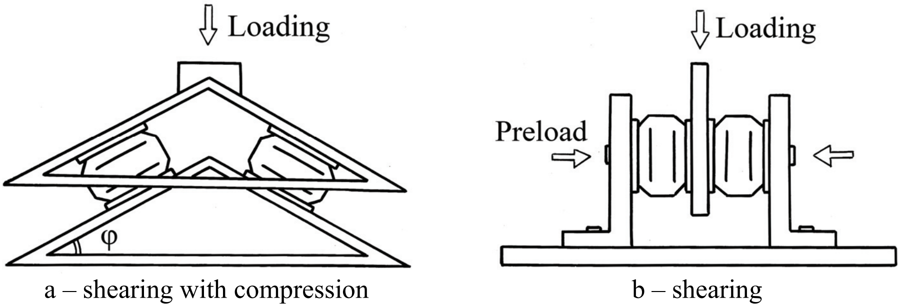

Fig. 1. Devices and schemes to load vibration isolators.

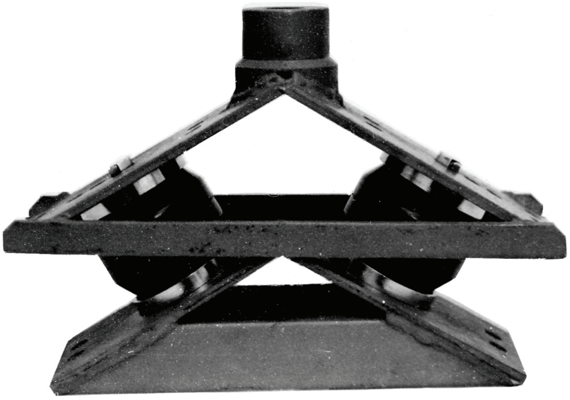

Fig. 2. Device to test vibration isolators of V-100 type at an angle φ = 30°.

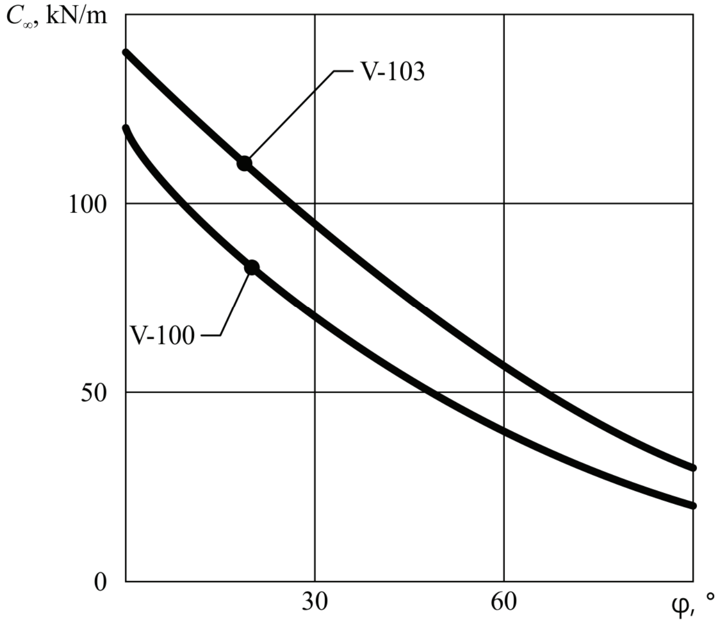

Fig. 3. Dependence of C_∞ upon angle φ for different types of vibration isolators.

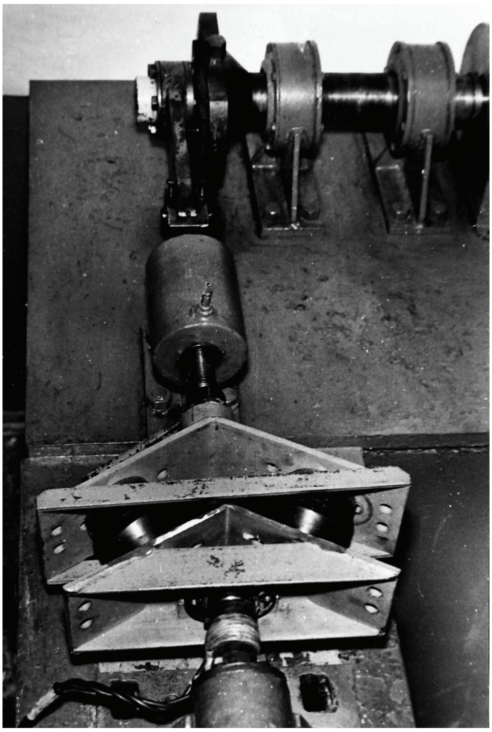

Fig. 4. Stand with a device for dynamic testing of vibration isolators at an angle φ = 30°.

Table 1. Results of determining stiffness of vibration isolators.

Type of vibration isolator	Stiffness of vibration isolators, kN/m					
	Quasi-static, C_∞				Dynamic, C_d	
	φ = 0°	φ = 30°	φ = 60°	φ = 90°	φ = 0°	φ = 30°
V-100	120.5	67.3	34.8	20.2	216.4	146.1
V-101	147.7	104.2	51.5	25.7	204.8	153.7
V-103	139.8	98.3	52.5	30.0	230.4	176.8

Table 2 represents values of the ratios of quasi-static and dynamic stiffness of vibration isolators in terms of different angles of external loading application.

Table 2. Values of the ratios of vibration isolators stiffness.

Type of vibration isolator	Quasi-statics			Dynamics
	$\frac{C_\infty^{\varphi=0^\circ}}{C_\infty^{\varphi=30^\circ}}$	$\frac{C_\infty^{\varphi=0^\circ}}{C_\infty^{\varphi=60^\circ}}$	$\frac{C_\infty^{\varphi=0^\circ}}{C_\infty^{\varphi=90^\circ}}$	$\frac{C_d^{\varphi=0^\circ}}{C_d^{\varphi=30^\circ}}$
V-100	1.79	3.46	5.96	1.48
V-101	1.41	2.86	5.75	1.33
V-103	1.42	2.66	4.66	1.3

Increment of heating-up temperature inside the vibration isolators in terms of the effecting external loading at an angle φ = 30° was 1.5-3.5 °C comparing to the axial compression (φ = 0°).

To determine the effect of fastening type of a vibration isolator on butt ends (with the help of cups and without them), quasi-static tests of vibration isolator V-103 with the cups of 20 mm and 50 mm depth were carried out. Table 3 generalizes the testing results.

Table 3. Effect of the available cups of the rubber component V-103 on butt-ends upon the quasi-static stiffness.

Conditions of the applied loading	Quasi-static stiffness, kN/m		
	Without cups	With cups (depths):	
		20 mm	50 mm
Axial compression (φ = 0°)	108.3	139.8	241.6
Compression with shearing, if:			
φ = 30°	78.2	98.3	175.0
φ = 60°	42.4	52.5	98.3
Pure shearing (φ = 90°)	8.3	30.0	40.0

Results and their discussion

Analysis of the obtained results shows following facts:

- rubber components demonstrate the highest quasi-static stiffness in terms of axial compression; the lowest quasi-static stiffness is observed in terms of shearing; and intermediate stiffness values are seen in terms of shearing with compression;
- changes in the values of dynamic stiffness of rubber components are of the same tendency as the changes in quasi-static one;
- changes in the angle of external loading application have practically no effect upon the heating-up temperature increase inside a rubber mass of a vibration isolator;
- a technique of rubber component fastening effects considerably its stiffness behavior.

Thus, the available cups of 20 mm depth increase the rubber component stiffness by 25-30 % comparing to free fastening. If the cup depth changes from 20 mm down to 50 mm, that results in stiffness increase by 70-80 %.

Conclusions

1. Angle of external loading application upon a rubber vibration isolator results in its stiffness changes; that should be taken into consideration while designing vibratory transportation machines, especially the ones of a resonant type.

2. Fastening technique, applied to rubber vibration isolator, effects significantly its stiffness behavior. Paying attention to the fastening technique makes it possible not only to widen the area of application for vibration isolators, but to reduce the range of the ones being manufactured.

References

1. Vaysberg, L.A. (1986). *Proyektirovaniye i raschet vibratsionnykh grokhotov*. Moskva: Nauka
2. Poturayev, V.N., Dyrda, V.I. (1977). *Rezinovyye detali mashin*. Moskva: Mashinostroyeniye
3. Bulat, A.F., Dyrda, V.I., et al. (2016). *Elastomery v gornom dele*. Kyiv: Naukova dumka