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EXPERIMENTAL DETERMINATION OF THE VARIATION OF THE ELASTIC DAMPING PROPERTIES MR MATERIAL IN A CONTINUOUS OPERATION

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ABSTRACT

The MP material is a porous structure produced by means of cold molding of the metal spiral pieces into the finished in terms of the shape and dimensions elastic members from which the vibration isolators are formed [1, 2]. The efficiency of use of the MP material in the anti-vibration systems depends largely on its elastic damping properties during operation. The empirical dependences of change of the MP material mechanical properties on the run time have been presented. The work is of experimental nature, the correlation between the process and operational parameters is based on the similarity theory and dimensional analysis. The findings of the research for the practical application are obtained in closed form.

Keywords: MP material, elastic member, vibration isolator, damper, hysteresis, stiffness, elasticity.

1. INTRODUCTION

The main requirement set up to the vibration-isolating and damping devices from the MP material under the steady cyclic loading consists in ensuring consistency of their elastic damping properties [4, 5] that are fully determined by the energy dissipation ratio, equivalent stiffness [6] and the value of residual information (dynamic shrinkage).

The coefficient of dissipation of energy in the material ψ is taken as the ratio between the energy dissipated during a cycle and the maximum potential energy of deformation. The relative equivalent stiffness is taken as $\overline{C_э} = \frac{C_э}{C_р}$ where $C_э$ is the equivalent stiffness (according to the direct polarization method), $C_р = \frac{T}{a}$ -.

$\overline{A} = \frac{A}{a}$ - stratified stiffness, relative strain amplitude; A – strain amplitude. T, a – ratio of the similar transformations on loading and shifting obtained under the condition $\overline{A} = 5$ [3].

Procedure: The task consisted in description of the behavior of the material properties during operation and determination of the main factors affecting this behavior. The study was performed on the sleeve elements (SE) assembled into an absorber (damper) according to the schedule of a two-direction hysteresis stop [7]. The experimental processing was performed with the use of the generalized variables method allowing excluding from consideration the direct impact of the geometrical dimensions, shape and initial parameters of the material.

2. METHODS AND MATERIALS

The long-duration testing was performed on the UKI-10M unit. The change of the performance with the run time was determined by the change of the dissipation ratio and equivalent stiffness at the static test unit.

In the Figure-1 there is the dependence of change of the dissipation factor during operation under different operating conditions.

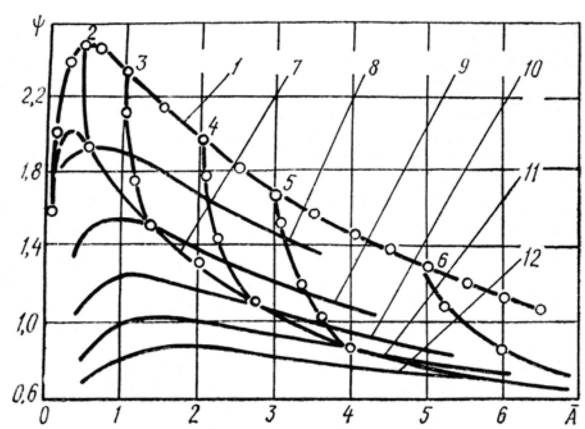

Figure-1. Dependence of the coefficient of the energy dissipation in the material on the relative strain amplitude during operation.

On the initial curve (1) a few points have been selected (2, 3, 4, 5, 6) corresponding to different relative strain amplitudes.

Starting from the first cycles the process of deformation of the SE was followed by the reduction of the dissipation factor for all modes. However, the nature and rate of the change was different and if the loading rate is constant they depended on the strain amplitude only. The reduction of the dissipation factor with increase in the run time is related to the changed nature of interaction between the elements at the contact points. During the

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running-in period the process curve changes to the operating one: the area of the actual contact increases, the fluid friction changes to the boundary one, the friction factor increases. As the results of the friction increase some elements (spiral turns) lose ability to the relative motion at the contact points and form the fixed element connections. In the contacts with the retained mobility after increase in the friction factor the temperature grows intensively.

The raise of temperature in a contact results in the seizure of surfaces. In this case the contacts forming fixed connections of elements increase the share of the fixed connections in the sample, and in the contacts with unstable seizure areas the abnormal wear is developed. This period of operation is characterized by the intensive surface destruction at the element contact points, the profuse discharge of the wear products and high rate of reduction of the dissipation factor in the processes 2, 3, 4, 5, 6 (Figure-1). The vibration heating of the sample results in the change of the mechanical change of the source material properties and deterioration of their elastic properties.

After a certain number of cycles equal to the number of setting cycles due to the wear the compression loads between the elements are reduced and the temperature in the sample drops. The material structure (ratio between the movable and fixed contacts) is stabilized. Changing of the dissipation factor proceeds according to the law 7 (Figure-1) that is common for all modes. At the same time the rate of change is reduced significantly, however, still remains different for each mode. Transition from one mode to another during the entire running period is performed according to the processes that are identical 8, 9, 10, 11, 12 in their form but located on the different dissipation factor levels.

The change of the relative equivalent stiffness depending on the relative strain amplitude during running (Figure-2) proceeds according to the initial law 1 towards the amplitude increase. At the small amplitudes $\overline{A} < 3$ the process of formation of the fixed element connections is expressed rather weaker as compared to the wear at the contact points. With the appearance of the wear areas the stiffness of connections between the elements is weakened that's why under normal conditions of loading (boundary friction, normal wear and tear) the relative stiffness of the SE decreases. Upon violation of the boundary friction conditions the change of the relative stiffness may precede according to the laws that differ from the initial one and under the hard friction modes (internal friction) the relative stiffness may increase.

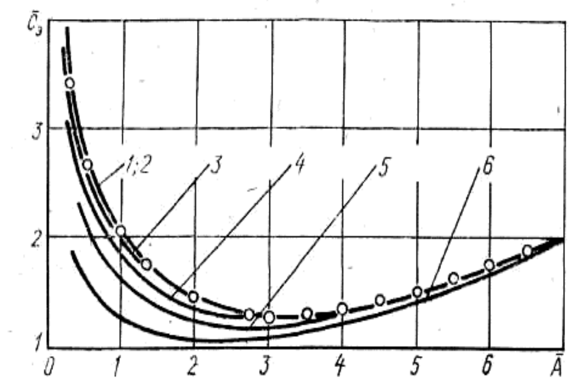

Figure-2. Dependence of the relative equivalent stiffness on the relative strain amplitude during running.

At the amplitudes $\overline{A} > 3$ the compression loads and vibration rate in the contacts increase, the friction factor as well as the temperature rises; the number of the fixed connections grows which results in the raise of the relative stiffness of the sleeve elements.

In the neighborhood of the point $\overline{A} = 3$ there is a balance between the processes of the connection weakening due to the wear and formation of the fixed element connections due to the increased friction factor. In this area the change of the relative stiffness during running is not significant.

By transition from a herder loading mode to an easier one (from the large relative amplitudes to small ones) the change of the stiffness proceeds according to the processes that are identical to 2, 3, 4, 5, 6. Such behavior is caused by the element wear and appearance of the dynamic setting of the sleeve elements.

The most efficient way of improving the stability of the material properties during operation is the change of the friction pattern in the contacts, for example, by means of the sample lubrication. Fluid, consistent and solid lubricants may be used for these purposes. The given dependences (Figure-3) allow drawing the conclusion on the efficiency of each method. Liquid fluids are efficient in terms of the material cooling, especially during circulation within the element contact area, however, the complicacy of application and low reliability of the oil preservation within the contact area restrict the wide use thereof. The use of the consistent lubricants is more available; however, this method of the wear prevention is not always efficient at the high vibration rates of the material deformation due to the fast lubricant burn-out.

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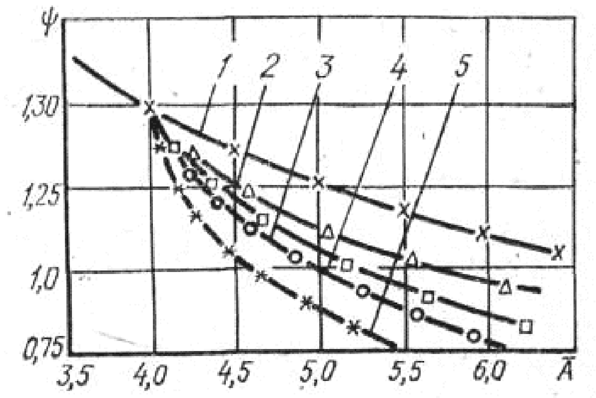

Figure-3. Impact of the lubricant kind on the friction factor behavior during operation: 1- initial curve (statics); 2 - fluid lubricant; 3 - solid lubricant; 4 - consistent lubricant; 5 - lubricant in the supply state.

The use of the solid lubricants on the basis of graphite or molybdenum disulphide may be considered to be prospective. The solid lubricants significantly reduce the wear within a wide range of rates of the contact surfaces sliding. In this case the main difficulty consists in the method of application of a thin lubricating film and further thermal treatment of the protective coat. However, the first experiments show that in the future this approach may significantly contribute to the solution of the issue concerning stability of the MP material properties under the cyclic loading conditions.

Another factor determining the stability of the properties of products made from the MP material is the dynamic shrinkage (setting) representing the difference between the height of the statically aged sample before and after testing. Accounting for the dynamic shrinkage is necessary by design of the sleeve absorbers and dampers for the normal operation of which during the entire life-time the following condition shall be satisfied:

$$A + У_ц \geq \Delta, \tag{1}$$

where $У_ц$ is the dynamic shrinkage;
Δ - axial preload of the elastic elements.

Breach of the condition (1) results in the appearance of the intermittent detachment of the elastic-damping elements of the vibration isolator and progressive fatigue material damage.

Starting from the first loading cycles the sample temperature increases gradually and reaches depending on the strain amplitude, frequency and duration of loading 150-350 °C. The raise of the temperature results in the burn-out of the lubricant and increase of the friction factor at the element contact points (spiral turns). The boundary friction changes to the dry friction and under the hard friction conditions (high vibration levels, large specific pressures, etc.) the external friction changes to the internal one. The element contact surfaces are seized and their relative displacement is followed by the significant surface damage and formation of the wear areas. The consequence of this is that after unloading the sample does not regain its original shape since the element elastic forces are not sufficient to exceed the friction forces in the contacts and bring the elements to their initial position.

Upon expiration of a certain running period depending on the friction conditions as the result of wear the compression loads and friction forces at the element contact points are reduced. This is accompanied by the sample temperature fall and reduced rate of increase in the dynamic setting. Experiments proved that the behavior of the dynamic setting depending on the deformation cycles number is determined according to the formula:

$$\frac{У_ц}{У_{цс}} = 1 - e^{-4N/N_c}.$$

The number of the deformation cycles (N) at which the fall of the sample vibration heating temperature and significant reduction of the shrinkage increase is observed may be taken as the number of the stabilization cycles N_c and the time during which the shrinkage has reached its stabilized value $У_{цс}$ - the stabilization time.

The duration and number of the stabilization cycles depend on the conditions and the sample deformation pattern. It follows from the diagram (Figure-4) that longer stabilization time corresponds to the smaller amplitude. After dynamic stabilization the shrinkage continues increasing, however, the increase value is not significant and does not exceed 10-15 % (Figure-4).

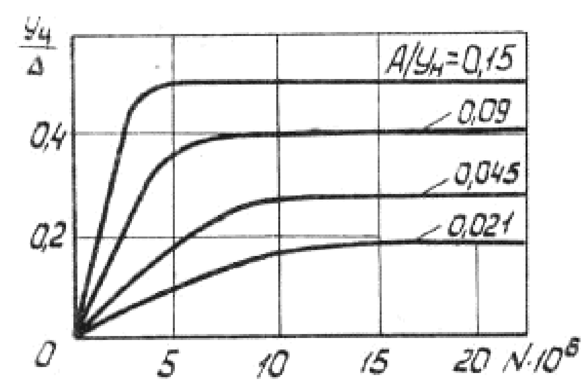

Figure-4. Process of the dynamic shrinkage stabilization.

The stabilized value of shrinkage under the normal loading conditions (within the limits of the permissible material deformation, without additional lubrication, at the temperature 0-150 °C) is mostly determined by the deformation amplitude and density of the semi-finished piece:

$$\frac{У_{цс}}{\Delta} = 1,8\sqrt{\frac{A}{У_{н}}}\left(1 - 4,6\frac{\rho_{з}}{\rho_{и}}\right),$$

where $У_{и}$ is the maximum deformation of an elastic element;
$\rho_{з}$ - density of the elastic element piece;
$\rho_{и}$ - density of the source wire material.

Thus, the causes of the dynamic shrinkage are the increase in the friction factor and wear at the points of contact of the elements made from the MP material as well as plastic deformations of elements due to the vibro-packing and heating thereof [8]. That's why in order to improve the stability of the elastic properties of the material and increase the vibration strength of the elastic elements it is needed to reduce the friction forces at the contact points since they determine the element wear and temperature behavior of the sample.

3. CONCLUSIONS

Thus, the experiments proved that the significant impact on the behavior of the material properties is exercised by the vibration speed determined by the deformation amplitude and loading frequency. The vibration speed relates to the temperature behavior at the element contact points, wear intensity, the nature of the friction process and as a result the change of the stiffness and elastic properties of the MP material as well as change of the mechanical characteristics of the source wire material causing plastic deformations in the material. That's why in order to improve the stability of the elastic material properties first of all it is needed to reduce the friction forces in the contacts since they determine the element wear and temperature behavior of the sample.

REFERENCES

[1] Ponomarev Yu.K., Ermakov A.I., Simakov O.B., Mikhalkin I.K. 2013. Metallic counterpart of rubber: a material for vibration and shock protection. Metallovedenie I termicheskaya obrabotka metallov. 1(691): 8-13.

[2] Ponomarev Yu.K., Ermakov A.I., Simakov O.B., Mikhalkin I.K. 2013. Metallic counterpart of rubber: a material for vibration and shock protection. Metallovedenie I termicheskaya obrabotka metallov. 1(691): 8-13.

[3] Buzitsky V.N., Troynikov A.A. Calculation sleeve shock absorbers. - In: Seismic resistance and reliability of aircraft engines and systems ap-preparations. Kuibyshev. Vol. 3.

[4] Ulanov A.M., Ponomarev Yu.K. 2009. Finite element analysis of elastic-hysteretic systems with regard to damping. Russian Aeronautics. 52(3): 264-270.

[5] Jiang H.-Y., Hao D.-G., Xia Y.-H., Ulanov A.M., Ponomarev Y.K. 2005. Damping characteristics calculation method of metal dry friction isolators. Journal of Beijing Institute of Technology (English Edition). 17(2): 173-177.

[6] Ao H.-R., Jiang H.-Y., Yan H., Xia Y.-H., Ulanov A.M. 2005. Research of a metal rubber isolation system based on complex stiffness. Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology. 37(12).

[7] Yan H., Wang L., Jiang H.-Y., Ulannov A.M. 2010. RETRACTED ARTICLE: Analysis of the basic mechanical parameters of metal rubber materials. ICACTE 2010 - 2010 3rd International Conference on Advanced Computer Theory and Engineering, Proceedings. 1, art. No. 5578992, pp. V1396-V1399.

[8] Ao H., Jiang H., Ulanov A.M. 2006. Estimation of the fatigue lifetime of metal rubber isolator with dry friction damping. Key Engineering Materials. 326-328 II, pp. 949-952.