THE MODEL OF DIAGNOSTIC OF NONLINEAR VISCOELASTOMERIC DAMPER

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Summary

Damping of mechanical vibrations is often realized by viscous dampers with nonlinear characteristic. The progressive wear them leads to a deterioration of working conditions of machinery and vehicles. Bad technical condition of the damper also adversely affects the occupants of the means of transport. In many cases, there are no effective methods for determining their condition. The aim of the study was to develop a computational model of the viscous damper takes account of the characteristics such as nonlinearity and asymmetry and its dependence on the parameters of extortion. Taking into account the impact of these factors on the instantaneous value of the force generated by the element enables the use of computational model to determine the technical condition.

Keywords: vibration damping, nonlinear effects, diagnosis, diagnostic model

MODEL DIAGNOSTYCZNY NIELINIOWEGO LEPKO-SPRĘŻYSTEGO TŁUMIKA DRGAŃ

Streszczenie

Tłumienie drgań mechanicznych jest często realizowane przez tłumiki wiskotyczne o nieliniowych charakterystykach. Stopniowe ich zużywanie się prowadzi do pogorszenia warunków pracy maszyn i pojazdów. Zły stan techniczny tłumika drgań wpływa również niekorzystnie na osoby przebywające w środkach transportu. W wielu przypadkach brak jest skutecznych metod określania ich stanu technicznego. Celem badań było opracowanie modelu obliczeniowego wiskotycznego tłumika drgań uwzględniającego jego cechy takie jak nieliniowość i niesymetryczność charakterystyki oraz jej zależność od parametrów wymuszenia. Uwzględnienie wpływu wymienionych czynników na chwilowe wartości siły generowanej przez taki element umożliwia wykorzystanie modelu obliczeniowego do wyznaczania miar stanu technicznego.

Słowa kluczowe: tłumienie drgań, efekty nieliniowe, diagnozowanie, model diagnostyczny

1. INTRODUCTION

Determining the state of the machine or the machine often makes it necessary to use large databases. Collecting diagnostic information during the experiments on real objects is time consuming and very costly. An alternative procedure is to perform simulation experiments on mathematical models. The task of diagnosing a technical object often necessitates troubleshooting based on the early symptoms of the condition. In practice, this often means the use of methods for the analysis of vibro-acoustic disturbances of low-energy signals [9, 12, 17, 18]. In this case, a necessary condition is to use a detailed model that in the best possible extent reflects reality. Determination of the current and future state allows the use of technical effective countermeasures. This allows you to avoid failure. The advantage of simulation diagnostics is also possible to optimize the process control operation [13, 14, 15, 16].

A difficult issue is the operation of a motor vehicle diagnostics built in shock absorber suspension. The fundamental role it plays shock is associated with a reduction of relative movements sprung and unsprung masses. The essence of the problem lies in the fact that despite the relative simplicity of construction automobile shock absorber is a component of the complex, non-linear dynamic properties. The aim of the study was to develop a dynamic model that takes account of the automobile shock absorber characteristics such as nonlinearity and asymmetry damping characteristics and its dependence on the parameters of extortion. Moreover, the model has taken into account the phenomenon of apparent stiffness of the shock absorber. Taking into account the effect of these parameters on the instantaneous value of the force generated by the damper allowed the development of a model that is compatible with the real object.

2. MODELING OF AUTOMOTIVE SHOCK ABSORBERS

The suspension dynamics simulations vehicles commonly used procedure is to model the shock absorber to a great extent simplification. The greatest possible simplification of the model in the form of the damping constant damping coefficient. Depending on the parent to conduct simulation studies, this approach is often justified, for example DOF simple models used to test control algorithms for vibration.

Features real damper is nonlinear and often asymmetric with respect to the origin [1, 4, 5, 6]. Depending on the damping force of the damper piston relative speed can be modeled using functions (eg. a polynomial of n-th degree) is determined separately for the movement of reflection and deflection.

In modeling the nonlinear damping characteristics of the shock absorber uses the theory of spline functions. The non-linear damper model is defined by a set of basis points by which the characteristic curve is determined conducted by spline functions. Such models can be found in commercial programs for the analysis of dynamic phenomena occurring in vehicles [20].

In each example cited previously attenuation modeling assumed uniqueness of the instantaneous value of the force generated by the shock absorber to the instantaneous value of the relative speed of movement of the piston and damper housing. Assumption leads to the conclusion that the shock absorber car is part of the viscous damping and the strength of the resistance movement in all conditions depends only on the velocity of extortion. This is a serious limitation of the range of dynamic models discussed the adequacy of the shock absorber to the range of low-frequency excitations. For such excitations do not occur the phenomenon of apparent stiffness of the damper and the effect is negligible influence of the amplitude of the pitch to force in the shape of the damping characteristics.

For the analysis of the dynamics of the shock absorber for higher frequency vibrations influence these parameters is significant. The phenomenon of apparent stiffness of the shock absorber test the position of the indicator illustrated by Figures 1.

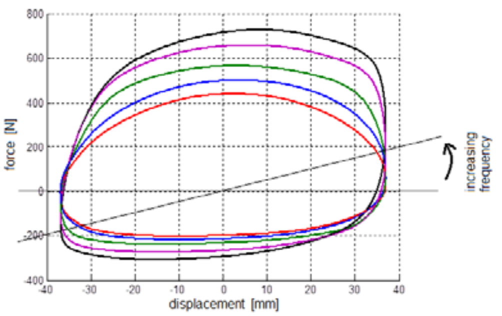

Fig. 1. The set of graphs operation of damper for a variety of frequency excitations

The higher the force, the greater the value of the seeming stiffness. This can be seen in the velocities graph as a widening of their width close to zero velocity override. Thus, the force generated by the shock absorber is the sum of two components: the suppression and seeming stiffness [4, 7, 8, 19].

Another aspect of examining the accuracy of computational models is the phenomenon of impact shock stroke length to force the shape of the damping characteristics. In the case of a sinusoidal force maximum velocity of the reciprocating motion of the piston of the shock absorber always get the time for which the offset value is zero, assuming that the origin is located in the middle of the length of the working stroke. The maximum value of the velocity force can be achieved in two ways - by increasing the length of the working stroke for a fixed frequency or force at a constant stroke length by changing the frequency of the force. Designated by such methods damping characteristics demonstrate compliance only when using the low-frequency excitations. In real traffic conditions, vehicle vibration from a wide range of frequencies, and the velocity of movement of the piston of the shock absorber of a few m/s occur for both the long and short of working strokes. For this reason, it is appropriate considering the damping characteristics of the shock absorber as a function of the two-argument. This approach was proposed in [2].

Empirically determined area representing the properties of the shock absorber in a limited range of variation of extortion is a model of the damper, in which it is assumed damping force dependence of the instantaneous value of the speed of movement of the piston, and the total length of the working stroke.

Property briefly discussed hydraulic shock absorber raises a question regarding the required level of detail of the model dynamic damper, which will be the basis for the development of diagnostic measures. The model being developed, the following assumptions:

- take into account the seeming stiffness of the shock absorber,
- defining the damping characteristics as a function of the two-argument [7, 8, 19, 21].

3. RESEARCH SHOCK ABSORBERS BENCH

Shock absorbers study performed on a digital recording of the indicator results. The position is driven by AC motor with adjustable using the drive speed. The drive from the engine is transmitted via a belt drive with toothed belt on the system by leaps and bounds crank radius adjustable crank. The movement of the shock absorber lower mounting is caused by the position of the slider mechanism and the upper suspension strut is attached to a strain gauge force transducer.

In order to determine the dynamic parameters of the hydraulic shock absorber, a number of studies in which used different combinations of length and frequency of working strokes of extortion.

Recording of results were made for each test frequency. To give a series of files, which contain the forces generated by the shock absorber. In order to determine the damping characteristics of the shock absorber to the charts work read maximum values of the forces in tension and compression at times where the rate of reciprocation of the slider position with the maximum cylinder pressure. In this way, for the working stroke of the shock absorber is replaced by a series of damping force obtained for the subsequent frequency domains.

The strong dependence of the damping characteristics of the working stroke length determines the need to take account of this phenomenon in computational models of liquids shock absorbers. The relationship describing this phenomenon in general is as follows:

$$F_d = f(v, w_g) \quad (1)$$

where: v - the current velocity of extortion, w_s - the total length of the stroke force

In the study was also determined the relationship describing the apparent stiffness of the damper. In experiment obtained values of seeming stiffness force for different frequency and different length of stroke. For each test a combination of stroke length and frequency domains of work were read chart of the forces that were generated by the shock absorber in times of zero value velocity extortion.

Characteristics of seeming stiffness of the damper force is a function of frequency and displacement force. So we can force seeming stiffness of the damper represented as:

$$F_{ss} = f(d, f) \quad (2)$$

where: d - kinetically forced displacement, f - frequency of extortion

The effect of frequency domains damper way of working is very significant. Twice a change in the frequency of working strokes absorber results in almost 50% increase in strength resulting from the elastic properties of the shock absorber. It should be noted that the ratio of the stiffness of the damper takes almost zero values for frequencies less than 0.5 Hz.

Consideration of dependencies described in Equations 1 and 2 allows to introduce the viscous vibration damper model as a pair of graphs surface (Fig. 2 and 3).

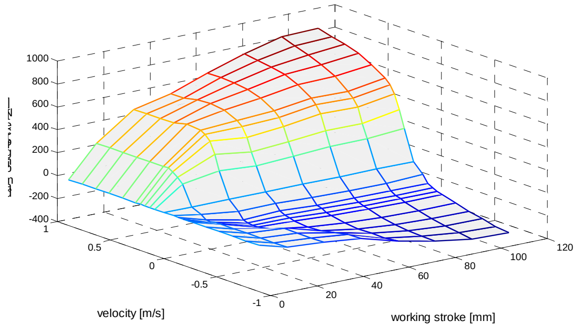

Fig. 2. The surface of damping force values

Instantaneous damping forces and apparent modulus may be based on such a model set by interpolation. So the appointment of the approximate values of the function at points other than nodes and estimation error of the approximate values. To do this, need find a function *F(x),* called the interpolation function, which in the nodes of interpolation has the same values as the function *y=f(x).*

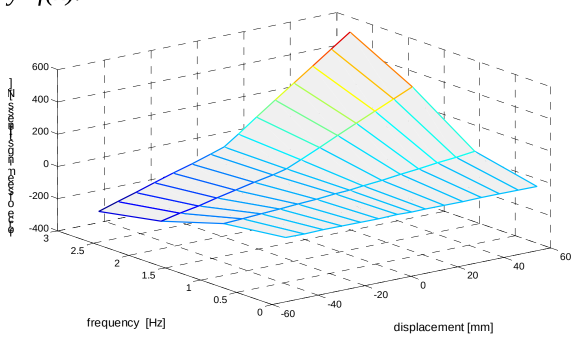

Fig. 3. The surface of seeming stiffness force values

Interpolation is in a sense opposite to the tabulation task functions. With the analytical form of the function build an array of values, while interpolation based on an array of functions we define its analytical form. The best way to determine the values of the damping forces and apparent resilience is a two-argument function interpolation using the theory of spline functions.

4. VISCOSITY-ELASTIC MODEL OF THE SHOCK ABSORBER

The obtained experimental results were used to develop a computational model of dynamic damper. The model consists of two equal modules, the structure bears some resemblance. The purpose of each module is to determine in each subsequent iteration of the damping forces, respectively, and the apparent stiffness of the damper according to an algorithm based on the method of interpolation functions of the two-argument.

Diagram of the algorithm used in the model to determine the response to the force of the shock absorber shown in Figure 4.

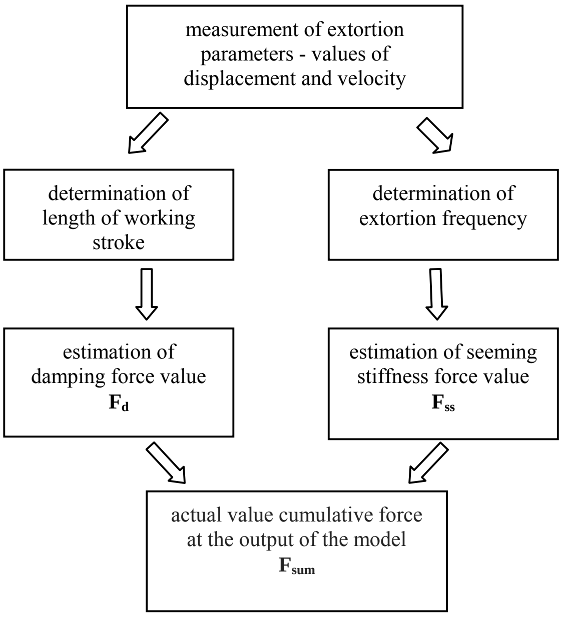

Fig.4. Scheme of the algorithm

Each module defines a model independently of the damping force, respectively, and the apparent elasticity. View main window model made in MATLAB / SIMULINK is shown in Fig. 5.

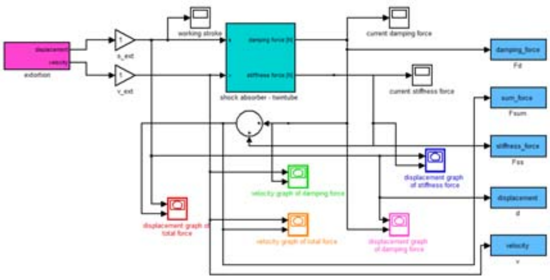

Fig. 5. Graphical model of damper

In the developed model to determine the value of the damping forces and apparent elasticity method was applied based on the interpolation of two-argument functions using the theory of spline functions. Examples of the results of the model for the selected parameters represent the force Fig. 6 to 14.

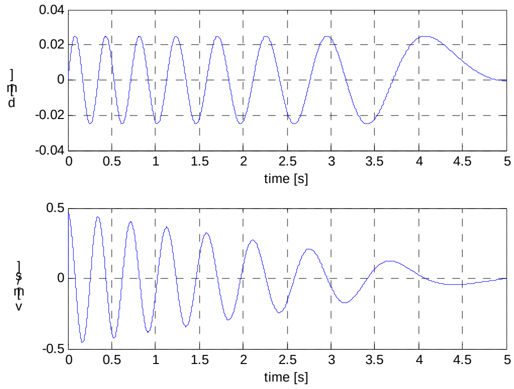

Fig. 6. Recorded parameters to force - working stroke of 25 mm

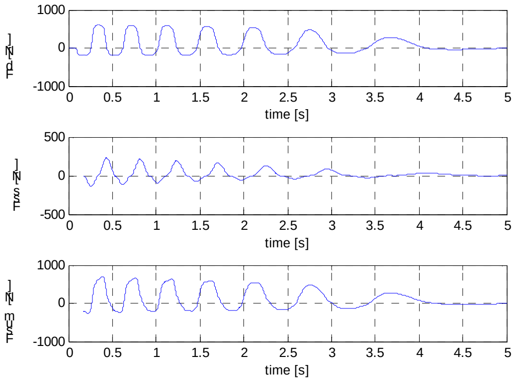

Fig.7 . Response time model - working stroke of 25 mm

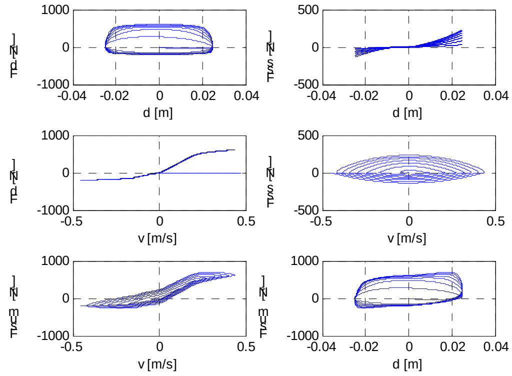

Fig. 8. Simulation results - 25 mm stroke force

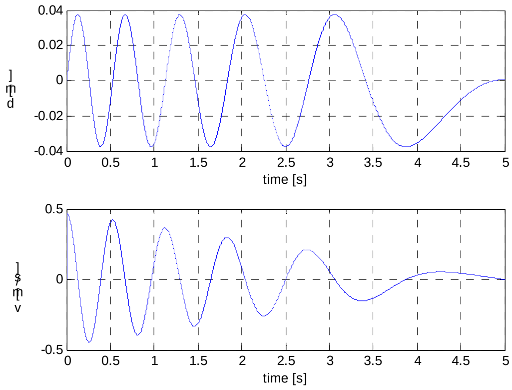

Fig. 9. Recorded parameters to force - working stroke of 37,5 mm

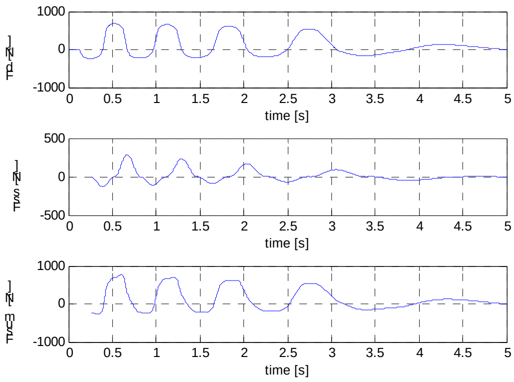

Fig. 10. Response time model - working stroke of 37,5 mm

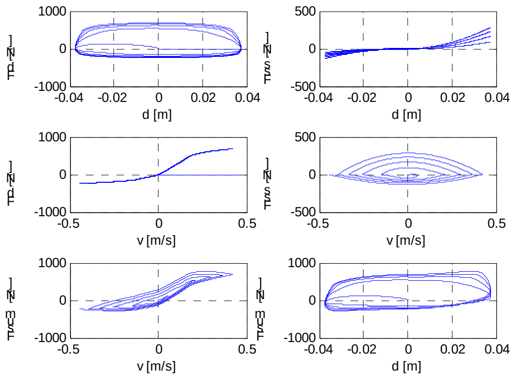

Fig. 11. Simulation results - 37,5 mm stroke force

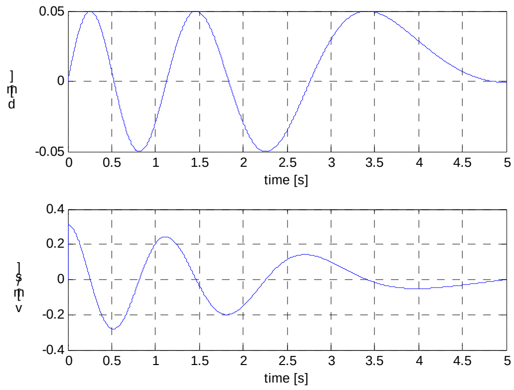

Fig. 12. Recorded parameters to force - working stroke of 50 mm

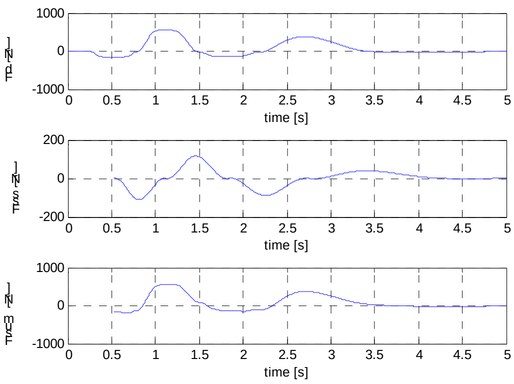

Fig. 13. Response time model - working stroke of 50 mm

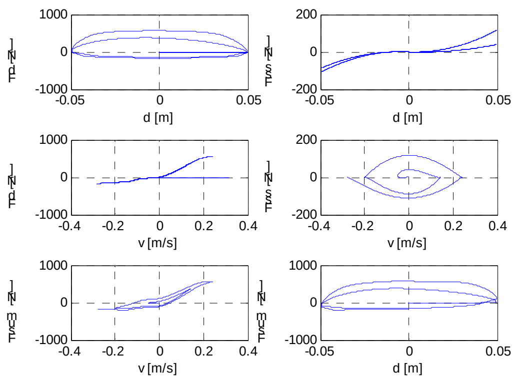

Fig. 14. Simulation results - 50 mm stroke force

The model has been identified for specific ranges of parameters force, which also constitute the arguments to the function describing the damping properties, and seemingly elastic shock absorber.

The results of simulation tests show its strong resemblance to the behavior of the actual item damping suspension test for the laboratory stand.

5. CONCLUSION

This enables the use of model visco-elastic shock absorber to develop the knowledge base necessary in the process of prototyping new shock absorber design solutions and later their diagnosis.

The structure of the model allows you to enter any data sets containing the damping characteristics and the seeming stiffness of the shock absorbers of new and damaged.

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