

CONSIDERATIONS ON THE COMPOSITE NEOPRENE VIBRATION ISOLATORS USED FOR THE MECHANICAL SYSTEMS BEARINGS. THE DYNAMICS OF THE NON-LINEAR MODELS

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Abstract: The study presents the results of theoretical and experimental researches and numerical modeling for some composite material structures of neoprene used to manufacture the viscous-elastic supports of the technological equipment with dynamic loads. This kind of equipment, which has a high level of vibration and mechanical shocks, can transmit great dynamic forces and mechanical moments to the environment through the bearings. The analyzed theoretical models are characterized by the rigidity coefficient and by the dissipation coefficient, making obvious the advantages of some types of composite structures. The article presents the amplitude and the power diagrams function of non-linear damping coefficients for some technological equipment.

1. INTRODUCTION

In order to damp dynamic action through shocks and vibrations, the bearings of the technological equipment have to comply with the following conditions: a good bearing capacity by appropriate values of the mechanical resistance, a good rigidity in order to attain static deflections under loading conducting to avoid the significant and possible destroying resonance and an optimum relative to low rigidity and high internal dissipation.

Construction of passive insulation elements in neoprene single microstructure mixture has demonstrated that the isolators can have the necessary elastic characteristics but low internal damping.

2. PHYSICAL MODELS OF THE COMPOSITE NEOPRENE BASED BEARING

The most frequent passive isolation systems are realized based on neoprene elements in a sandwich construction having intermediary steel shims and the same neoprene mixture for each layer. To fulfill the above desiderates, it has to take into consideration a new approach regarding realization and modeling of the isolators from composite neoprene. The structure is made from micro structural composite rubber by using some appropriate grading of the powder materials – smoke black and air introduction in nanometer spaces by cork poudrette or chemical foam compound.

The macrostructure composite isolator consists of identical neoprene layers separated by steel shims, each layer consisting of macrostructure distinct units having various physic-mechanical characteristics.

The rheological modeling for the neoprene isolator behavior shows the increase of the internal energy dissipation by increasing of the hysteretic factor (damping structure coefficient).

According to [1], the rheological modeling for the neoprene isolators with composite structures puts into evidence the possibility to realize these type of dampers based on microstructure composite mixture consisting of neoprene smoke black and chemical foam compound or solids with entrapped air (cork poudrette).

Figure 1 and fig. 2 show the microstructures of two types of rubber used for macrostructure composite; the physic-mechanical characteristics of these rubber types are shown in Table 1. The mechanical characteristics of the units made from these rubber types are shown in Table 2.

Figure 3 shows the macrostructure of one layer of composite neoprene made from two units of SAB 31 and two units of SAB 4a. The sizes $A \times B \times h$ of each unit are $0.5 \times 0.5 \times 0.25$ [m].

The bearing with sandwich composite structure shown in fig. 4 is made from four identical layers (as in fig. 3) with the sizes $a \times b \times h$ $1 \times 1 \times 1$ [m]. Table 3 shows the mechanical characteristics of the sandwiches (composite structures/materials).

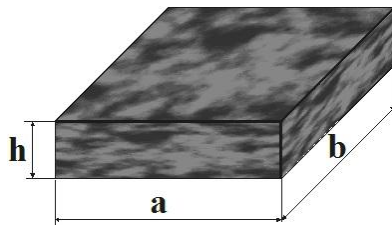


Fig. 1 Neoprene type SAB 31

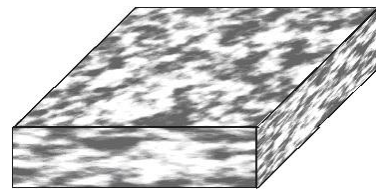


Fig. 2 Neoprene type SAB 4a

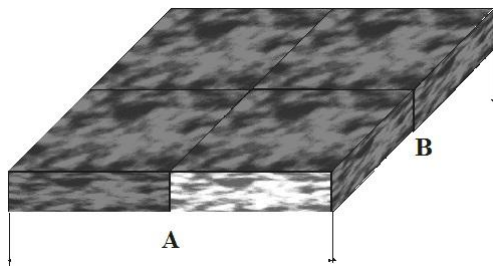


Fig. 3 One layer of composite neoprene

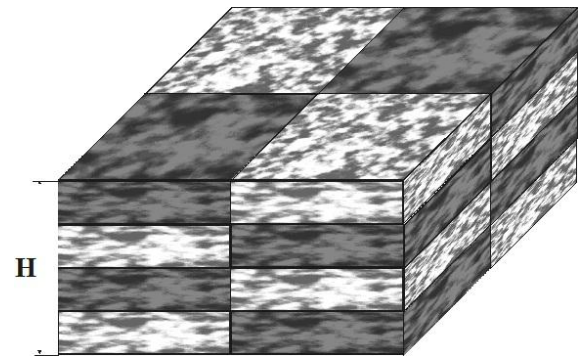


Fig. 4 Sandwich composite (4 layers)

Table 1. The characteristics of different neoprene types used for composites

Characteristic	Unit	Rubber type	
		SAB 31	SAB 4a
Longitudinally modulus E	MN/m ²	4.30	7.00
Shear modulus G	MN/m ²	0.80	1.16
Hardness grade	⁰ ShA	55	65
Hysteretic factor Δ	-	0.170	0.250
Hysteretic dissipation ratio ζ	-	0.085	0.125

Table 2. The characteristics of one layer of composite macrostructure neoprene

Characteristic	Unit	Model			
		V-K ¹⁾	H-M ²⁾	V-K + H-M ³⁾	
Rigidity coefficient	for compression k_z	MN/m	30.40	33.52	28.36
	for shearing k_x	MN/m	3.920	4.600	3.900
Hysteretic dissipation factor Δ	-		0.218	0.500	0.380
Critical damping fraction ζ	-		0.109	0.250	0.190

Table 3. The characteristics of composite macrostructure neoprene sandwich (4 layers)

Characteristic		Unit rate	Model		
			V-K ¹⁾	H-M ²⁾	V-K + H-M ³⁾
Rigidity coefficient	for compression k_z	MN/m	7.600	8.380	7.900
	for shearing k_x	MN/m	0.980	1.150	0.975
Hysteretic dissipation factor Δ		-	0.218	0.500	0.380
Critical damping fraction ζ		-	0.109	0.250	0.190

3. MATHEMATICAL MODELS OF NON-LINEAR SYSTEM. NUMERICAL SIMULATION, DYNAMIC ANALISYS

The goal of the numerical simulation was to calculate the amplitude of the vibrations and the loss of power function of the damping parameters, for the neoprene composite isolators used to support the technological equipment.

Considering 1DOF vibrating mechanical system perturbed by a harmonic force, according to [1] and [2], the mathematical model used for dynamic analysis is as follows

$$m\ddot{x} = F_d + F_{el} + F_0 \sin 2\pi ft, \quad (1)$$

where: \ddot{x} is the generalized acceleration

m - mass of the system

F_d - damping force

F_{el} - elastic force

F_0 - amplitude of disturbing force

f - frequency of disturbing force

The calculations were made for an inertial vibrator conveyor modeled as 1DOF with the next parameters:

-suspended mass: $m = 250\text{kg}$

-rigidity: $k = 300\text{kN/m}$

-damping coefficients:

■ for the linear model:

$$b_0 = 0 \div 60000\text{Ns/m}$$

■ for the model with non-linear damping:

$$b_1 = 0 \div 180000\text{Ns}^2/\text{m}^2$$

$$b_2 = 0 \div 600000\text{Ns}^3/\text{m}^3$$

-amplitude of harmonic disturbing force:

$$F_0 = 12400\text{N}$$

-frequency of harmonic disturbing force:

$$f = 15.8\text{Hz}$$

According to [2], the expression for damping force taking into consideration that the numerical modeling was a polynomial one, like the next

$$F_d = b_0\dot{x} + b_1\dot{x}^2 \operatorname{sgn}(\dot{x}) + b_2\dot{x}^3, \quad (1)$$

where: \dot{x} is the generalized velocity

b_0 - the viscous damping coefficient

b_1 - the coefficient for the damping force proportional to the square of the velocity

b_2 - the coefficient for the damping force proportional to the 3rd power the velocity

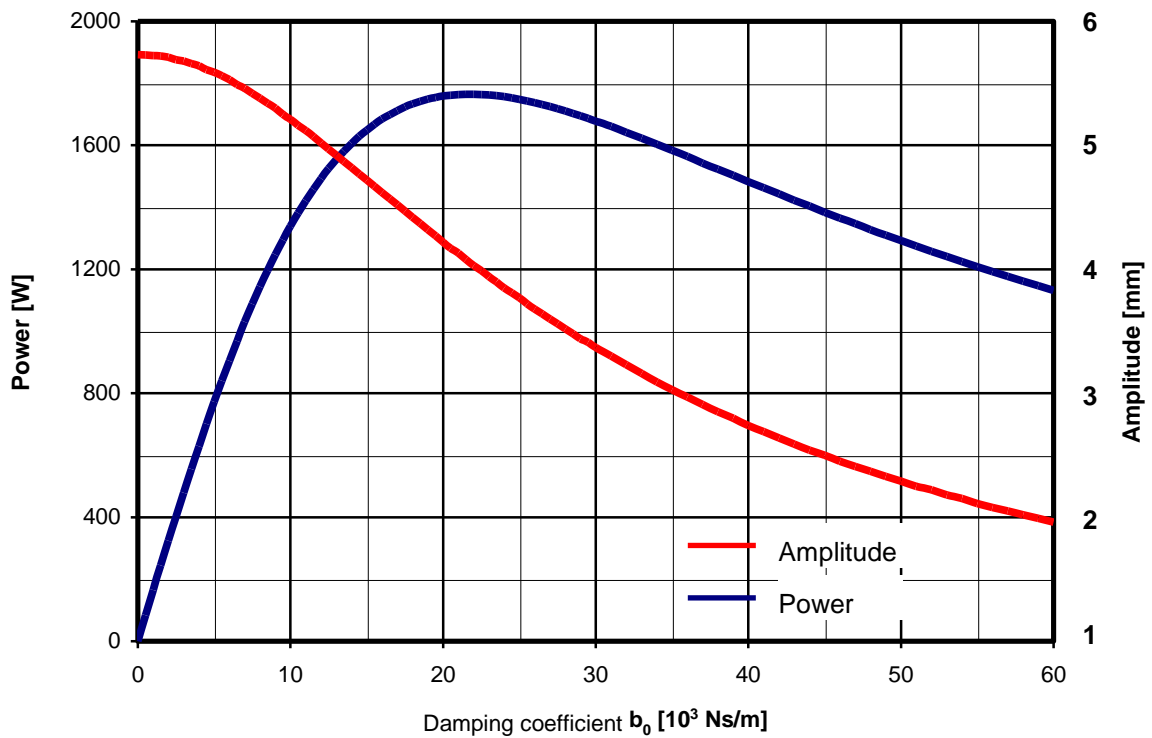


Fig. 5 The amplitude and power characteristics of the linear model

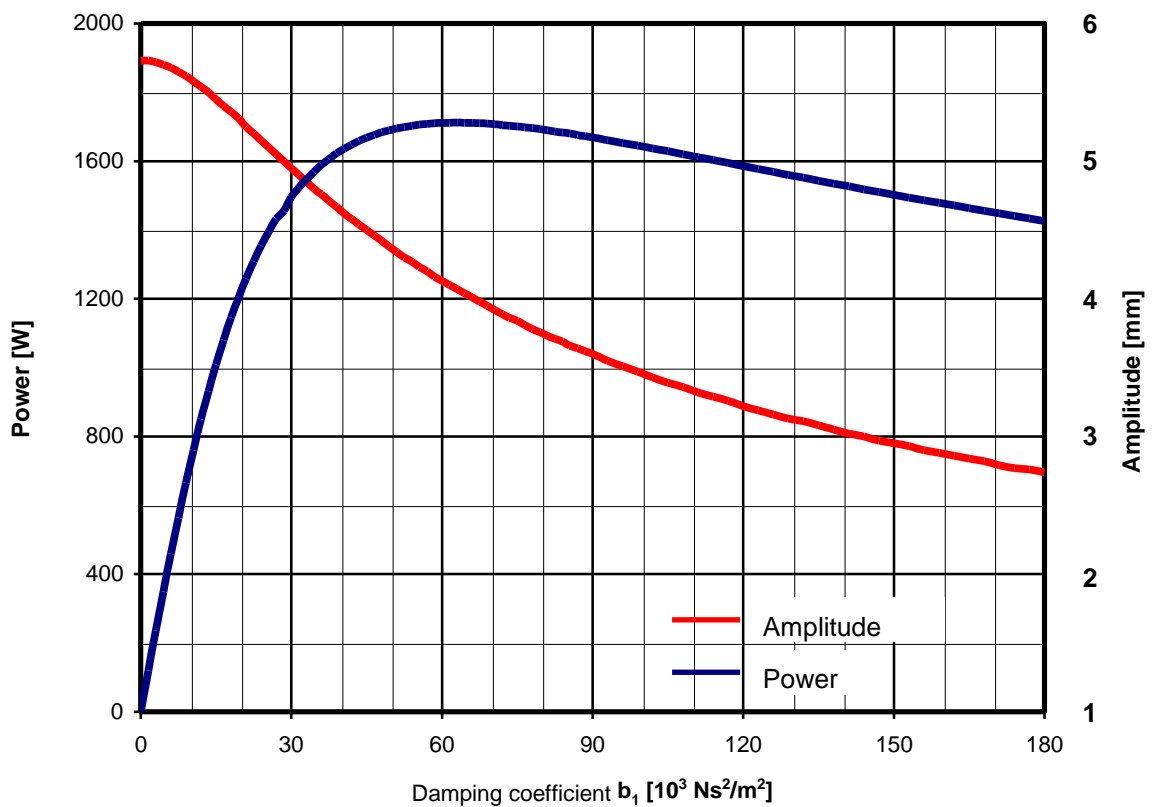


Fig. 6 The amplitude and power characteristics function of the damping coefficient b_1

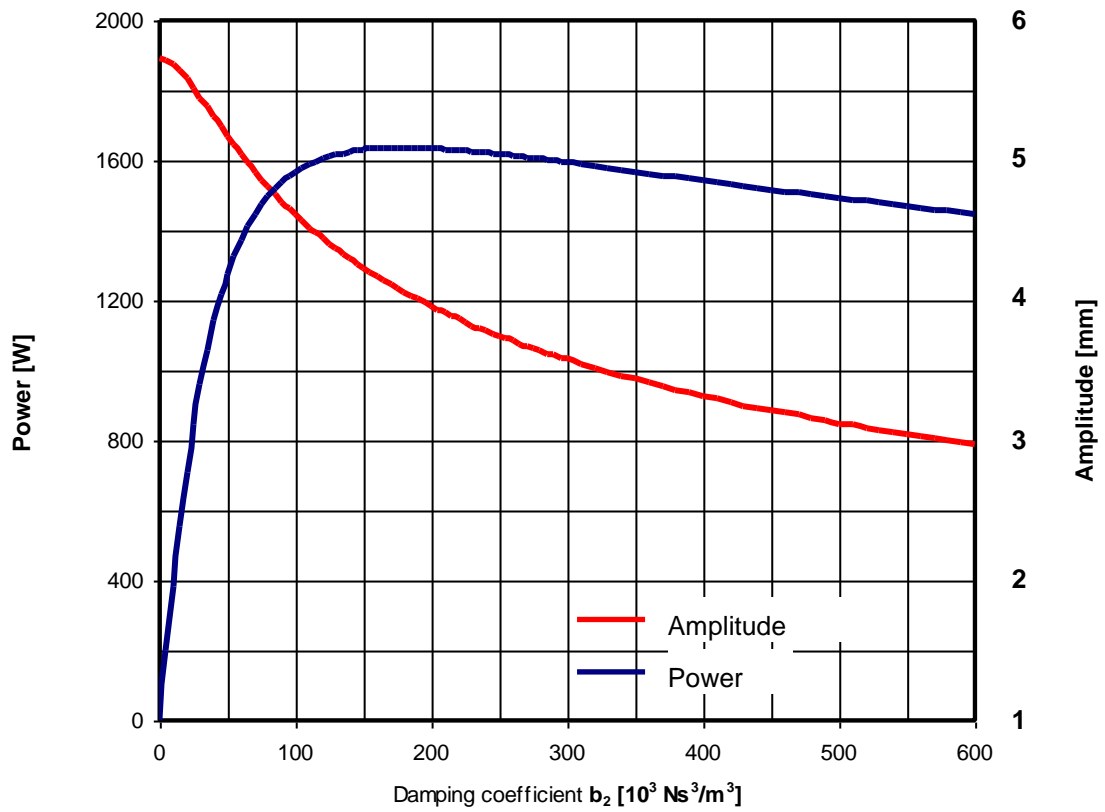


Fig. 7 The amplitude and power characteristics function of the damping coefficient b_2

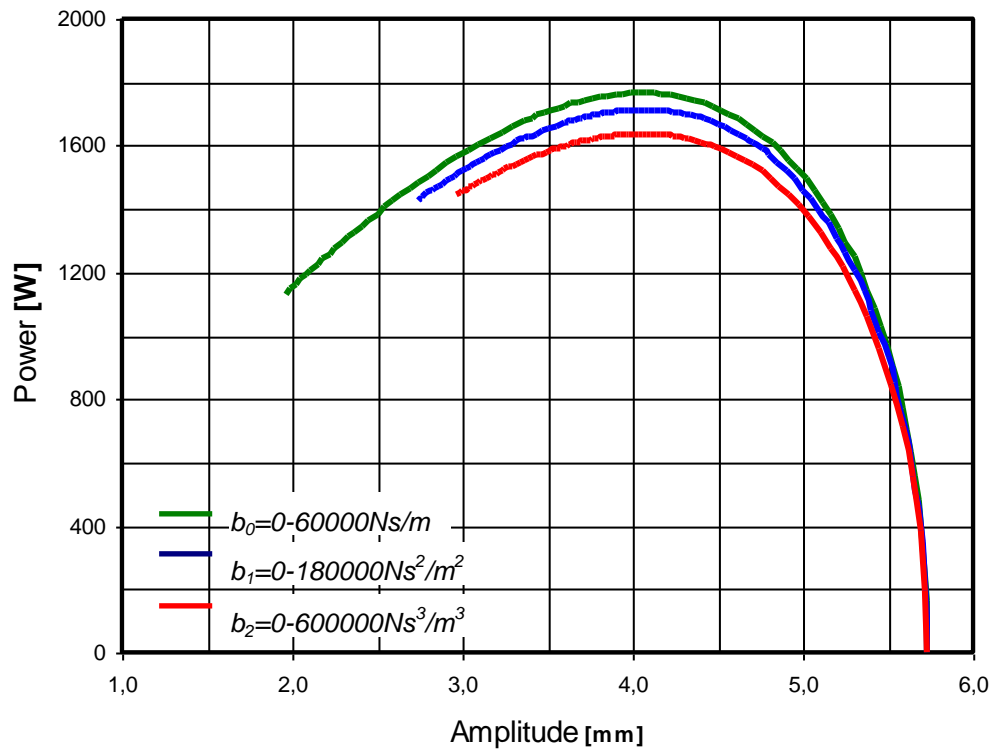


Fig. 8 The power characteristics function of the amplitude of the vibration

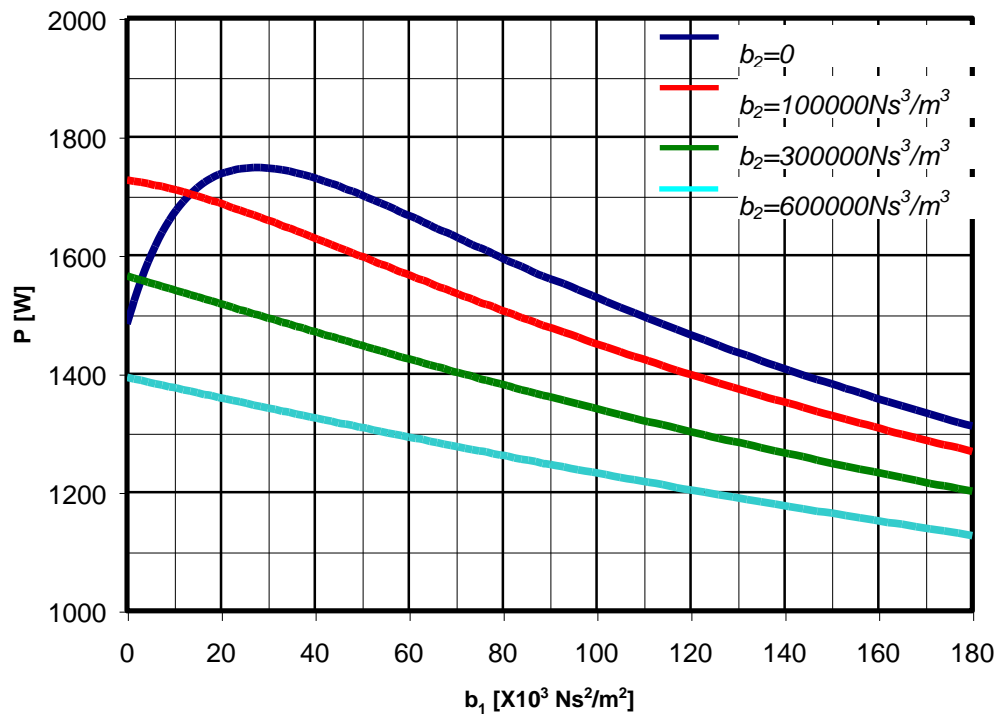


Fig. 9 The power characteristics function of the non-linear damping coefficient b_1 (with $b_0=12\text{kNs/m}$ and b_2 -parameter)

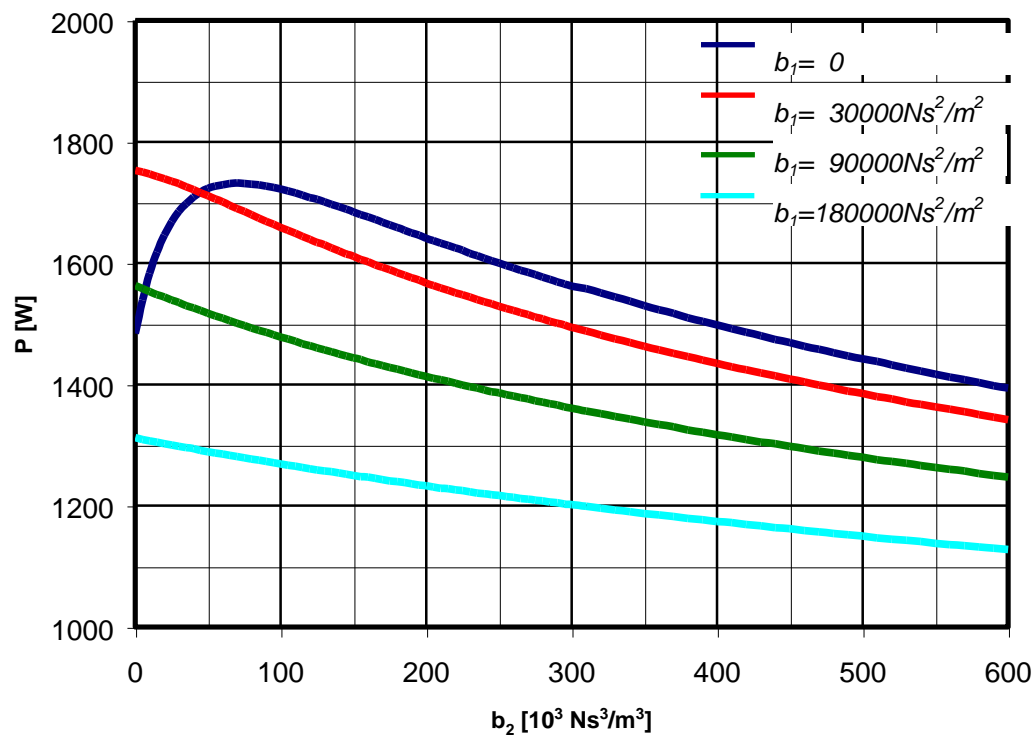


Fig. 10 The power characteristics function of the non-linear damping coefficient b_2 (with $b_0=12\text{kNs/m}$ and b_1 -parameter)

6. CONCLUSIONS

Figures from 5 to 10 show the power and amplitude characteristics function of the damping coefficient for the system from §3 modeled as an 1DOF mechanical system with non-linear dissipation (2).

The non-linear damping force was done by four bearing structures made from neoprene composite sandwiches (rubber type SAB 31 and SAB 4a) with the dimensions $a \times b \times h$ 200×200×200 [mm]..

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