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PREDICTION OF ACOUSTIC PARAMETERS OF LAYERED SYSTEMS

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ABSTRACT
Up to this time we meet in technical practice problems of vibrations, especially influence of vibrations upon human. A person is not ever protected in the effective way, in some cases the proclaimed protective element does not suppress effects of vibrations but increases them. The work describes possibilities of the mathematical modelling use at designs of antivibration systems (based upon layered systems). The frequency dependence of predicted transmission is compared with the datas obtained from measuring of transmission or the transmission loss at the same layered system. The results showed that on the basis of this new proposed methodology it is possible to predict, with the great accuracy, antivibration effects of layered systems and in such way to optimise considerably the technical and economical preparation of manufacture. This is documented on example of review dumping properties of working gloves.

1 - INTRODUCTION
To detail the transmission or transmission loss of layered vibration system, we elaborated the mathematical model [1]. This model was verified in a number of vibroinsulation layered systems both for longitudinal and cross vibrations [1], [2]. We also adapted and subsequently verified the design of antivibration gloves. Compared with preceding solving, the basic change reposes on the fact that in addition to limit conditions for the fixed last chain member or the free last chain member, the model was adapted for the long last member to infinity, too. This conception corresponds e.g. to the case when the vibroinsulation system is formed by layered antivibration glove and the last transmission chain is human hand, the length l_n of which can be presupposed when compared with the glove thickness as the long one to infinity, Fig. 1.

2 - PREDICTION OF ACOUSTIC PARAMETERS
The transmission between the 0 input to system and K output from arbitrary system member is given by the relation

$$TR = \frac{|\tilde{v}_k|}{|\tilde{v}_0|} \text{ or } TR = \frac{\left|\tilde{F}_k\right|}{\left|\tilde{F}_0\right|} \tag{1}$$

and transmission loss

$$D = 20\log\frac{|\tilde{v}_0|}{|\tilde{v}_k|} \text{ or } D = 20\log\frac{\left|\tilde{F}_0\right|}{\left|\tilde{F}_k\right|} \tag{2}$$

where $|\tilde{v}_0|$ is the amplitude of vibration velocity at 0 input to the vibration system, $|\tilde{v}_k|$ is amplitude of vibration velocity at K input to k member of vibration system, $\left|\tilde{F}_0\right|$ is force amplitude at 0 input to vibration system, $\left|\tilde{F}_k\right|$ is force amplitude at K output from k member of vibration system.
These variables are determined from the equation

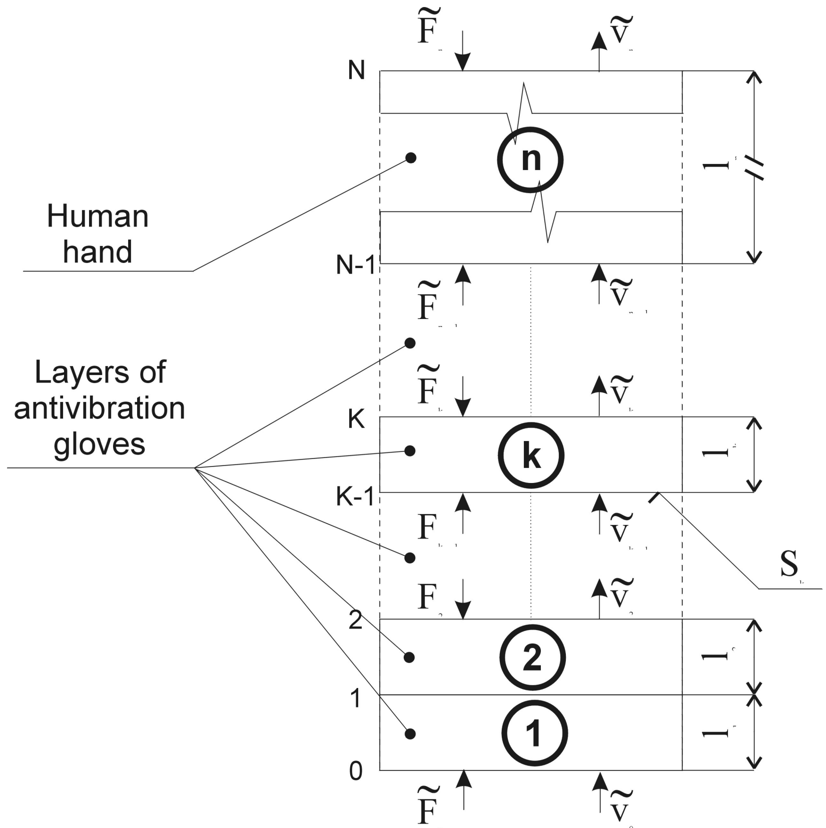

Figure 1: Layered vibration system.

$$\left\| \begin{array}{c} \tilde{F}_0 \\ \tilde{v}_0 \end{array} \right\| = \|A_{01}\| \cdot \|A_{12}\| \ldots \|A_{k-1,k}\| \cdot \left\| \begin{array}{c} \tilde{F}_k \\ \tilde{v}_k \end{array} \right\| \tag{3}$$

where $\left\| \begin{array}{c} \tilde{F}_0 \\ \tilde{v}_0 \end{array} \right\|$ means the complex state matrix of variables at 0 input to vibration system, $\left\| \begin{array}{c} \tilde{F}_k \\ \tilde{v}_k \end{array} \right\|$ means the complex state matrix of variables at K output from k member of vibration system,

$$\left\| \tilde{A}_{k-1,k} \right\| = \left\| \begin{array}{cc} \cos\tilde{\gamma}_k l_k & \tilde{Z}_k \sinh\tilde{\gamma}_k l_k \\ \dfrac{1}{\tilde{Z}_k} \sinh\tilde{\gamma}_k l & \cos\tilde{\gamma}_k l_k \end{array} \right\| \tag{4}$$

In this equation there means: l_k thickness of corresponding k-th layer,

$$\tilde{\gamma}_k = \frac{i\omega}{\tilde{c}_j} \tag{5}$$

$$\tilde{Z}_k = \rho_k \cdot S_k \cdot \tilde{c}_k \tag{6}$$

where: ω is the angular frequency, $\tilde{c}_k = \sqrt{\dfrac{\tilde{E}_k}{\rho_k}}$ so-called propagation velocity of longitudinal wave motion in the presupposed medium of k layer, ρ_k material thickness of presupposed k layer, $\tilde{E}_k$ complex modulus of elasticity in tension or compression of k-th material layer, $\tilde{S}_k$ surface area of k-th presupposed layer section vertical to the direction of longitudinal wave motion propagation.

The mentioned method also allows the solving for the disharmonic signal [1].

In case of antivibration gloves we will be interested in the transmission among 0 input to first system member and N-1 input to last system member – then the hand. This model was verified for the experimental working glove (HP) by comparison of calculated variables according to mathematical model with variables measured in the laboratory.

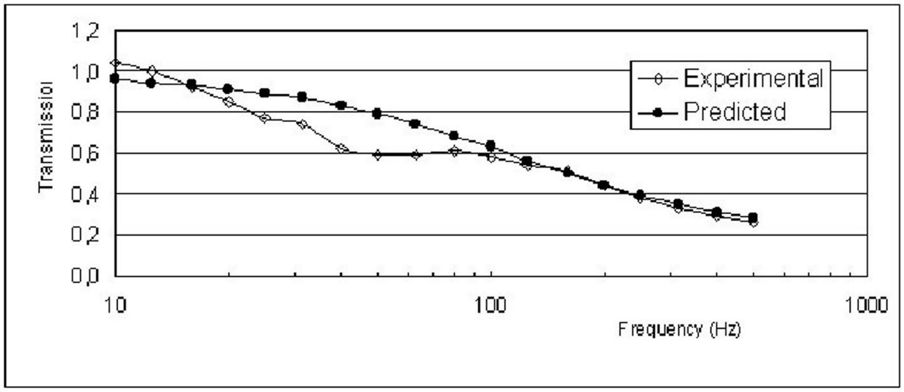

Figure 2: Comparison of predicted and experimentally taken transmission for gloves HP.

The calculation was executed for variables mentioned in the Table 1, at the same time densities of glove materials and their thicknesses were determined for the deformed glove by pressure of 0.01 MPa corresponding to power on the palm of 30 N according to CSN EN ISO 10819 (Czech standard). Material hand properties were determined on the basis of biomechanical studies [3] when estimating viscoelastic properties of human tissue and hand deformation by the pressure of working instrument.

Gloves	Layer	Section S (m^2)	Thickness l (m)	Density ρ (kg/m^3)	Modulus E' (MPa)	Modulus E" (MPa)
HP	1	0,003	0,0010	600,00	12,500	0,000
	2	0,003	0,0010	30,00	0,040	0,000
	3	0,003	0,0044	1100,00	0,070	0,000
	4	0,003	0,0006	300,00	29,500	0,000
Hand	5	0,003	∞	1600,00	0,450	0,100
1	1	0,003	0,0009	674,16	20,000	0,000
	2	0,003	0,0041	63,11	0,090	0,000
	3	0,003	0,0004	450,00	72,000	0,000
Hand	4	0,003	∞	1600,00	0,045	0,100
2	1	0,003	0,0008	619,00	14,000	0,000
	2	0,003	0,0053	549,53	0,110	0,000
	3	0,003	0,0003	533,33	71,000	0,000
Hand	4	0,003	∞	1600,00	0,450	0,100
3	1	0,003	0,0007	695,65	14,000	0,000
	2	0,003	0,0037	572,97	21,000	0,000
	3	0,003	0,0004	700,00	83,000	0,000
Hand	4	0,003	∞	1600,00	0,450	0,100
4	1	0,003	0,0007	590,00	25,200	0,000
	2	0,003	0,0052	570,00	41,400	0,000
	3	0,003	0,0003	690,00	49,500	0,000
Hand	4	0,003	∞	600,00	0,450	0,100

Table 1: Parameters of gloves materials and human hand.

From the good correspondence of results predicted by the mathematic model to measured variables is evident. At Fig. 3 the comparison of 4 gloves types is illustrated for material properties mentioned in Table 1.
It points the glove 4 is least suited one which is given by the fact that mechanical properties of individual glove layers are a little different.

3 - CONCLUSIONS

From the mentioned above it is evident the described mathematical model allows designing and estimation of antivibration properties of working gloves, too. When compared with experimental estimation the next advantage of this methodology is that mathematic model works with exactly defined hand of given mechanical properties and so that it allows the objective comparison of products. Compared with it,

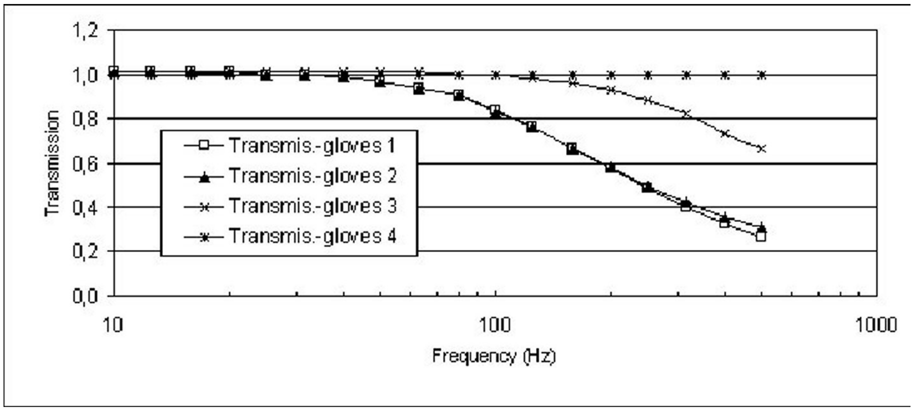

Figure 3: Comparison of predicted transmission for 4 types of gloves.

the direct measuring of vibration transmission on human is influenced by the variety of mechanical and geometrical properties of the test dummy.

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