Propagation of Deformation Waves in the Piano Hammer Felt

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ABSTRACT

The piano hammer felt made of wool is a unique and indispensable coating matter of wooden mallets. Experimental testing of piano hammers, which consist of a wood core covered with several layers of compressed wool felt demonstrates, that all hammers have a hysteretic type of the force-compression characteristics, which are essentially nonlinear [1, 2]. A main feature of hammers is that the slope of the force-compression characteristic is strongly dependent on the rate of loading. These phenomena require that the piano hammer felt made of wool is a microstructured material possessing history-dependent properties, i. e. a material with memory.

The nonlinear, hysteretic model of the piano hammer that is in a good agreement with experimental data was presented in [2, 3]. In addition to the elastic parameters, two hereditary parameters (hereditary amplitude and relaxation time) are introduced in order to describe the hysteretic behavior of the hammer.

According to piano hammer model (and in reality), the duration of contact between the hammer and the string decreases with increasing of the striking velocity of the hammer. It means that the speed of an unloading wave, traveling from the contact point to the hammer kernel and back, increases with the growth of its amplitude.

The numerical simulation of the wave propagation in the felt material was performed taking into account all elastic and hereditary felt properties in order to analyze the dependence of the wave speed on its amplitude. The constitutive equation was chosen in a form, which corresponds to the hammer felt model.

The third order nonlinear partial differential equation was derived and solved numerically, with initial conditions that correspond to the hammer felt loading in experiments. The relationship between the speed of deformation wave and its amplitude was obtained, and it was shown that the unloading of the hammer felt is caused by the wave reflected back from the hammer kernel. The solution of the linear problem was also analyzed, and the rate of the wave attenuation in the felt material was estimated.

REFERENCES

[1] A. Stulov. Hysteretic model of the grand piano hammer felt. *J. Acoust. Soc. Am.*, **97**, 2577–2585, 1995.

[2] A. Stulov. Experimental and computational studies of piano hammers. *Acta Acoustica united with Acoustica*, **91**, 1086–1097, 2005.

[3] A. Stulov. Dynamic behavior and mechanical features of wool felt. *Acta Mechanica*, **169**, 13–21, 2004.