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EXPERIMENTAL ANALYSIS OF EFICIENCY OF MASS DAMPERS

I. Gołębiowska*, M. Dutkiewicz**

Abstract: *In the first part of the paper types of vibrations of overhead transmission lines have been presented indicating the need to reduce these vibrations with the use of different dampers. In the second part the results of the experiments with mass damper, called Stockbridge damper, and its efficiency are presented. Stockbridge dampers effectively reduce vibrations by absorbing the energy supplied from the outside. In the real cases the power input comes from the wind. The efficiency of vibration damping is analyzed in the frequency domain corresponding to aeolian frequencies. Two-mass dampers were analyzed and their dynamic characteristics were presented and described by the power function in the frequency domain. The additional parameter - phase angle between excitation force and the velocity of the vibrating damper was presented as well.*

Keywords: Stockbridge damper, Mass damper, Tuned vibrations, Dynamic absorber, Aeolian vibrations, Overhead transmission lines.

1. Introduction

Stockbridge dampers whose efficiency is the subject of this paper play a significant role in the reducing the aeolian vibration of overhead transmission lines (OTL) (Vecchiarelli et al., 2000). Among different types of vibrations caused by the wind, particularly these vibrations are dangerous as they lower the ultimate and serviceability states of power transmission lines. Besides aeolian vibrations, wind may cause the galloping or wake induced vibrations (Holmes, 2001). Aeolian vibrations may cause the damages of transmission lines because of fatigue of steel or aluminum, the materials from which the lines are made. Various dampers, type of Stockbridge, torsional or spiral dampers are often attached to the transmission lines to minimize these vibrations (Gołębiowska, 2015). Among the Stockbridge dampers, the asymmetrical damper is a multi-resonance system with dissipation of energy by friction between strands of messenger. Stockbridge dampers may dissipate the energy in every direction and this is the main advantage of application them. Furthermore these dampers may be used on transmission lines of large diameter and properly optimized may attenuate vibrations in wide frequency range.

2. Application of tuned mass dampers attached to transmission lines

Aeolian vibrations of transmission lines due to wind actions are characterized by high frequency and small amplitudes of vibrations (Diana et al., 1993). Apart from them, oscillations of high amplitude and low frequency called galloping and wake induced vibrations of average amplitude but lower than aeolian frequency are also observed. Aeolian vibrations are in the range of 3 to 150 Hz at wind speed from 1 to 7 m/s acting perpendicular to the line, which usually happens in open plots, in the area without buildings and infrastructure. The amplitude of oscillation does not exceed diameter of the conductor. These vibrations are difficult to observe due to the fact that transmission lines diameters are from 6 to 50 mm, which exceeds the amplitudes of vibrations. The maximum amplitude of vibrations occurs at resonance, when the natural frequency of conductor is close to the vortex frequency. These vibrations can be controlled by the use of different dampers (Wang et al., 1997, Scanlan 1978, Uno 1991). Attaching the damper (m_D) to the vibrating mass (m) causes a reduction of vibration of this mass (Fig. 1).

* Prof. Dr Eng. Irena Gołębiowska: Department of Building Construction, University of Science and Technology, ul. Prof. S. Kaliskiego 7, 85-796 Bydgoszcz, Poland; tel.: +48 052 340 85 79, fax: +48 052 340 82 25; igolebio@utp.edu.pl

** Dr. Eng. Maciej Dutkiewicz: Department of Building Construction, University of Science and Technology, ul. Prof. S. Kaliskiego 7, 85-796 Bydgoszcz, Poland; tel.: +48 510 035 090, fax: +48 052 340 82 25; macdut@utp.edu.pl

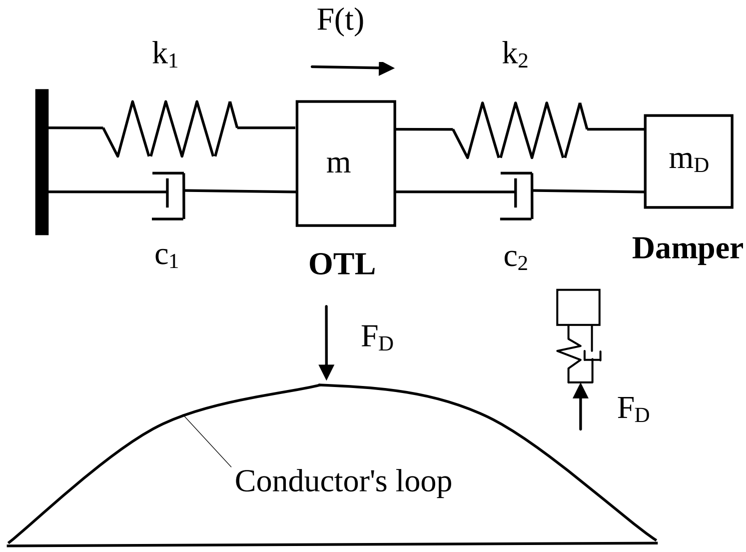

Fig. 1: Principle of tuned mass damper attached to the transmission line.

The use of Stockbridge damper is still very popular solution. Stockbridge damper is constructed from a flexible cable or rod (messenger) and the masses at its ends (Fig. 2) (Krispin et al., 2007). The vibrations of the line are passed through the clamp mounted the damper's messenger to the conductor and consequently the masses on the ends of the damper begin to vibrate. By careful selection of parameters of the damper such as mass at the ends of the messenger, stiffness and length of the damper's messenger, one can design the optimal damping of the transmission energy line (Gimsing et al., 2012). First Stockbridge damper held at the ends of the messenger masses made of concrete blocks. Nowadays steel masses at end of the damper's rod are used and galvanized steel is applied for damper's rod. From the point of reduction of vibrations, the location of damper on the cable is significant.

The purpose of the dampers is reduction of vibration by absorbing energy from the wind and stabilization of the movement of the conductor to avoid deformation that can cause the damage. According to analysis performed in the paper (Meynen et al., 2005) the value of safe limit deformation of the conductor is 200 microns/m.

3. Principle of damper behaviour

Principle of the damper behaviour reffers to the vibrating transmission line that causes the vibrations of the masses of the damper and movement of the messenger. Movement of the masses and messenger bending cause the interstrands frictions and dissipation of energy (Fig. 2.).

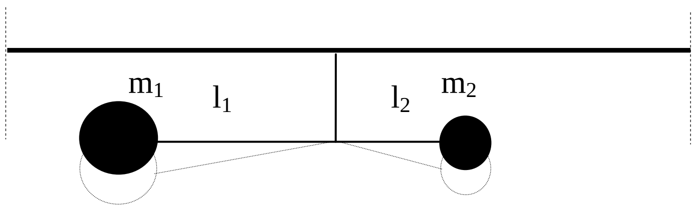

Fig. 2: Model of Stockbridge damper.

Nowadays the messengers are designed with several individual strands, with numbers up to 19, to better dissipate the energy. During the optimization of the damper, the appropriate cross section, length of the mesenger, number of strands and the size of the masses at the ends of messenger are designed.

Symmetrical dampers have two degrees of freedom, which correspond to the first and second mode of vibrations. Asymmetric dampers have four modes of vibrations, alternately for larger and smaller mass of the damper giving a wider range of effective frequencies of vibration damper. Basically, two dampers are attached to the span of the line in the place of an anti-node where the amplitude of the standing wave is maximum. More than two dampers are connected to the line in the case of longer spans.

4. Determination of the effectiveness of vibration dampers and the parameters of the experiment

Effectiveness of dampers were measured as the value of dissipation energy through the damper. The exciting force was input to the damper through the connection clamp.

Experiment stand consists of shaker, force sensor, accelerometer, amplifier, postprocessing analyser. Target frequencies were in the range of 4 to 100 Hz, that can happen in real conditions in the case of aeolian vibrations. The aim of the experiment was to measure the acceleration/velocity and control the exciting force acting on the damper to determine the value of the total energy dissipated by the damper. The experiments were performed for fix damper's parameters: m_1=1.6 kg, m_2 = 1.3 kg, messengers length l_1= 230 mm, l_2 = 180 mm, 19 was the number of individual innerstrands of messenger. During the experiment the phase angle between the excited force and response velocity of vibration are determined.

Accelerometer and force transducer were mounted close to the clamp of the damper. The parameters of the measurements were fixed. A sweep rate of 0.2 decade / min was used. Clamp velocity was held constant at 0.1 m / s. The damper power is determined as (IEC 61897, 1998):

$$P = 0.5\ x\ F\ x\ V\ x \cos\phi \qquad (1),$$

where: P is the power [W], F is the exciting force [N] - peak value, V is the velocity of the damper clamp [m/s], ϕ is the phase value between the velocity and the force [degree].

5. Results and discussion

During the experiments of forced vibration of two-mass dampers, the maximum of energy dissipation were observed: peaks no. 1 and 3 corresponding to the vibration of mass m_1 and peaks 2 and 4 for the mass m_2 (Fig. 3). Fig. 3 shows the curves of energy dissipation in the frequency domain for three dampers of the same type. Maximum value of power dissipation is 0.8 W at frequency 7 Hz, 0.7 W at 20 Hz, 1.4 at 36 Hz and 2.5 Hz at 67 Hz.

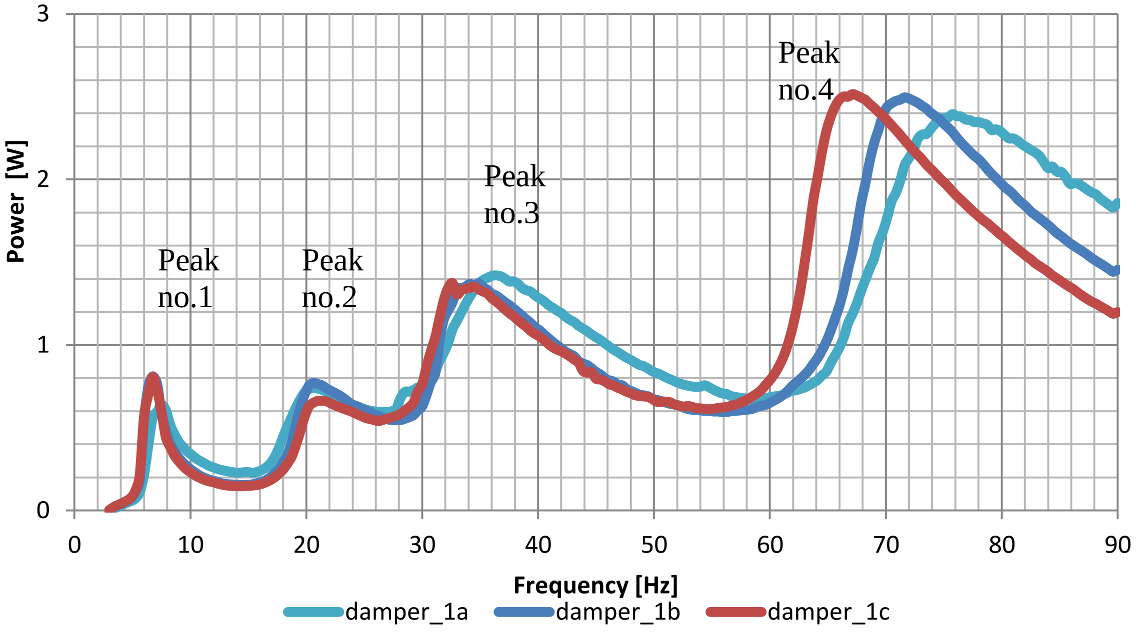

Fig. 3: Damper power curves.

Fig. 4 shows the curves of phase angle between the force and response velocity of vibration, which present the conformity of received results.

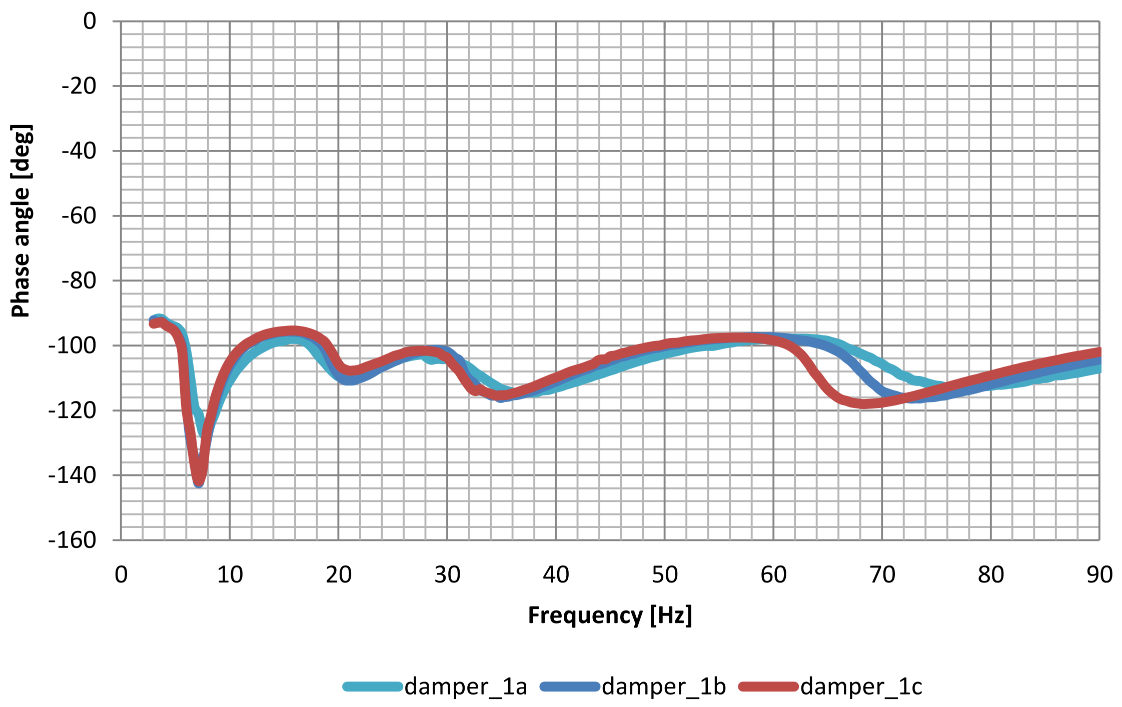

Fig. 4: Phase angle between force and velocity.

6. Conclusions

In the paper the efficiency of asymmetrical Stockbridge dampers was analysed. The efficiency of vibration damping was analyzed in the frequency range corresponding to aeolian vibrations. Dampers were analysed and their dynamic characteristics were determined by power function in the frequency domain. Phase angle between force and response velocity was determined. Received results confirm the efficiency of the tested dampers in the analyzed range of frequencies.

The choice of parameters of the damper such as weights, length, stiffness and damping of messenger, location of the damper on the line is one of the steps carried out the research to optimize the vibration of overhead transmission lines in the field of mechanical damping. This research also will cover issues related to the aerodynamic damping e.g. selection of the shape of the damper and results will be performed in the future papers.

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