18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012
pp. 298–299
Paper #63

USE OF ELECTRO-MAGNETIC DAMPING FOR VIBRATION CONTROL

G. J. Stein [*], R. Darula [**], S. Sorokin [**]

Abstract: *Vibration of machines is an unwanted phenomenon, and it is usually of interest to eliminate it. There are various means to be used in order to reach the goal. The utilization of electromagnet augmented by an external shunt circuit is analyzed in this paper. The magnetic force is used to introduce additional electromagnetic damping into vibrating mechanical system. The hysteretic losses and eddy currents are included in the model, in order to take into account more realistic dynamic behaviour of the system. The mathematical model of the controller is derived using lumped parameter approach. The parameters are assumed from an experimental set-up using an industrial type of electromagnet. Considering the harmonic excitation of mechanical system, a steady-state response and performance of the controller is analyzed. Simulation results show the influence of introduced electromagnetic damping on the dynamical response of the system.*

Keywords: ***electromagnet, oscillatory system, damping, natural frequency detuning***

1. Introduction

In rotating machinery a resonance phenomena can cause severe problems or even a failure of components. In order to avoid it, vibration control needs to be implemented. Except of passive means active and semi-active methods of vibration control can be implemented in vibration reduction as well. Piezoelectric, electro-dynamic and electro-magnetic actuators are widely used for such a control strategy, as presented e.g. in (Bishop, 2002; Giurgiutiu & Lyshewski, 2009).

This contribution, based on authors' previous work (Darula et al., 2011), analyses the electromagnetic actuation principle. It has been shown that the controller of interest is capable to introduce damping, as well as alter damped natural frequency of the oscillatory system. In order to model more realistic system, internal electrical losses are introduced, which were not considered in (Darula, et al. 2011). It is shown that electrical losses significantly influence the system properties.

2. The vibration controller

The use of an industrial circular type electromagnet with a ferromagnetic yoke fixed by a spring-damper system, as shown in Fig. 1, is analyzed. A coil of N_w turns with a wire resistance R_W is energised by a direct current I_{DC} and it generates a static magnetic field. Exposing the yoke into vibration, described by a mechanical displacement $w(t)$, the air gap width $d(t)$ changes in time which causes variation of an air gap reluctance.

According to Faraday's law, change in reluctance, i.e. a change of primary magnetic flux, is responsible for induction of alternating voltage $u_i(t)$ in the coil, where it forces a current $i_i(t)$ to flow in the electrical shunt circuit.

[*] Ing. George Juraj Stein, PhD.: Institute of Materials and Machine Mechancis, Slovak Academy of Sciences; Račianska 75; SK-83102 Bratislava 3; SR, e-mail: stein@savba.sk

[**] MSc. Radoslav Darula & Prof. Sergey Sorokin, DSc.: Department of Mechanical and Manufacturing Engineering, Aalborg University; Fibigerstraede 16; DK-9220 Aalborg East, DK, e-mail: dra@m-tech.aau.dk, svs@m-tech.aau.dk

From the Lenz's law, the direction of $i_i(t)$ is opposite to I_{DC}, i.e. the magnetic field generated in the coil ($i_i(t)$ contribution) opposes the primary field generated by I_{DC}. Using the shunt resistance R_S, the current $i_i(t)$ is dissipated.

The combination of the static magnetic force due to the DC current I_{DC} and the oscillatory, dynamic one, due to the induced current $i_i(t)$, influences the structure's stiffness and thus its natural frequency. Moreover, extend of damping is governed by intensity of induced current $i_i(t)$. Both effects are non-linear, because of the $1/d(t)^2$ character of the magnetic force F_M, which is dependent on the square of the sum of the currents $i_i(t)$ and I_{DC} (Bishop, 2002; Giurgiutiu & Lyshewski, 2009).

The equation of motion of the analysed SDOF oscillatory system (Fig. 1) is (Darula, et. al., 2011):

$$m_{\mathrm{m}} \frac{d^2 w(t)}{dt^2} + b_{\mathrm{S}} \frac{dw(t)}{dt} + k_{\mathrm{S}} w(t) = F(t) - F_{\mathrm{M}}(t).$$

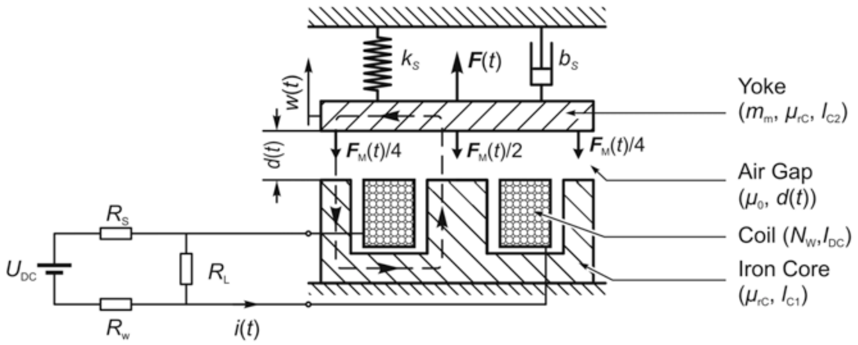

Fig. 1: Schematics of the analyzed electro-mechanical system (flux line is denoted dashed)

To extend the model derived in Darula, et al. (2011) material losses within the electrical circuit, which are supposed to influence the performance of the controller, are taken into account. Considering these losses and linearising the equation of motion, to make the problem tractable, the displacement frequency response function (FRF) in respect to harmonic excitation force $F(t)$ is derived.

3. Results

On hand of available experimentally determined numerical data for a particular set-up (Darula, et. al., 2012) the FRF course is numerically simulated. From the numerical results follows that the acting magnetic force causes:

- Generation of higher harmonics,
- Change (decrease) in oscillatory system natural frequency, i.e. de-tuning of the system,
- Inclusion of additional electro-magnetic damping, so decreasing the vibration transmissibility. The attainable extent of the de-tuning and of the additional electro-magnetic damping is influenced by the electrical parameters of the electromagnet and of the external shunt resistor.

Acknowledgement

This contribution is a result of the project No. 2/0075/10 of the Slovak VEGA Grant Agency for Science and InterReg IV A – 'Silent Spaces' Project, whose one Partner is Aalborg University.

References

Bishop, R.H., ed. (2002) *The Mechatronics Handbook*. CRC Press, Boca Raton.

Darula, R., Stein, G.J. & Sorokin, S. (2011) An Application of Electromagnetic Induction in Vibration Control, in: *Proc.10th Int.Conf. ICoVP 2011* (J. Naprstek, et al. eds), TU Liberec, Liberec, pp. 447-453.

Darula, R., Stein, G.J., Kallesøe, C.S. & Sorokin, S. (2012) Identification and Mathematical Modelling of the Electromechanical Vibration Controller, in: *Proc. 11th Int.Conf. ESDA 2012*, submitted.

Giurgiutiu, V. & Lyshewski, S.E. (2009) *Micromechatronics: Modeling, Analysis and Design*, 2nd ed. CRC Press, Boca Raton.