Tomasz SZMIDT, Robert KONOWROCKI
Institute of Fundamental Technological Research, Polish Academy of Sciences,
ul. Pawińskiego 5B; 02-106 Warszawa, Poland,
E–mail:, tszmidt@ippt.pan.pl, rkonow@ippt.pan.pl

Flutter vibrations of pipe conveying air damped by electromagnetic devices of motional type

1 Introduction

The problem of dynamics of fluid-conveying pipes has been intensively studied since the fifties of XXth century. According to M. P. Païdoussis, one of the pioneers of these studies, it has become a model dynamical problem [2008]. When the flow velocity is sufficiently high, the steady equilibrium position becomes unstable, and self-excited lateral vibrations appear [Gregory and Païdoussis, 1966]. This phenomenon can be easily observed in a loose garden hose conveying water, in which momentum flux causes the follower thrust and a snake-like motion of the free end. We are going the influence of electromagnetic forces generated by devices of motional type [Graves et al., 2000] on dynamic stability of a cantilever pipe conveying air, see Fig. 1.

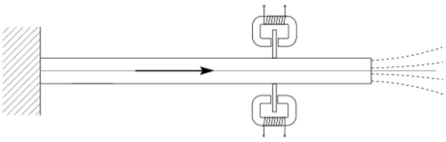

Fig. 1. Pipe discharging fluid with a motional-type electromagnetic device.

2 Matematical modelling of an electro-mechanical-magnetic coupling of the considered object

The transverse motion of the pipe coupled with magnetic induction actuators is governed by the following system of ordinary differential equations.

$$EI\frac{\partial^4 w}{\partial x^4} + E^* I\frac{\partial^5 w}{\partial x^4 \partial t} + MV^2\frac{\partial^2 w}{\partial x^2} + 2MV\frac{\partial^2 w}{\partial x \partial t} + \left(m + M + M_a\delta_a\right)\frac{\partial^2 w}{\partial t^2} = \frac{A}{\mu_0}\left(B_2^2 - B_1^2\right)\delta_a$$

$$\left(\frac{AN^2}{R} + \frac{1}{8}\sigma l a^2\right)\frac{dB_{1,2}}{dt} + \frac{2}{\mu_0}\left(z^* \pm w\left(x_a, t\right)\right)B_{1,2} + \frac{l}{\mu_r \mu_0}B_{1,2} = \frac{NU}{R}$$

where δ_a denotes Dirac's delta, *L*-column length, m-column mass density, *EI*-bending stiffness, *l*-magnetic circuit length, 2*a*-magnetic circuit diameter, z^*-Gap width, *M*-mass of both armatures, *N*-Coils number, *R*-Electric circuit resistance, σ-electrical conductivity of core, μ-relative magnetic permeability of core, μ_0-magnetic permeability of vacuum.

3 Experimental method

A viscoelastic pipe made of ABS with an attached aluminium plate is mounted vertically in a solid clamped configuration. The plate moves together with the pipe within the perpendicular magnetic field generated by actuators. This motion generates eddy currents in the plate and a drag force, which is a consequence of the Lenz law. The electromagnetic actuators are powered by an amplifier, and controlled by a real time unit. This would allow us to perform various control strategies. Still, in this study the devices operate in a passive mode, so the constant voltage is supplied to them.

Three laser displacement sensors are aimed at the pipe to measure its lateral deflection. The motion of the pipe in a perpendicular direction is blocked by a thread. The sensors are connected to a real-time unit though a measurement card.

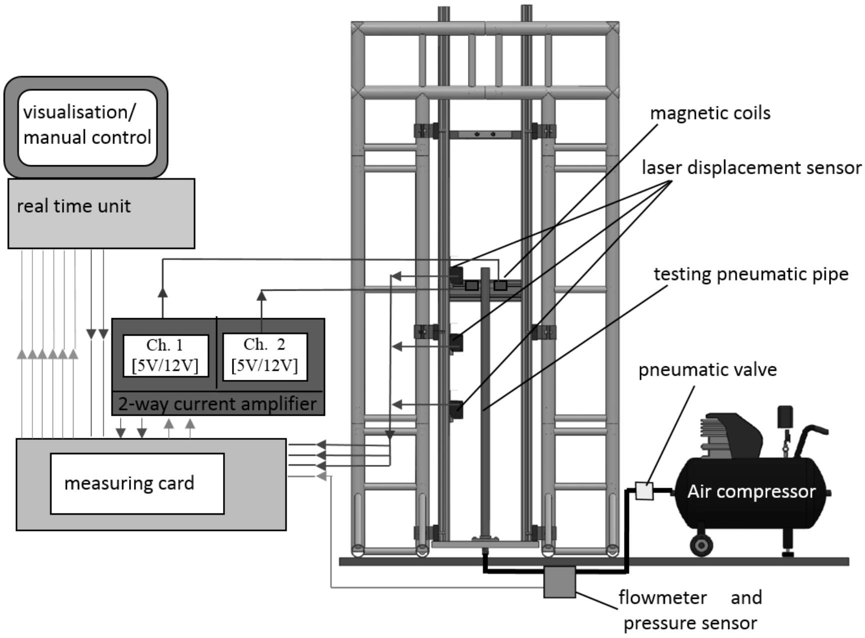

Fig. 2. Schematic of the experimental set-up.

4 Summary

The analysis of stability the pipe with electromagnetic coupling in active elements has been done. Application of electromagnetic actuators leads to an increase in the critical flow velocity.The frequency of self-excited vibrations can either change with the voltage supplied depending on the position of the active elements.

References

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