6th WMCAUS 2021
World Multidisciplinary Civil Engineering - Architecture - Urban Planning Symposium
30 August-3 September, 2021 - Prague (Czech Republic)

VIBRATIONS OF SLENDER STRUCTURES CAUSED BY VORTICES

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Introduction

Slender cylindrical structures can experience flow induced vibration (FIV). One type of FIV is vortex vibrations, it arises due to oscillating forces caused by flow separation and vortex detachment. At the certain preferred frequency, a phenomenon occurs during which vortices are alternately broken off on both sides of the body and dropped into the track. During this process, called vortex detachment, the body experiences a large pressure drop at the back of its surface and a significant fluctuating lateral force. This process causes the body to vibrate with significant amplitudes, which can lead to fatigue failure. The paper presents a brief review of theoretical and experimental studies on vortex induced vibrations - VIV of short, stiff, elastically supported cylinders. The research focused mainly on determining the influence of selected parameters - mass, damping and Reynolds number on the cylinder response, both in one direction and simultaneously in the direction of flow and transversely to the flow direction, as well as searching for a map vortex images in a trace (spin pattern map). A thorough understanding of this phenomenon is essential for the successful development of techniques to reduce or eliminate these vibrations. Fatigue failure of vibrating structures and average drag force due to vortex vibration - VIV are major problems in structural engineering where slender structures are exposed to wind.

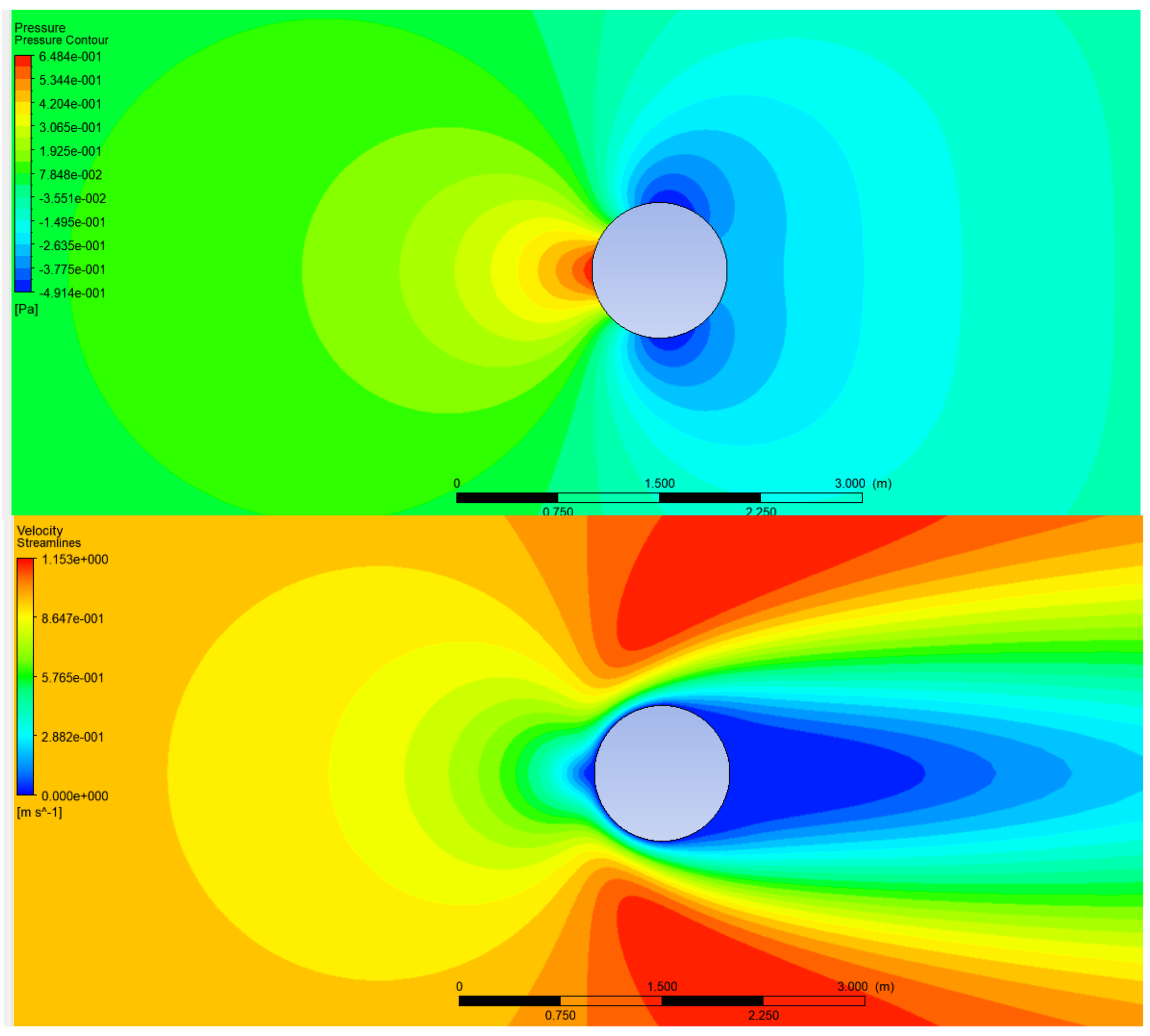


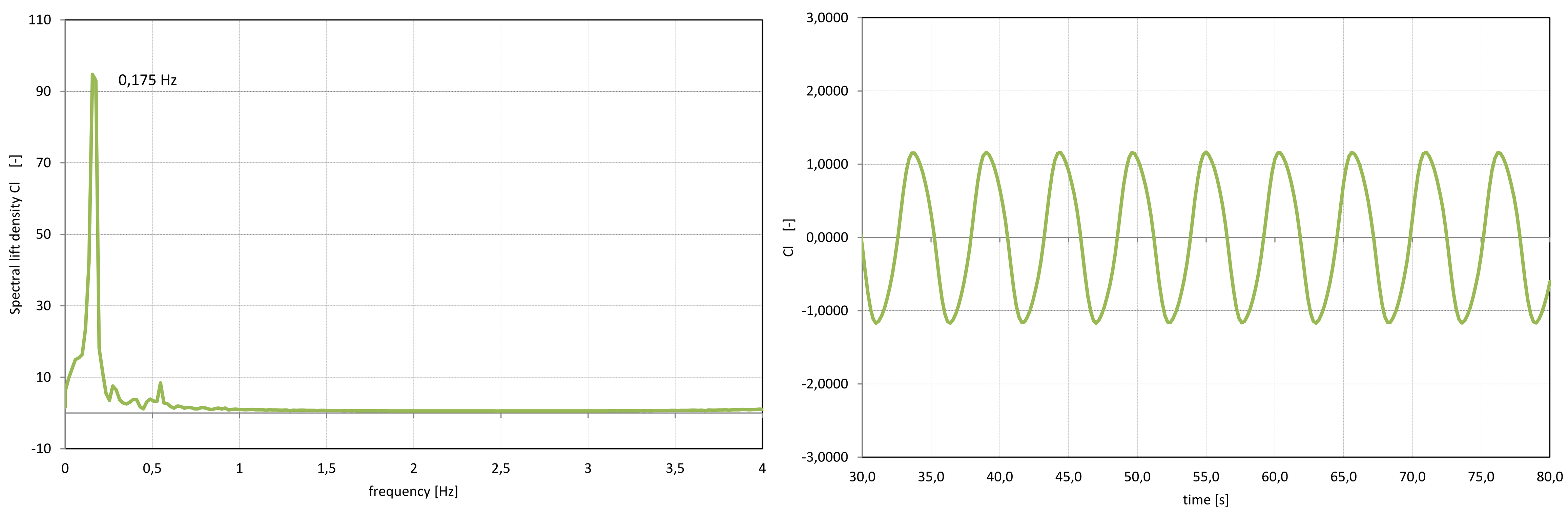
Figure 1. Pressure (a), velocity (b) contours for cylinder, for Re=10000

Classification of vibrations and their most important features

An important feature of VIV is synchronization (lock-in). In the case of a stationary cylinder, the frequency of vortex break-off increases linearly with increasing flow velocity. On the other hand, when the roller is oscillating, its vibrations affect the separation of the vortices - in such a way that the frequency deviates from the linear relationship and synchronizes with the movement of the roller. The VIV models can be divided into two groups. The first group consists of models with one degree of freedom. The second group of models are the so-called coupled models. If a rigid cylinder, elastically supported, is immersed in the flow, the forces due to the vortex break away will cause the cylinder to vibrate. This movement is vibration caused by vortices. Depending on the method of support, the cylinder can only vibrate in the longitudinal or only transverse direction, or it can vibrate in both directions

Patterns and diagrams

If we assume only one degree of freedom of the system, e.g., in the crossflow direction, the equation of motion is as follows in pattern (1)
Excitation force can be described as follows in pattern (2)
Figure 2 presents the example of Authors' research of variation of lift coefficient with time and spectral lift density for cylinder, for Re = 6.5 x 10^4



$$\ddot{y} + 2\xi\omega_n\dot{y} + \omega_n^2 y = \frac{F_y}{m} \quad (1)$$

$$Fy(t) = \frac{1}{2}\,\rho\, v_x^2\, D\, C_{Le} \sin(\nu\, t + \delta) \quad (2)$$

Figure 2. Variation of lift coefficient with time (a) and spectral lift density for cylinder (b) for Re = 140 x 10^3

Discussions & Conclusions

Vortex-induced vibrations of bluff bodies is of great importance in various engineering applications, such as cables, chimneys, tall buildings, power lines, etc. The periodicity of the flow due to the vortex breaking away from a non-tidal body immersed in the flow can cause it to vibrate if the body is resiliently supported or flaccid, this phenomenon is called VIV. The flow around a freely vibrating cylinder is associated with many different interesting phenomena, under certain conditions the movement of the cylinder causes the vortices to break away at the vibration frequency of the cylinder, this phenomenon is called lock-in or synchronization. It is visible in a wide range of cylinder vibration frequencies centered around the vortex break-off frequency for a stationary cylinder. During lock-in, vibrations of significant amplitudes occur which can lead to fatigue failure of the structure. Another interesting phenomenon related to the VIV is hysteresis. The oscillation amplitude for a certain range of Re number and close to the outer frequency limits for lock-in depends on whether the flow velocity increases or decreases during the experiment. Important parameters affecting the response of a rigid cylinder resiliently supported in the flow are mass ratio, damping ratio, structural stiffness, Reynolds number and aspect ratio.

Acknowledgements

This paper has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00003