COMSOL CONFERENCE
2015 KUALA LUMPUR

Air Flow Conditions For Flutter Energy Conversion Device

AHMED B. ATRAH

Universiti Kebangsaan Malaysia (UKM), Faculty of Engineering & Built Environment

Malaysia

Abstract

Fluid flow has the potential to provide significant mechanical energy input for electromagnetic energy harvesters. The effect of a bluff body, such as cylinder played a significant role in the creation of a Karman vortex profile in the fluid flow. We study the effect of the number and position of the Duffy cylinder on the characteristic of the aerodynamic system of the elastic belt such as the lifting force. In such a configuration, a flutter energy conversion device (FECD), which could be placed in turbulent boundary layers, can work as an energy harvester (Figure 1). In this work, we focus on the interference between flow disturbing conditions by using three cylindrical bluff bodies in three configurations.

The dependent variables for this solution domain contain pressure p and the fluid particle velocity vector u = {u,v,w}T , where x, y and z are the Cartesian directions. The fluid flow is assumed to be laminar and Newtonian for simplicity, and the constant density of air ρ is 1.225 kg/m3. We have conducted 2D simulations by using COMSOL Multiphysics to determine the aerodynamic parameters around the belt during the flutter process. The cylinder radius and belt width were set at 5mm and 25 mm respectively. The attack angle of the belt was altered to visualize the 2D idealized flow and pressure distribution. When the airflow speed was 3 m/s and for one cylinder, the laminar flow was lightly disturbed while passing through the belt (see Figure2 which shows the velocity field around the cylinder and flexible belt). When the number of cylinders was two, turbulent flow appears, and the variation of lift force on the belt becomes more (see Figure 3). The pressure difference also increased between the top and bottom layers, which developed in torsion and lift forces.

The simulation of proposed structure has introduced an aerodynamic flutter-based energy conversion device driven by the airflow in an indoor ventilation duct. Simulation results demonstrated that two cylinders have a higher fluctuation of lift force than one or three cylinders, which can increase the output power of the energy harvester (figure 4).

Reference

[1] Raczynski, Radoslaw, and Grzegorz Litak. "Air Flow Conditions for Polymer Energy Harvesting." In Applied Mechanics and Materials, vol. 791, pp. 315-320. Trans Tech Publications, 2015.

[2] Pimentel, D., P. Musilek, A. Knight, and J. Heckenbergerova. "Characterization of a wind flutter generator." In Environment and Electrical Engineering (EEEIC), 2010 9th International Conference on, pp. 81-84. IEEE, 2010.

[3] Fei, Fei, and Wen J. Li. "A fluttering-to-electrical energy transduction system for consumer electronics applications." In Robotics and Biomimetics (ROBIO), 2009 IEEE International Conference on, pp. 580-585. IEEE, 2009.

[4] Bhuyan, M. S., B. Y. Majlis, M. Othman, Sawal H. Md Ali, C. Kalaivani, and S. Islam. "Bluff Body Fluid Interactions Modelling for Micro Energy Harvesting Application." In Journal of Physics: Conference Series, vol. 431, no. 1, p. 012024. IOP Publishing, 2013.

[5] Fei, Fei, John D. Mai, and Wen Jung Li. "A wind-flutter energy converter for powering wireless sensors." Sensors and Actuators A: Physical 173, no. 1 (2012): 163-171.

[6] Paxson, Benjamin, and Adam M. Wickenheiser. "Design considerations for small-scale wind energy harvesters driven by broadband vortex-induced vibrations." In SPIE Smart Structures and Materials+ Nondestructive Evaluation and Health Monitoring, pp. 90571K-90571K. International Society for Optics and Photonics, 2014.

[7] Bhuyan, M. S., B. Y. Majlis, M. Othman, Sawal H. Md Ali, C. Kalaivani, and Shabiul Islam. "Development of a Fluid Actuated Piezoelectric Micro Energy Harvester: Finite Element Modeling Simulation and Analysis." Asian Journal of Scientific Research 6, no. 4 (2013): 691.

[8] Fei, Fei, Shengli Zhou, John D. Mai, and Wen Jung Li. "Development of an indoor airflow energy harvesting system for building environment monitoring." Energies 7, no. 5 (2014): 2985-3003.

[9] Akaydın, Hüseyin Doğuş, Niell Elvin, and Yiannis Andreopoulos. "Flow-Induced Vibrations for Piezoelectric Energy Harvesting." In Advances in Energy Harvesting Methods, pp. 241-267. Springer New York, 2013.

Figures used in the abstract

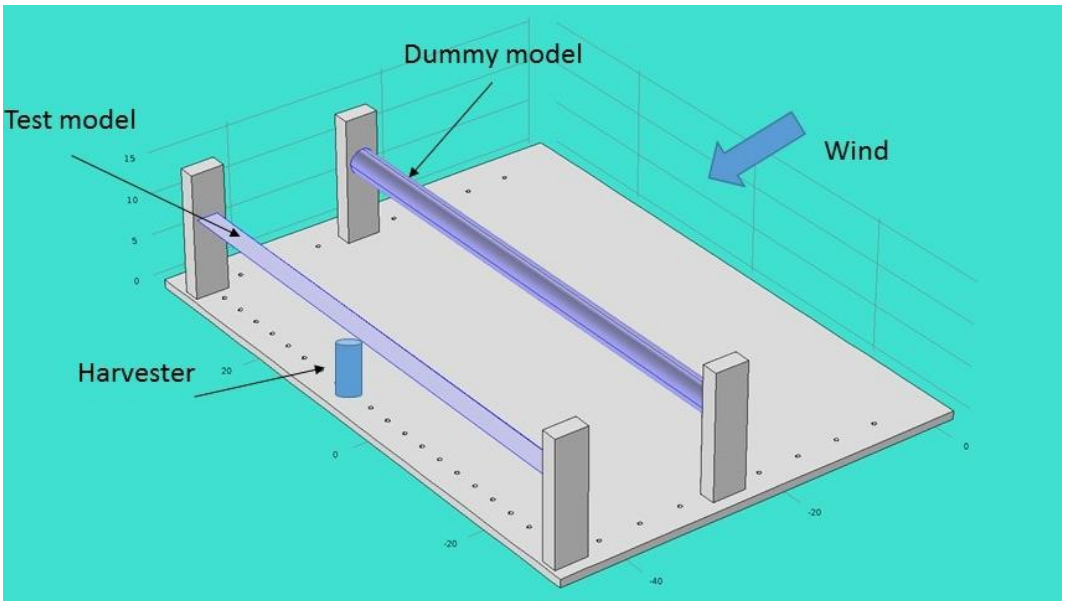

Figure 1: Schematic of proposed energy harvester

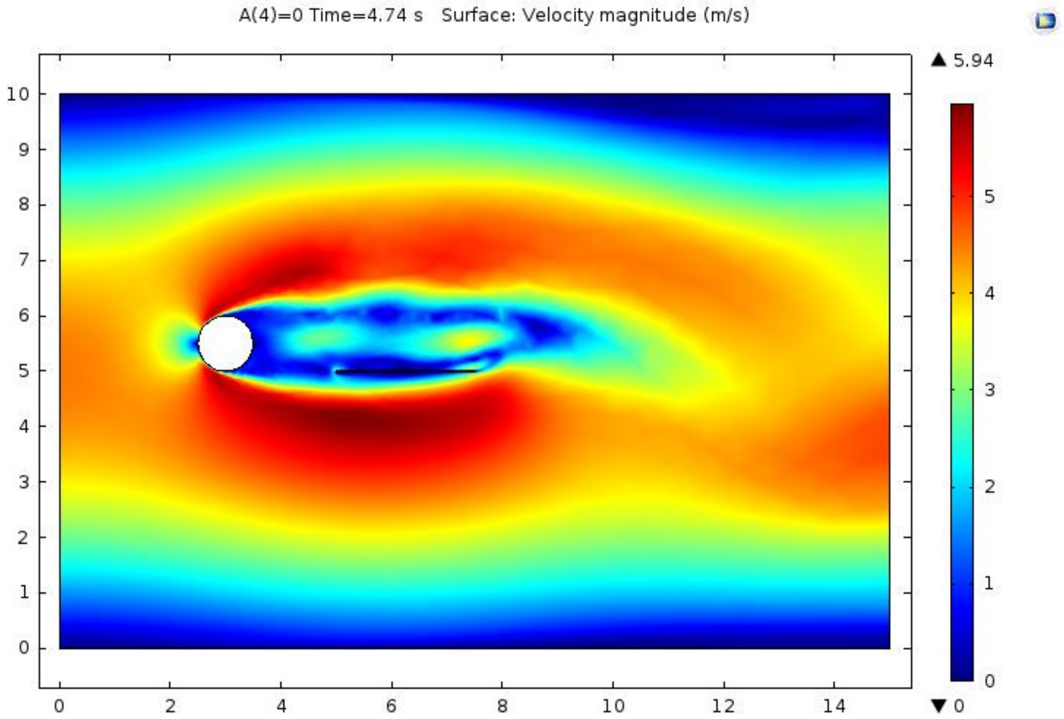

Figure 2: One cylinder velocity profile for 3 m/s inlet and 0° attack angle

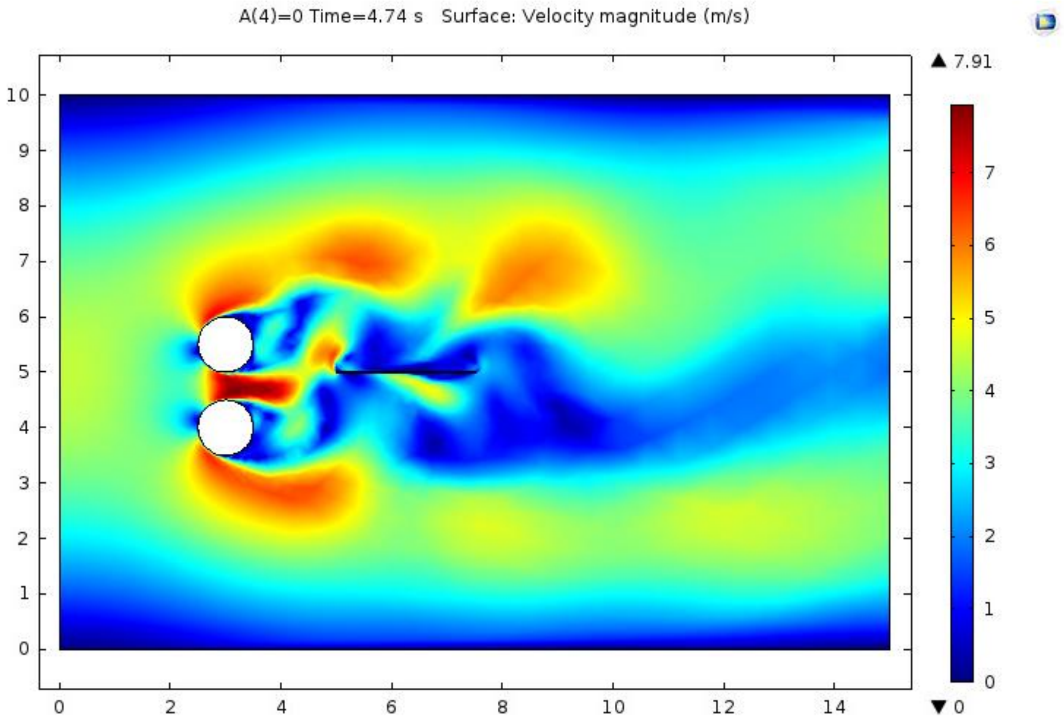

Figure 3: Velocity profile for two cylinders

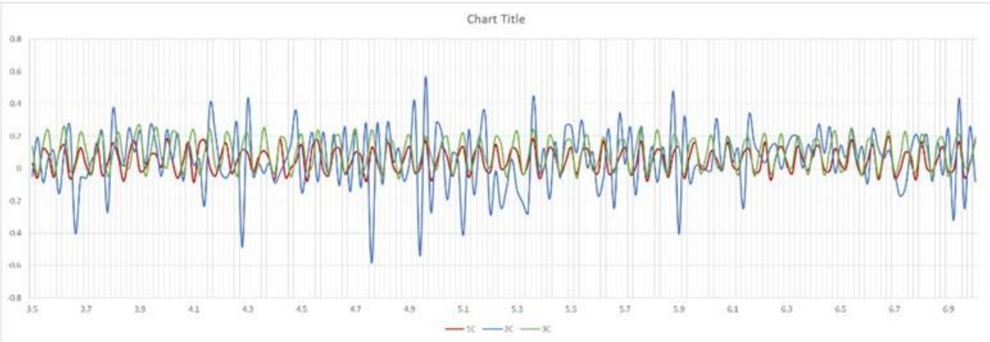

Figure 4: Lift force vs time based on the number of cylinders