Assessment Of Hydrodynamic Forces On A Moving Piston In A Submerged Cylinder

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Abstract

The WaveEL buoy developed by the company Waves4power is characterized as a point absorber and has a 36 meters long vertical cylinder where a water-piston is oscillating due to induced motion from the waves. Estimating the wave loads on the piston is a challenge due to the presence of adjacent cylinder walls. The narrow leakage channel between the piston and the cylinder walls presents a phase shift to the relative motion of the oscillating water flow and the piston. Waves4power have developed a Simulink model of WaveEL-system where power output is calculated based on tube flow, water surface level and water-piston motion. The current lumped system model of the WaveEL buoy roughly considers hydrodynamic forces based on averaged values of coefficients representing added mass and damping.

A clear understanding of the dynamic loading on the piston is essential for accurately predicting end-stop impacts on bumpers in the cylinder, which is a key factor in the design of more robust and sustainable wave energy converters. In order to both consider bumper impact as well as power uptake through the water-piston, added mass and added damping have to assessed for the proposed system.

A 2D axisymmetric Fluid-Structure Interaction (FSI) model of the submerged WaveEL buoy was developed which are based on the CFD module as well as the Structural mechanics module. The transient SST turbulence model was employed where the acceleration of the water mass is generated from a periodic volume force implemented in the water-piston. The aim is to better understand how leakage flow around the piston influences the hydrodynamic forces and, ultimately, energy conversion efficiency. The excitation force is numerically characterized and decomposed into added mass and added damping components using sample covariance analysis. These components are then evaluated against Reynolds (Re) and Keulegan-Carpenter (KC) numbers.

Leakage widths at 1, 2, 3, 10 and 25 cm were simulated for a periodic pulse with a force amplitude of 100 kN and a time period of 6.0s. Initial findings suggests that added mass decrease with increased leaking widths due to a loss in acceleration of the water mass. Moreover, added damping is also reduced which indicates lower power uptake. Further analysis will aim to find correlations and expressions of the KC-number to added mass, as well as the Re-number for added damping, for different leakage widths. By doing so, a better description of the coupling motion of the water piston and tube water can be made in the lumped model which could provide better assessment of power uptake and bumper force impact.

Figures used in the abstract

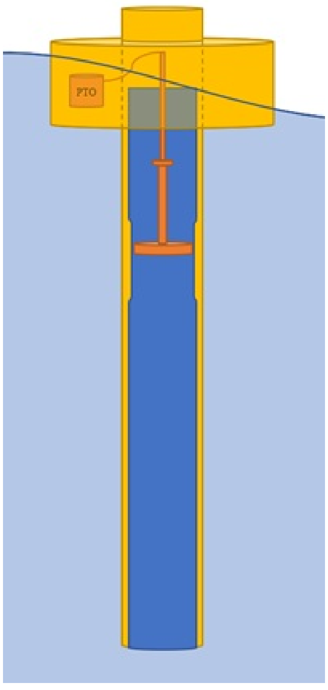

Figure 1 : Schematic view of the WaveEL buoy.

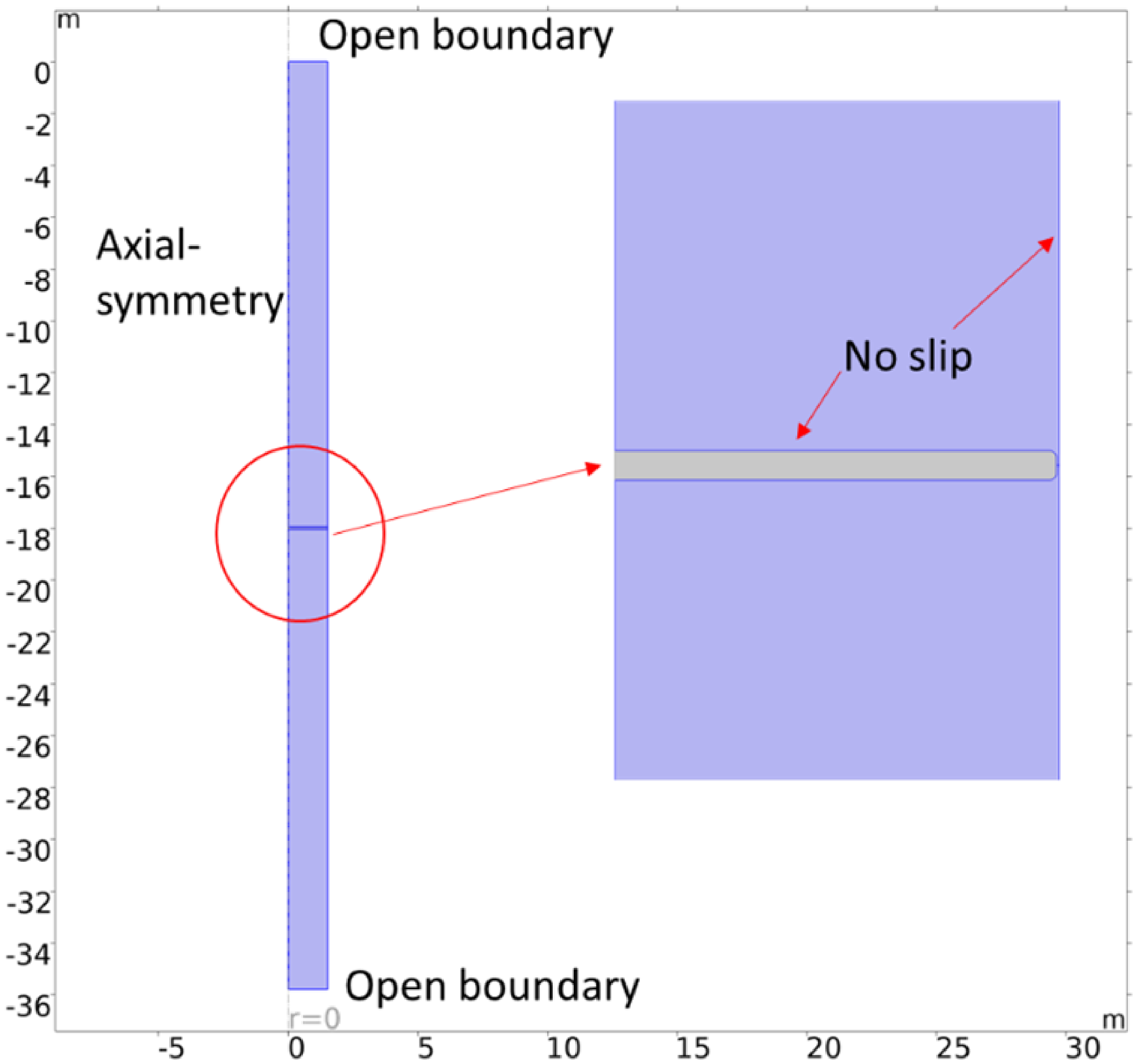

Figure 2 : The submerged acceleration tube. The red circle highlights water piston and the leakage width.

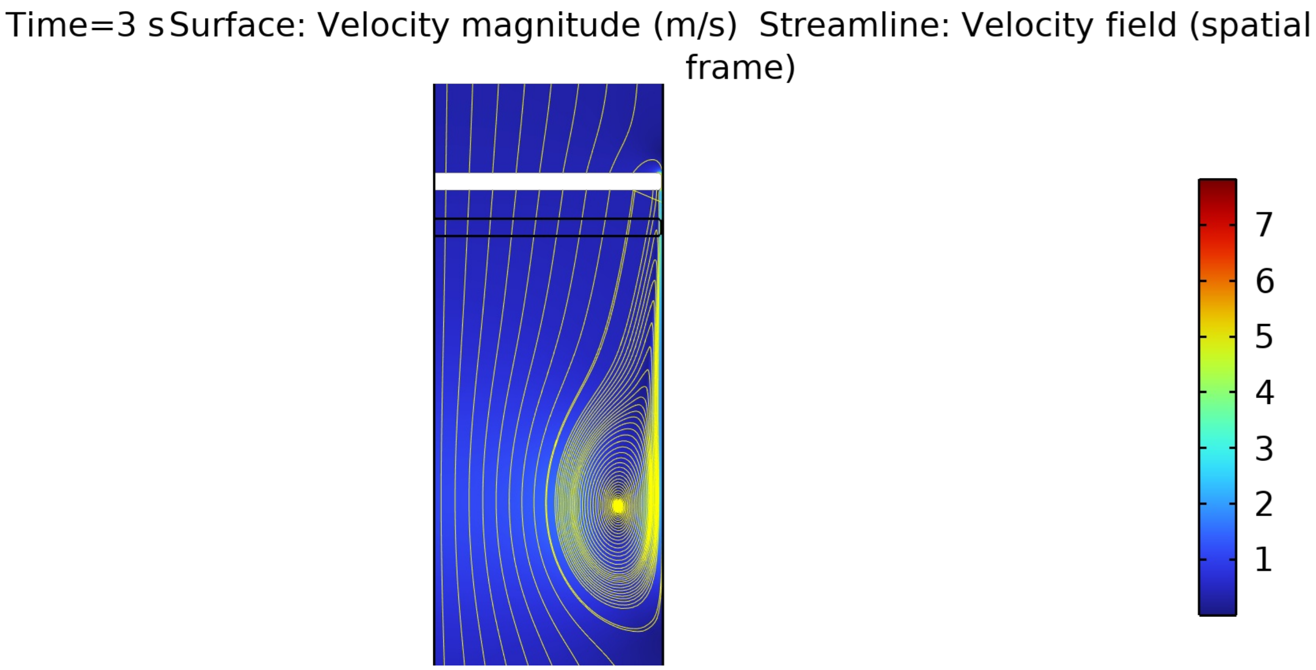

Figure 3 : Velocity field and water-piston displacement after 3 seconds.

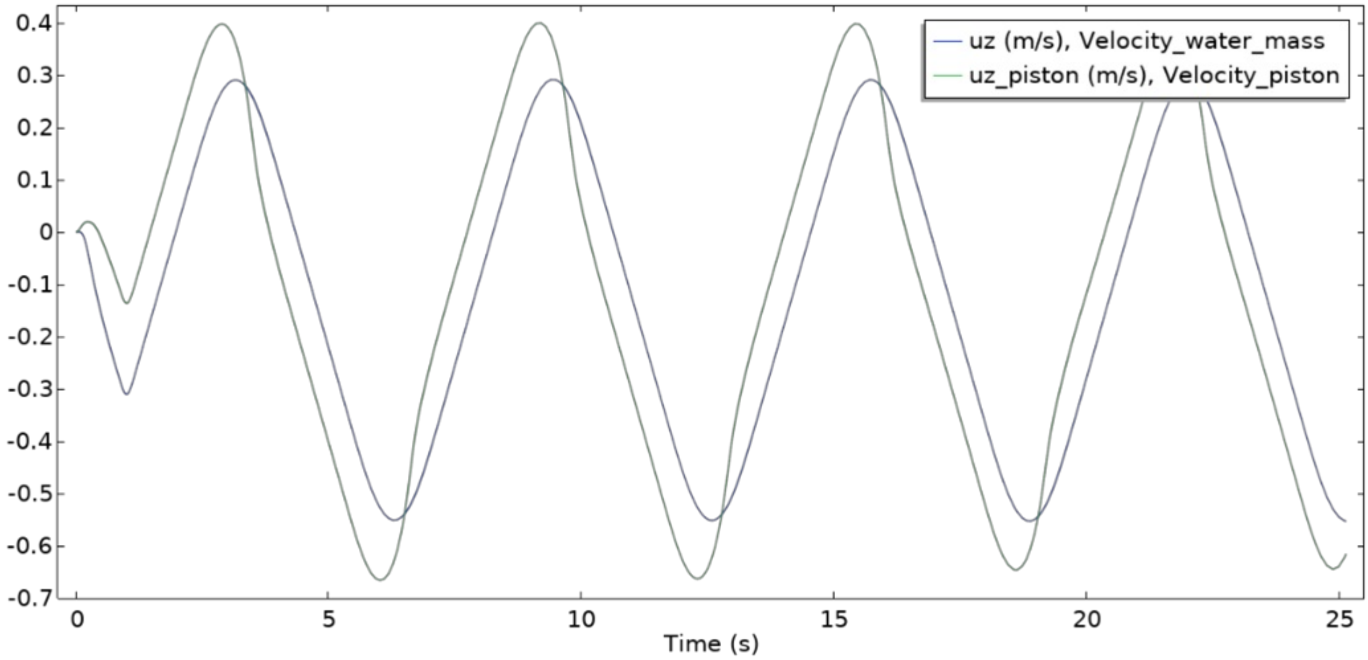

Figure 4 : Volume averaged z-component velocity of the water mass and the velocity of the water piston based on an induced piston volume force with a period of 2π.