Inviscid Flow Investigation of a Streamlined OWC Device

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Cross-Disciplinary Research Area: Energy and Sustainability

1. Objective

The overall objective is to conduct a numerical investigation of a novel Oscillating Water Column (OWC).

The specific objectives include:

- To optimize the OWC geometry.
- To estimate the efficiency of the OWC.

2. Methodology

The continuity equation for incompressible fluid flow is given by:

$$\nabla . \bar{V} = 0$$

The Euler equation applied to the Inviscid Flow:

$$\rho \frac{D\bar{\boldsymbol{V}}}{Dt} = \rho \boldsymbol{g} - \nabla p$$

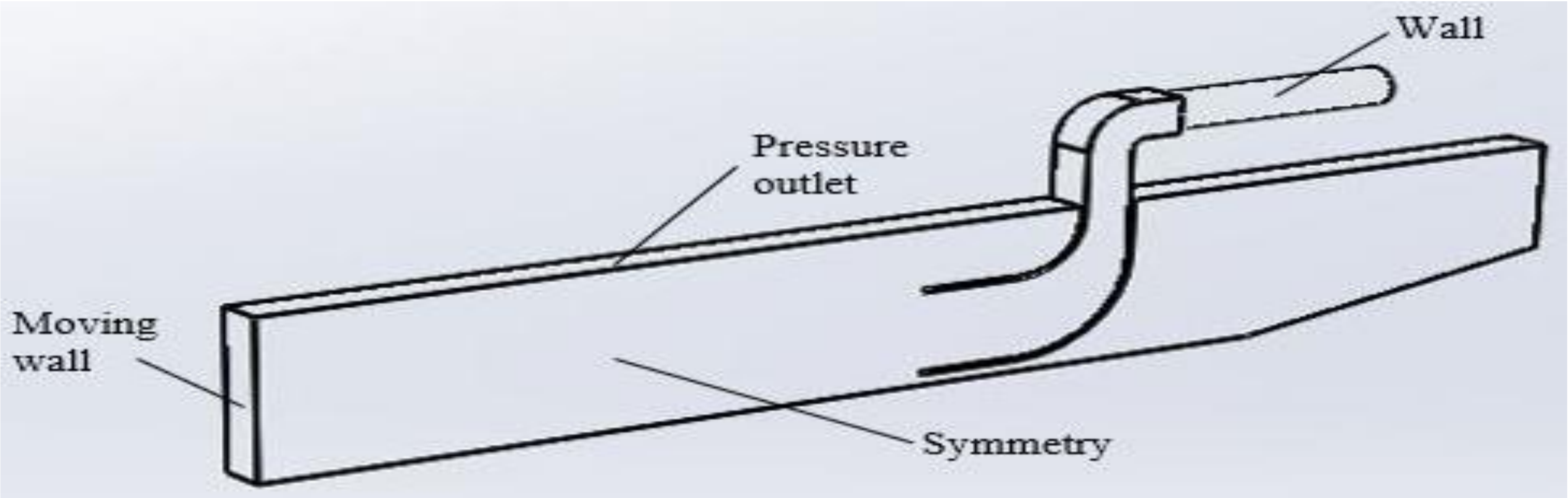

Fig. 1: Boundary Conditions on Streamlined OWC and Numerical Wave Tank (NWT)

The moving wall boundary condition is defined by a User Defined Function (UDF) in Fluent as:

$$v = -(2\pi r)\left[tan^{-1}\left(\frac{S}{2d}\right) sin\left(\frac{2\pi t}{T}\right)\right]$$

To distinguish between the air and water phase using a volume fraction, a scalar quantity ϕ is used and defined as

$$\phi = \begin{cases} 0 & air \\ 0 < \phi < 1 & water - air\ interface \\ 1 & water \end{cases}$$

Pneumatic power absorbed from the waves by the OWC device is given by

$$P_{OWC} = \left(P_s + \frac{1}{2}\rho_a V^2\right) V\left(\frac{\pi D^2}{4}\right)$$

Power of incident water waves

$$P_W = \frac{1}{32\pi}\rho_W g^2 H^2 T b$$

Pneumatic efficiency of the system:

$$\eta_{OWC} = \frac{P_{OWC}}{P_W}$$

3. Description of the Streamlined OWC Cases

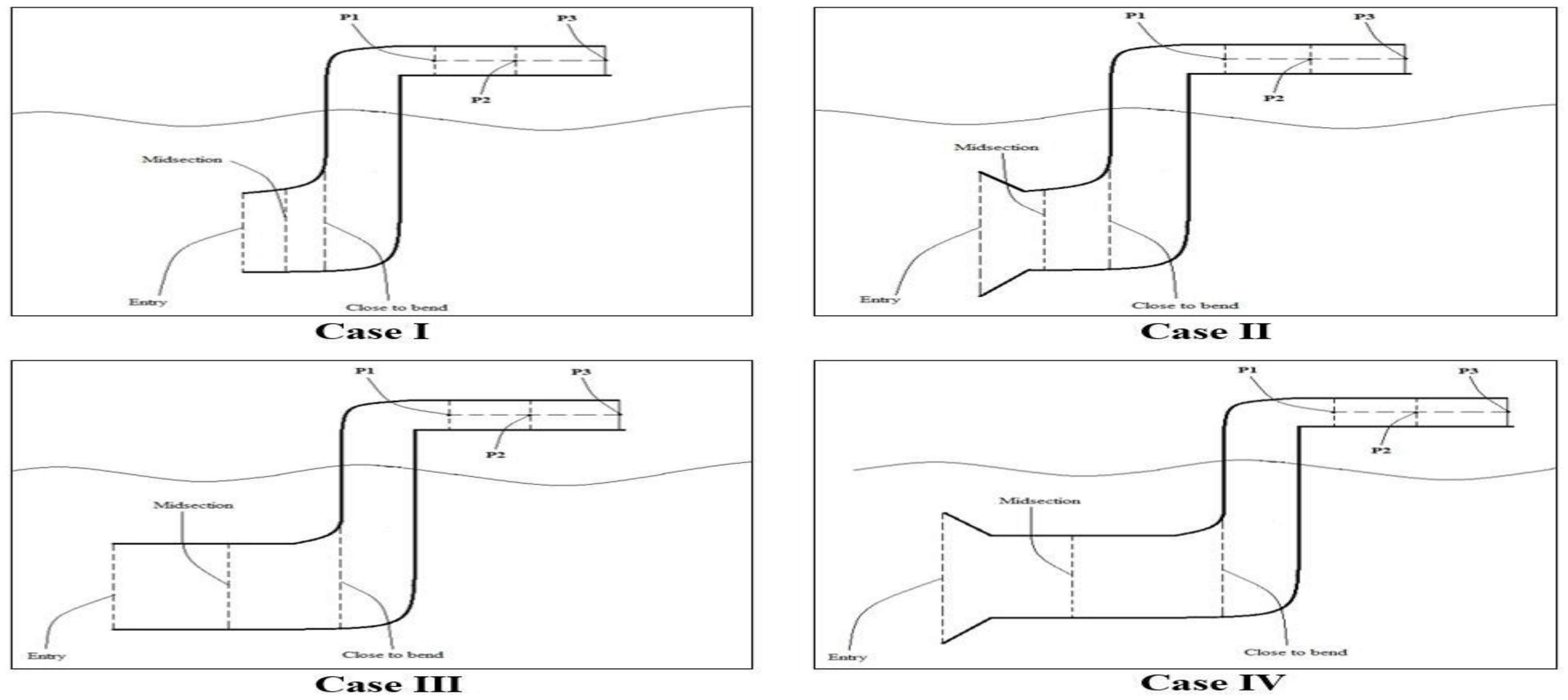

Fig. 2: Streamlined OWC Cases

- Case I - Geometry designed to follow the streamline of the flowing water.
- Case II - Same configuration as Case I but with a flap at the entry.
- Case III - Has an extended chamber attached to Case I.
- Case IV - Same configuration as Case III but with a flap at the entry.

4. Grid Independence Study and Meshing

A grid independence study carried out using the same NWT as in Fig. 1 but on a Conventional Offshore OWC geometry yielded the results below:

Table 1: Grid Independence Analysis on a Conventional Offshore OWC.

Element Size	Number of Nodes	Number of Elements	Average Power Produced
0.0080	54344	45108	0.001019
0.0050	293768	264859	0.004873
0.0035	678224	629492	0.005087

- Cartesian mesh was used for the entire domain.
- Grid convergence: 4.4% between element sizes of 0.005 m and 0.0035 m for Conventional Offshore OWC.
- Element size used for the Streamlined OWC is 0.0034 m

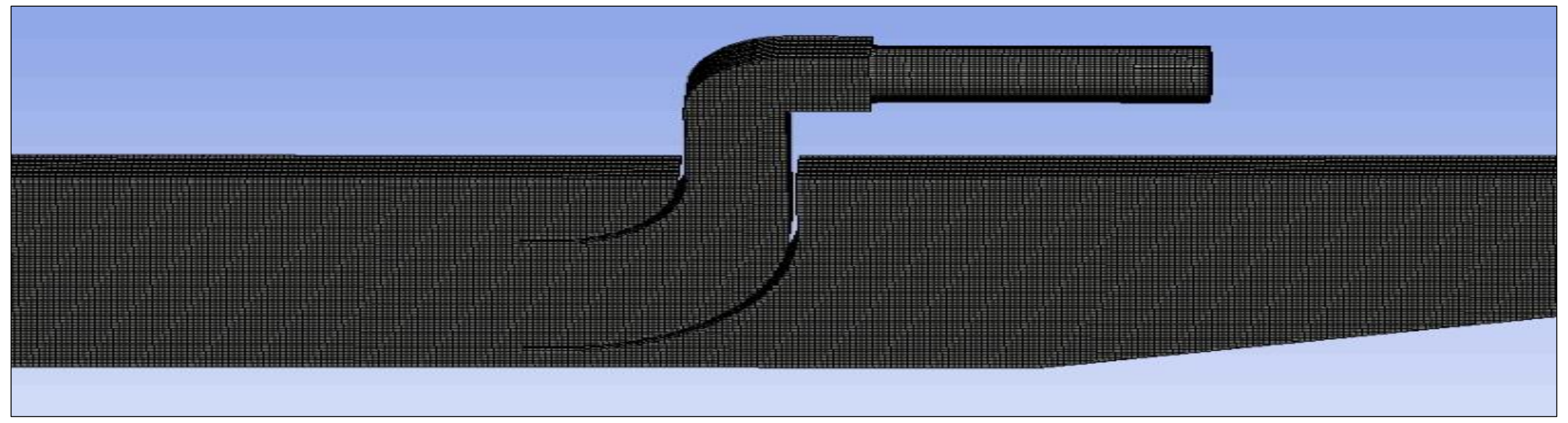

Fig. 3: Mesh of the Streamlined OWC System

5. Results

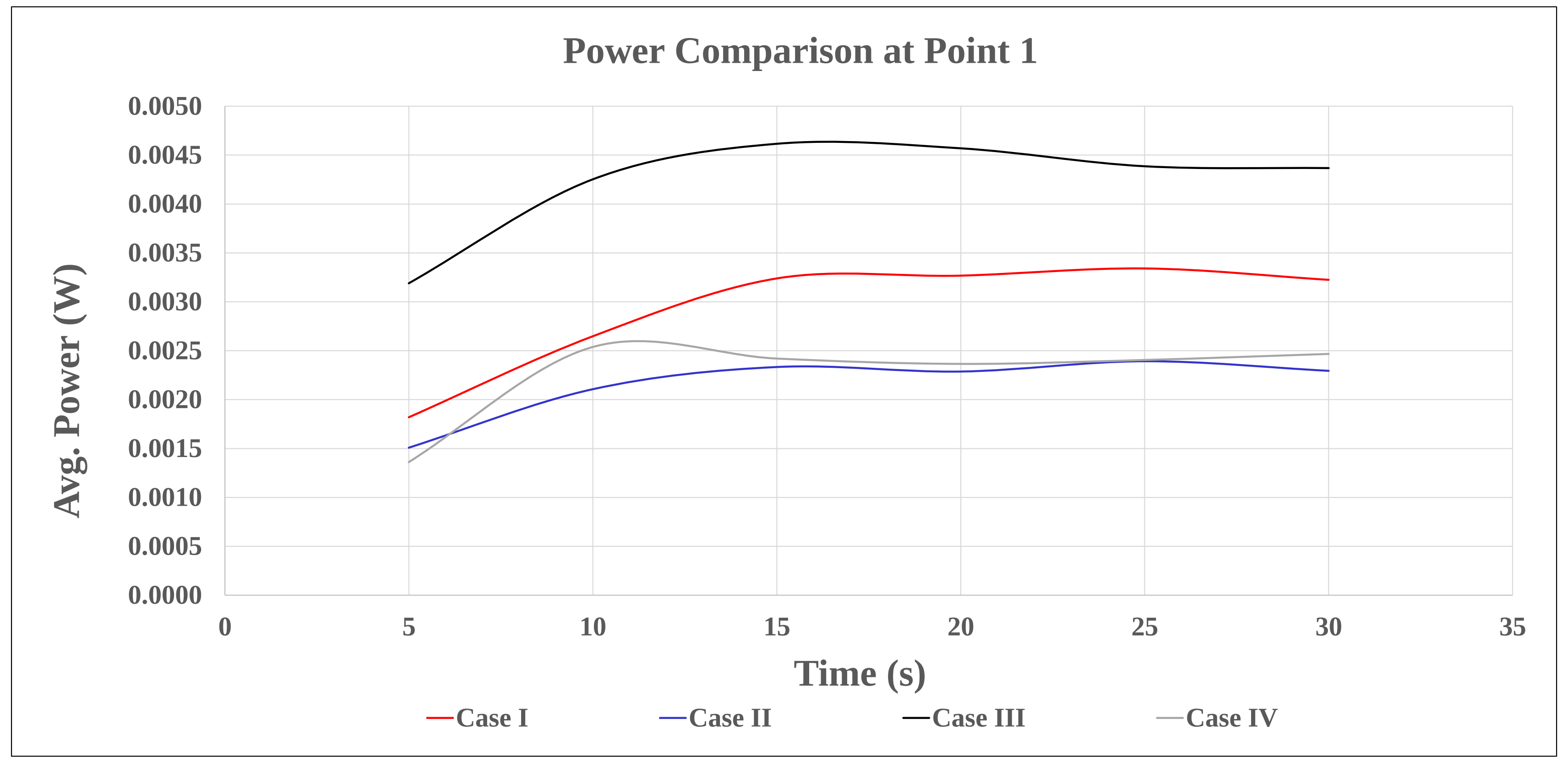

Fig. 4: Plot of Avg. Power (W) vs Time (s) at Point 1

Table 2: Efficiency Estimation of the Streamlined OWC.

Cases	Average Power Per Unit Width = 0.711350 W			
	Width, b (m)	Incident Wave Power across the width, P_w (W)	Average Power Produced by OWC at P1, P_{OWC} (W)	Efficiency of OWC, η_{OWC}
I	0.06	0.042681	0.003225	0.076
II	0.06	0.042681	0.002294	0.054
III	0.06	0.042681	0.004368	0.102
IV	0.06	0.042681	0.002365	0.055

6. Concluding Remarks

The pneumatic power produced by the Cases with the flap decreased compared with the geometries without a flap. Also, Case III with an extended chamber and with no flap produced the highest pneumatic efficiency at 10.2%.

Acknowledgements

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References

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