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Hydrokinetic Turbines

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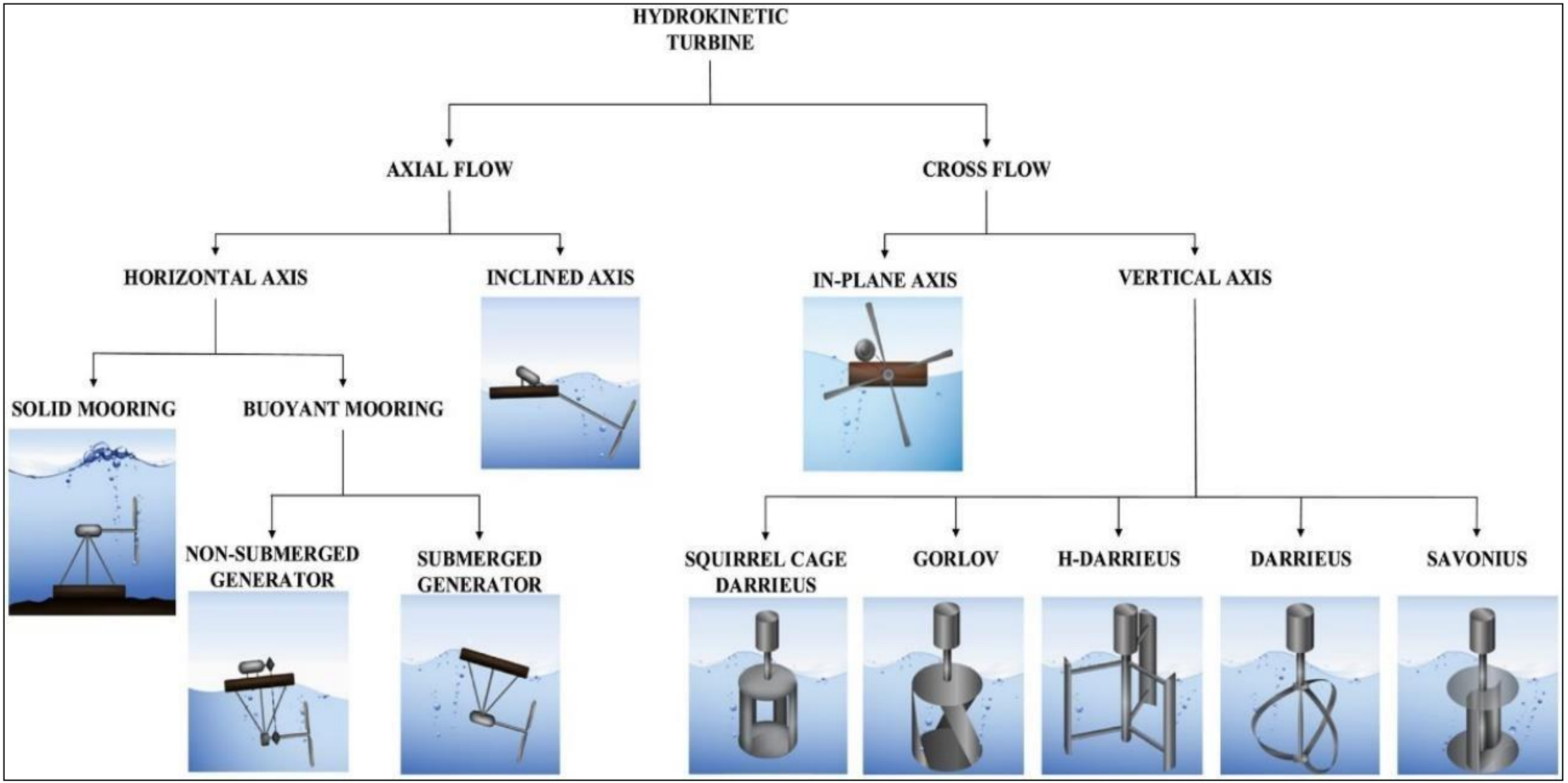
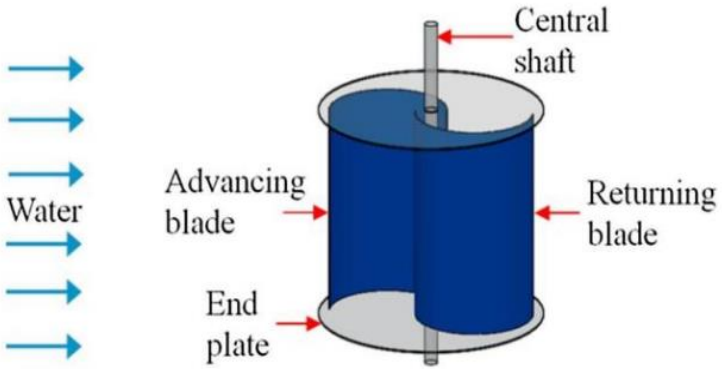
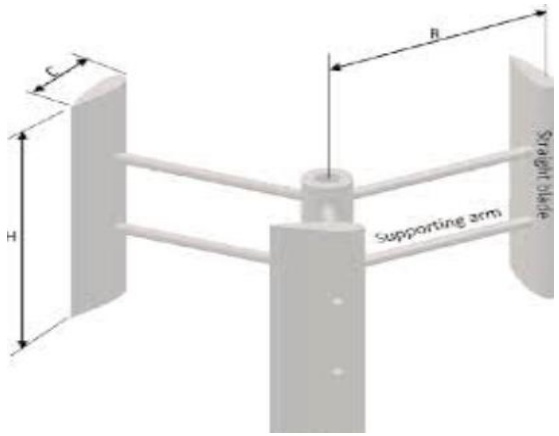
Classification of Hydrokinetic Turbine



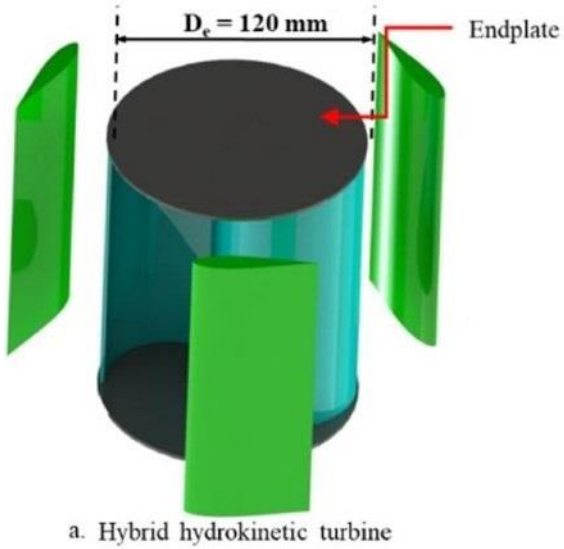
Cross Flow Hydrokinetic Turbines



Savonius hydrokinetic turbine (Talukdar, et al.,(2018)



Darrieus hydrokinetic turbine



a. Hybrid hydrokinetic turbine

Hybrid Hydrokinetic turbine (Kamal, et al., (2022))

Literature Review (Cross Flow HKT)

- Different parameters like number of blades, no. of stages, blade radius, blade arc angle, aspect ratio, twist angle, solidity ratio, pitch angle has been analyzed using both numerical and experimental approach for the Savonius, Darrieus and Hybrid HKT.

Reference	**Sarma et al. (2014)**	**Mosbahi et. al. (2019)**	**Salleh et al. (2021)**	**Salleh et al. (2022)**	**Patel and Patel (2022)**
Turbine	Savonius turbine	Helical Savonius (90°)	Savonius Turbine With deflector	Savonius Turbine With deflector	Savonius turbine without blocking plate
Analysis type	Experimental and Numerical	Experimental	Experimental	Experimental	Experimental

Literature Review (Cross Flow HKT)

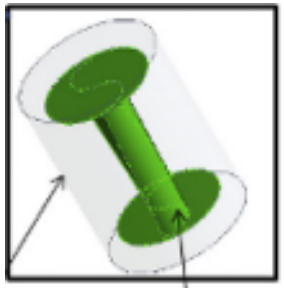
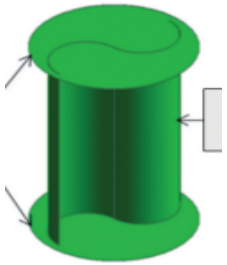
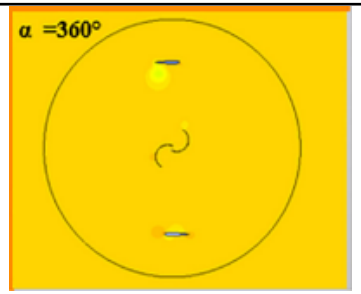
Reference	Ma et al. (2022)	Zhang et al. (2022)	Yosry et al. (2021)	Yosry et al. (2021)	Cacciali et al. (2021)
Turbine	Darrieus Turbine	Helical Turbine	Darrieus Turbine	Darrieus Turbine	Darrieus Turbine
Analysis type	3D numerical	Experiment	Experiment	Experiment	Experiment

Reference	Kamal and Saini (2022)	Saini and Saini (2021)	Sahim et. al (2014)	Sahim et al. (2014)
Turbine	Hybrid turbine	Hybrid turbine	Hybrid turbine	Hybrid turbine with deflector
Analysis type	Numerical	Numerical	Experiment	Experiment

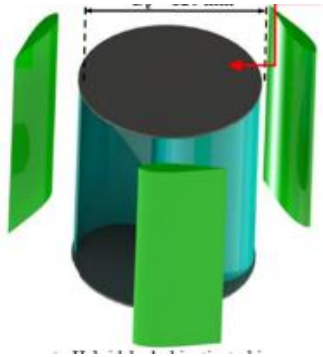
Experimental Facility in HRED

- A novel rectangular water channel made up of stainless steel complemented by a bell mouth opening to guide water stream flow towards the rotor.
- channel is facilitated with depth and slope adjustment mechanism powered by a motor
- The length and width of the water channel are as 4000 mm and 700 mm, respectively.
- Two axial flow pumps with each pump capacity of 150 lit/sec were used

Research work carried out in HRED on Cross Flow HKT

References	Turbine	HKT Profile	Objectives	Findings
Kumar et.al. 2017	Straight blade and twisted Savonius turbine		Numerical investigation of effect of blade arc angle and blade shape factor for different Tip Speed Ratio (TSR) and flow velocity	The optimum geometrical parameters for Savonius twisted blade was found to be as arc angle of 150^0 and blade shape factor of 0.6.
Sood et.al. 2021	Savonius with straight blades		Wake recovery distance has been analyzed for 4 different diameters of rotor operating at different water depth.	Depending on the rotor diameter and flow velocity, it was found that 90% of initial velocity is recovered at '25D'
Saini et.al. 2018	Hybrid turbine		To study the effect of radius ratio and attachment angle on performance of hybrid HKT.	The maximum power coefficient was found to be 0.34 at TSR value of 2.4 for the radius ratio of 0.2 and attachment angles of 30^o and 60^0.

Research work carried out in HRED on Cross Flow HKT

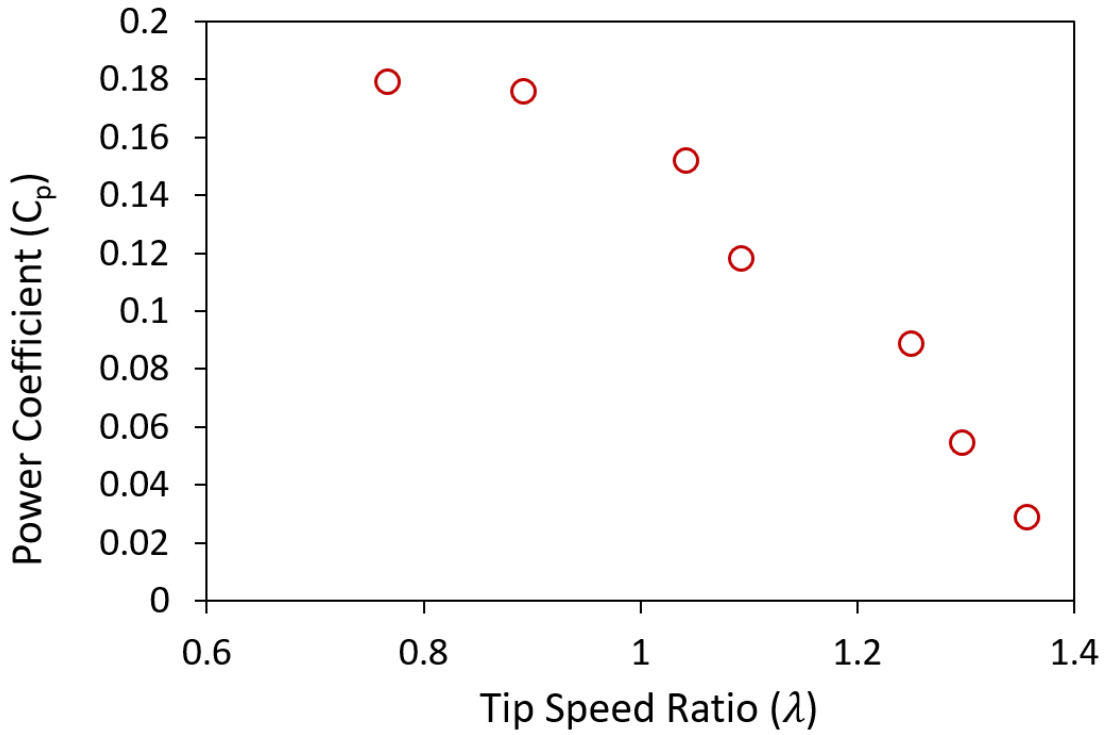
References	Turbine	HKT Profile	Objectives	Findings
Kamal et.al. 2022	Kamal et.al. 2022		To investigate the effect of 5 different hybrid HKT models on the performance having Savonius blade helical angle of 0^{o}, 45^{o}, 90^{o}, 135^{o}, and 180^{o}.	The maximum power coefficient was found for 45^{o} and velocity of 0.5 m/s for TSR value of 0.9.
Reddy et.al. 2024	Helical HKT		To investigate the influence of aspect ratio on the performance and wake recovery at different TSR and water velocities.	The peak power coefficient increased with the rise in aspect ratio for TSR value 1. The aspect ratio had an influence on wake recovery when it was increased from 0.75 to 1.25.

Experimental Data for Savonius HKT

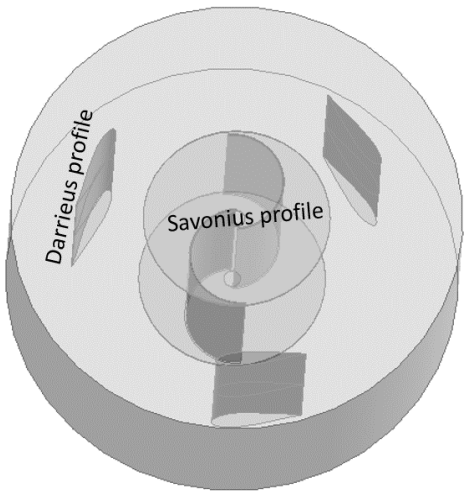
$$\text{Power Coefficient } (C_P) \frac{= Power\ Output}{P\ theoritical} = \frac{\text{Tx } \omega}{\frac{1}{2}\rho A V^3}$$

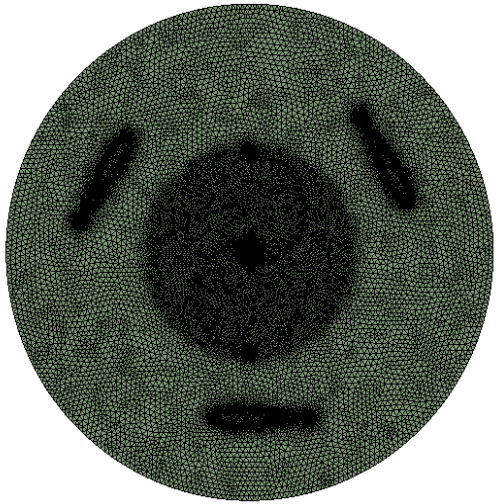
$$\text{Tip Speed Ratio } (\lambda) = \frac{\omega x\ D}{2V}$$

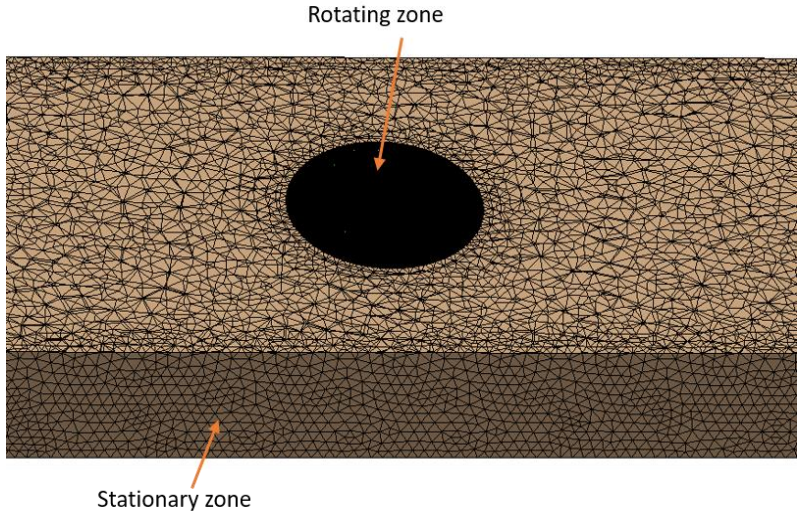
Design Parameters	**Dimensions (mm)**
Diameter of Savonius turbine (D_s)	120
Height of Savonius turbine (H_s)	150
Savonius blade shape	Semi-circular (0°)
Number of blades (Savonius)	2
Channel length (L_c)	4000
Channel width (W_c)	700
Depth of water (H_w)	300
Inlet Velocity	9.5 m/s



Numerical Simulation on Hybrid HKT



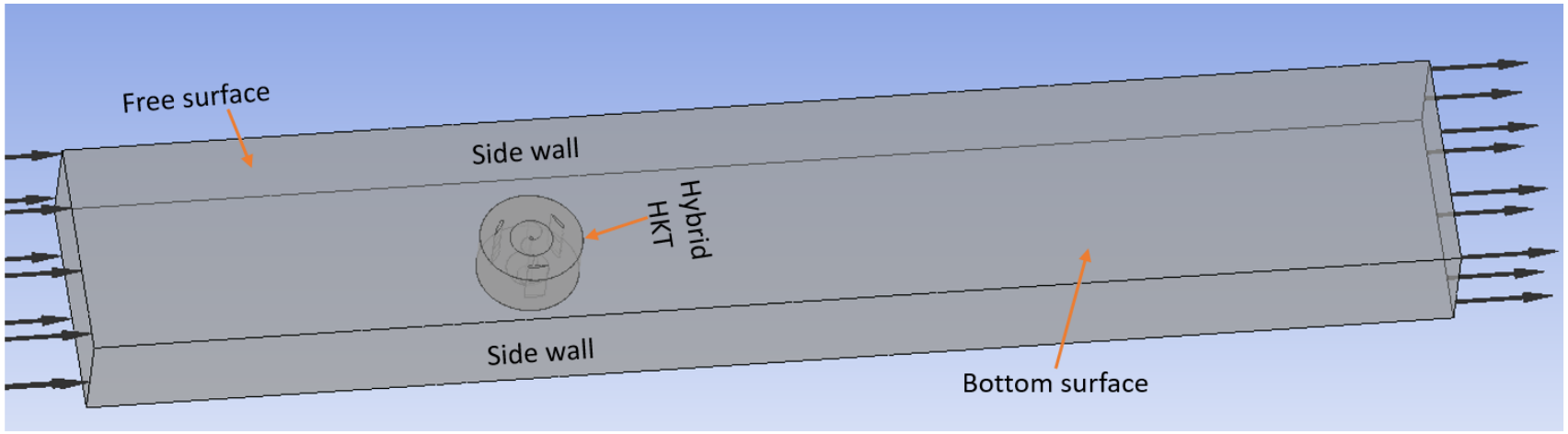




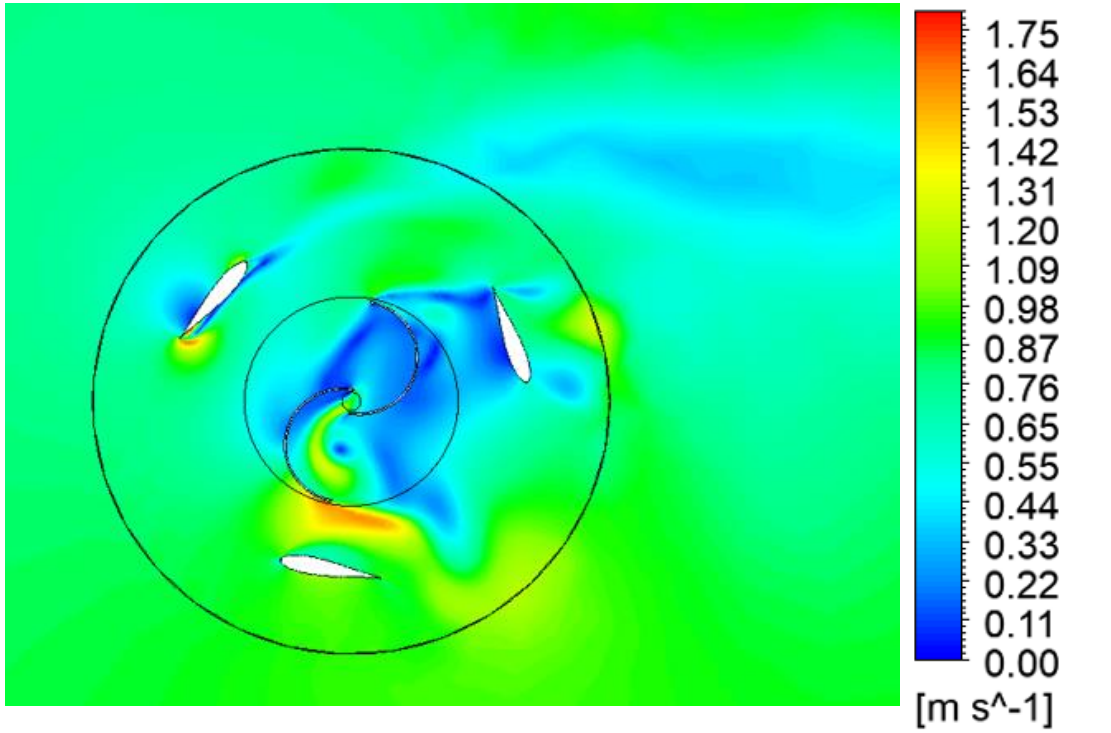
Meshing in fluid domain and around the turbine

Design Parameters	Dimensions (mm)
Diameter of Darrieus turbine (D_d)	200
Chord length of Darrieus turbine (c)	60
Height of Darrieus turbine (H_d)	150
Darrieus Blade profile	S1046
Number of blades (Darrieus)	3
Diameter of Savonius turbine (D_s)	120
Height of Savonius turbine (H_s)	150
Savonius blade shape	Semi-circular (0^o)
Number of blades (Savonius)	2
Channel length (L_c)	4000
Channel width (W_c)	700
Depth of water (H_w)	300

Numerical Simulation on Hybrid HKT



Boundary conditions for hybrid HKT



Conclusions

Three different turbines and their optimum design parameters reviewed:

- Savonius turbine is suitable for low flow velocity (even up to 0.5 m/s), as it has good self-starting capability. It may also be used for higher velocity but its power coefficient is very low (about 20%).
- Darrieus turbine has a higher power coefficient (40-45%), but fails to self-start at lower flow velocity.
- Hybrid turbine (combination of Savonius and Darrieus turbine) helps to improve the starting capability of Darrieus turbine, but may increase the cost of turbine due to complex profile.

Acknowledgement

- Nitish Prasad (Ph.D. Scholar at HRED, IIT Roorkee)

References

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Thank You