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DESIGN & FABRICATION OF SURFACE HYDRO KINETIC TURBINE

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Abstract—This study focuses on the design, fabrication, and performance analysis of a floating surface hydrokinetic turbine for power generation in canal flow conditions. The system utilizes the kinetic energy of flowing water and operates without the need for dams or height difference, making it environmentally friendly and cost-effective. Experiments were conducted at a flow velocity of 1.2 m/s to evaluate the effect of turbine inclination angle on performance parameters such as torque, angular velocity, and power output. The theoretical power was calculated as 29.8 W, while the maximum actual power obtained was 10.13 W. The highest efficiency of 34% was achieved at an inclination angle of 22°. The results show that turbine inclination significantly influences efficiency, and proper optimization can improve performance. This study demonstrates the feasibility of using hydrokinetic turbines for small-scale, sustainable energy generation in irrigation canals and rural areas.

Index Terms—Hydrokinetic turbine, Canal flow, Renewable energy, Floating turbine, Efficiency analysis, Inclination angle,
Power generation, Low-head hydropower

I. INTRODUCTION

In recent years renewable energy sources have increasingly contributed to global energy production with a total supplement of around 2179 GW (approximately 34% of global installed power capacity) of which hydropower is the largest contributor of approximately 1151 GW (approximately 18% of global installed power capacity) Considering the climate change crisis and ever increasing global electricity demand, there is a pressing need to rapidly accelerate this trend and transition to a renewable energy dominant portfolio that significantly reduces carbon emissions within the next decade. This can be achieved largely through the rapid expansion of utilityscale renewable energy projects and markets using mature and cost-effective renewable energy conversion technologies, e.g., solar, hydro and wind turbines Efforts are also needed to accelerate the development of new renewable energy industries and markets using next generation energy conversion technologies with the ability to extract untapped renewable energy reserves, including low-head (potential) hydropower and hydrokinetic (HK) power in water currents and waves. Studies on the opportunities for energy development such as those in water conduits create a forefront to accelerate development by allowing insights into available opportunities

Ideally a renewable energy conversion technology should have a minimum cost per annual average energy production as well as minimal and mitigatable environmental impacts with a maximum power output. Hydropower generation through the use of water conveyance systems can be a valuable global renewable energy asset, but relatively little of this potential has been accurately assessed or developed globally. This renewable energy resource can be harvested from existing water-infrastructure without the need to construct new dams or diversions, significantly reducing construction costs and the need to develop additional capital intensive centralized generation systems. By avoiding water impoundment, environmental impacts are minimized, further reducing the shortand long-term economic impact of environmental externalities. Furthermore, innovative technologies have been developed, including low-head hydro technologies that efficiently generate at low heads of approximately 3 m (9 ft), and near-zero head HK also referred to current energy conversion (CEC) devices, technologies that generate with no local potential energy head requirement. Projects with the potential to generate at least 1 000 MWh annually (100 kW installed capacity) can achieve competitive levelzed costs of energy (LCOE) of approximately $0.07 to 0.08$ per kWh [6] and additional renewable-energydevelopment incentives can further reduce project development costs. Smaller projects can also be viable investment opportunities in alternative energy markets where electricity costs from conventional sources such as diesel generation are high. For electricity demand located near flowing water, microhydro systems such as HK schemes may in many cases be the most economical and reliable option for generating electric power

II. THEORETICAL BACKGROUND

Hydrokinetic energy conversion is based on extracting the kinetic energy of flowing water without requiring a significant head difference. The available power in a water stream depends on the fluid density, flow velocity, and the effective area interacting with the turbine. The theoretical power available in the flow can be expressed as:

$$P = \frac{1}{2}\rho A V^3 \quad (1)$$

where ρ is the density of water, A is the projected area of the turbine, and V is the velocity of the water stream.

However, it is not possible to extract all the available kinetic energy. According to Betz theory, the maximum efficiency is limited to 59.3% [?].

The actual mechanical power produced by the turbine is given by:

$$P_a = \tau \cdot \omega \quad (2)$$

where τ is torque and ω is angular velocity.

The coefficient of performance is defined as:

$$C_p = \frac{P_a}{P} \quad (3)$$

The performance depends on turbine geometry, flow conditions, and inclination angle. Optimization of these parameters improves energy extraction efficiency [?], [?].

III. MATERIALS

The development of the floating hydrokinetic turbine required careful selection of materials to ensure structural strength, durability, and resistance to water-induced degradation. All components were chosen based on their mechanical properties, availability, and suitability for operation in a flowing water environment.

The modular belt, made of high-density polyethylene (HDPE), serves as the primary moving element of the turbine. HDPE was selected due to its high impact resistance, low weight, and excellent resistance to moisture and corrosion. These properties make it suitable for continuous operation in water without significant wear or degradation.

The shaft is fabricated from mild steel, providing the necessary strength to transmit torque generated by the turbine. Mild steel offers a good balance between mechanical strength and cost, making it appropriate for small-scale energy systems. Bearings made of cast iron (P-207) are used to support the shaft and enable smooth rotational motion while minimizing frictional losses.

The vane elements, attached to the modular belt, are designed to maximize the drag force exerted by the flowing water. Their geometry is selected to ensure effective interaction with the flow while minimizing backflow effects. The frame structure, also made of mild steel, provides rigidity and maintains alignment of all components during operation.

Polystyrene floats are incorporated to provide buoyancy, allowing the turbine to remain at the water surface. This floating arrangement ensures adaptability to variations in water level and simplifies installation in canal systems.

The selection of these materials ensures that the turbine remains lightweight, corrosion-resistant, and mechanically stable, which are essential for reliable operation in hydrokinetic applications.

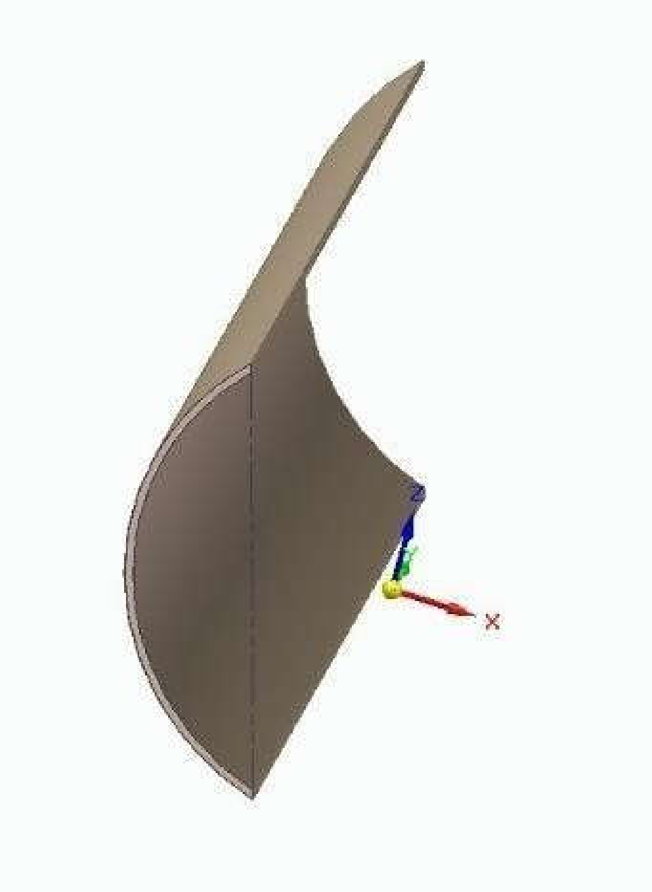

Fig. 1. CAD model of the turbine vane designed in Solid Edge with optimized curved geometry.

IV. MATERIALS AND METHODOLOGY

A. Material Selection

The selection of materials for the hydrokinetic turbine was carried out based on mechanical strength, resistance to water exposure, ease of fabrication, and cost-effectiveness. Since the turbine operates in a flowing water environment, materials with good corrosion resistance and durability were preferred.

High-density polyethylene (HDPE) was used for the modular belt due to its excellent resistance to moisture, impact strength, and lightweight characteristics. Mild steel was selected for the shaft and frame because of its high strength and ease of machining. Cast iron bearings (P-207) were used to support the shaft and ensure smooth rotational motion with reduced frictional losses. Polystyrene material was used for floats to provide buoyancy and maintain the turbine at the water surface.

Fig. 2. Modular belt link illustrating the component used for vane attachment and motion transmission in the turbine system

B. Design of Vane

The vane is the primary component responsible for energy extraction from the flowing water. The design of the vane was focused on maximizing drag force while minimizing flow separation and backflow losses.(1)

Different vane geometries ranging from flat to curved profiles were considered. The final geometry was selected based on its ability to generate higher hydrodynamic force under given flow conditions. The vane dimensions were chosen considering the available flow depth and clearance from canal boundaries.

The design parameters of the vane are given below:

- Outer diameter: 135 mm
- Inner diameter: 133 mm
- Chord length: 115 mm
- Length of vane: 230 mm

The vane thickness was selected to withstand the forces exerted by water while keeping the overall system lightweight. The geometry ensures effective interaction with the flow and continuous energy extraction.

C. Design of Modular Belt and Gear System

The modular belt serves as the moving platform for the vanes and plays a key role in converting the drag force into rotational motion. The belt used belongs to the ISMB-50 category and is made of HDPE material.(3)

The important specifications of the belt are:

- Pitch: 50 mm
- Thickness: 16 mm
- Minimum width: 150 mm
- Maximum tensile load: 750 kg

The belt is driven by a gear mechanism that ensures smooth motion and proper engagement. The gear specifications are as follows:

- Number of teeth: 12
- Outer diameter: 195 mm
- Working diameter: 174 mm
- Bore diameter: 40 mm
- Hub width: 30 mm

The belt and gear system were designed to ensure continuous operation with minimal slippage and efficient transmission of motion.

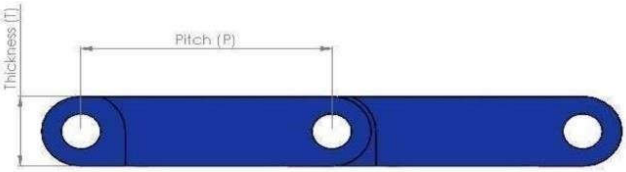

Fig. 3. Structural frame design of the hydrokinetic turbine showing the supporting arrangement.

D. Design of Shaft

The shaft is responsible for transmitting the mechanical power generated by the turbine. A mild steel shaft was selected to withstand torsional loads and ensure structural integrity.

The shaft consists of both square and circular sections to facilitate proper connection with the gear and bearings. The design parameters are: 2

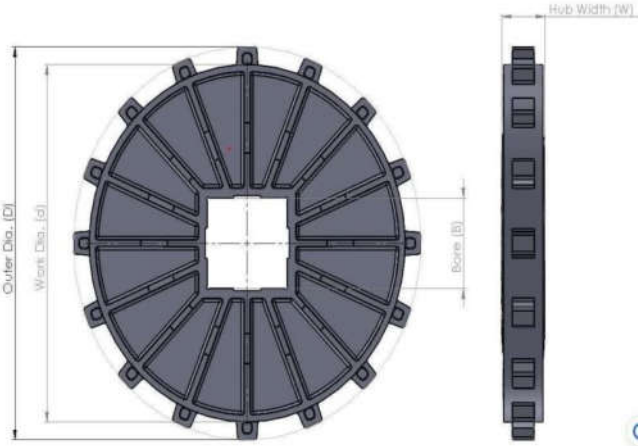

Fig. 4. Structural frame design of the hydrokinetic turbine showing the supporting arrangement.

- Length of square shaft: 310 mm
- Outer edge of square shaft: 38 mm
- Thickness: 3 mm
- Diameter of circular shaft: 32 mm
- Length of circular shaft: 100 mm

The shaft dimensions were selected to safely transmit torque without excessive deformation or failure.

E. Design of Frame

The frame provides structural support to the entire turbine assembly and ensures proper alignment of all components. It is fabricated using mild steel rectangular pipes.(5) The design specifications are:

- Cross-section: 50 mm × 25 mm
- Thickness: 2 mm
- Outer dimensions: 90 mm × 38 mm

Fig. 5. Structural frame design of the hydrokinetic turbine showing the supporting arrangement.

G. Methodology

1) Site Conditions: The experimental study was conducted in an irrigation canal with steady and uniform flow conditions. The measured parameters of the canal are:

- Width: 3.5 m
- Depth: 1 m
- Flow velocity: 1.2 m/s

These conditions provide a suitable environment for evaluating hydrokinetic turbine performance under low-velocity flow.

The frame is designed to withstand hydrodynamic forces and maintain stability during operation in flowing water.

F. Buoyancy System

Polystyrene floats are used to provide buoyancy to the turbine. The floating configuration ensures that the turbine remains at the water surface and adapts to variations in water level. This eliminates the need for complex support structures and simplifies installation in canal environments.

2) Experimental Procedure: The turbine was installed in the canal and aligned with the direction of water flow. The system was anchored using ropes to maintain stability during operation.

Experiments were conducted by varying the inclination angle of the turbine. For each angle, the system was allowed to reach steady-state operation before taking measurements.

Torque was measured using a weight and string arrangement connected to the shaft. Rotational speed was measured using a tachometer, and angular velocity was calculated from the measured speed.

3) Performance Evaluation: The theoretical power available in the flowing water was calculated using:

$$P = \frac{1}{2}\rho A V^3 \tag{4}$$

where ρ is the density of water, A is the effective flow area, and V is the velocity of water.

The actual power output was determined using:

$$P_a = \tau \cdot \omega \tag{5}$$

The coefficient of performance was calculated as:

$$C_p = \frac{P_a}{P} \tag{6}$$

The efficiency of the turbine was evaluated by comparing actual power output with theoretical power.

Fig. 6. Performance testing of the turbine under real flow conditions.

4) Test Parameters: The experiments were conducted for inclination angles ranging from 16° to 24°. The variation of torque, angular velocity, power output, and efficiency with respect to inclination angle was analyzed to determine the optimal operating condition.

V. RESULTS AND DISCUSSION

VI. Results and Discussion

The performance of the hydrokinetic turbine was evaluated under different inclination angles, and the measured values are presented in Tables I and II. The analysis focuses on the variation of torque, angular velocity, power output, and efficiency with respect to turbine inclination.

From Table I, it is observed that both torque and angular velocity increase with inclination angle up to a certain limit and then decrease. This indicates that the interaction between flowing water and vane surfaces improves initially with increasing angle, resulting in better momentum transfer and higher rotational motion. However, beyond the optimal angle, the flow interaction becomes less effective, leading to a reduction in both torque and rotational speed.

The variation of power output and efficiency is presented in Table II. The results show that the actual power generated by the turbine follows a trend similar to torque and angular velocity. As the inclination angle increases, the power output improves due to increased hydrodynamic force acting on the vanes. The maximum power output is achieved at an intermediate angle, after which a decline is observed.

The coefficient of performance (C_p) and efficiency also exhibit a similar pattern. The increase in efficiency with inclination angle indicates improved energy conversion capability of the turbine. At lower angles, the interaction between water flow and vane surface is not fully effective, resulting in lower efficiency. As the angle increases, the flow aligns better with the vane geometry, enhancing energy extraction.

Beyond the optimal inclination angle, a reduction in efficiency is observed. This can be attributed to flow separation, increased turbulence, and partial bypass of water over the vane surface, which reduces the effective force acting on the turbine. As a result, both power output and efficiency decrease at higher angles.

The results clearly indicate the existence of an optimal inclination angle at which the turbine achieves maximum performance. This optimal condition represents a balance between effective flow interaction and minimal hydrodynamic losses. The study demonstrates that turbine orientation is a critical parameter in hydrokinetic energy systems and must be carefully optimized to achieve maximum efficiency.

TABLE I

MEASURED TORQUE AND ANGULAR VELOCITY AT DIFFERENT INCLINATION ANGLES

Angle of Inclination (°)	Torque (N·m)	Angular Velocity (rad/s)
24	1.329	6.17
22	1.4176	7.15
20	1.2404	6.525
18	1.063	5.301
16	0.886	4.71

A. Power Calculations

The experimental values obtained were recorded and are presented in tabular form. The velocity of the water stream at the test location was measured as 1.2 m/s.

The theoretical power available in the flowing water was calculated using:

$$P = \frac{1}{2}\rho A V^3 \tag{7}$$

where $A = 0.06$ m^2, $\rho = 1000$ kg/m^3, and $V = 1.2$ m/s. Substituting these values, the theoretical power is obtained as:

$P = 29.808$ W

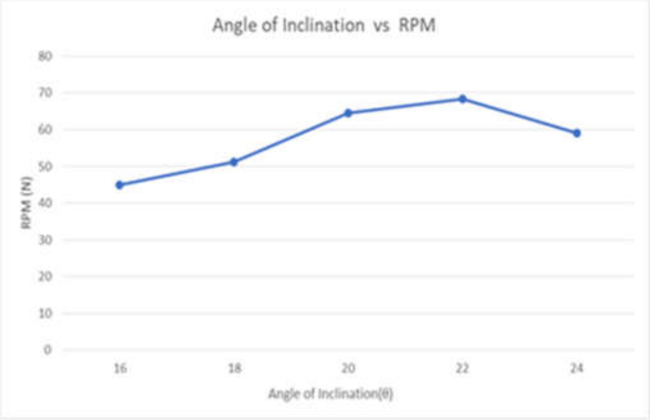

Fig. 7. Variation of rotational speed (RPM) with respect to inclination angle of the turbine

The actual power output of the turbine was calculated using:

$$P_a = \tau \cdot \omega \tag{8}$$

The computed actual power values for different inclination angles range from 4.17 W to 10.13 W. The maximum actual power of 10.13 W was obtained at an inclination angle of 22°, while the minimum value of 4.17 W was observed at 16°.

The coefficient of performance (C_p) varies between 0.1399 and 0.3400, indicating the efficiency of energy extraction under different operating conditions. Similarly, the efficiency of the turbine ranges from approximately 14% to 34%, with the highest efficiency achieved at 22° inclination angle.

These values clearly indicate that the turbine performance improves with inclination angle up to an optimal point and decreases beyond it. The detailed values of actual power, coefficient of performance, and efficiency are presented in Table II.

TABLE II

POWER OUTPUT, COEFFICIENT OF PERFORMANCE, AND EFFICIENCY AT DIFFERENT INCLINATION ANGLES

Theoretical Power (W)	Actual Power (W)	C_p	Efficiency (%)
29.808	8.19993	0.275092	27.50916
29.808	10.13584	0.340038	34.00376
29.808	8.09361	0.271525	27.15248
29.808	5.634963	0.189042	18.9042
29.808	4.17306	0.139998	13.9998

The influence of the angle of inclination (θ) on system performance was evaluated by analyzing the variations in torque and efficiency.

The torque vs. angle of inclination curve exhibits a monotonic increase in torque from 16° to 22°, indicating improved force transmission and effective utilization of input energy with increasing inclination. The maximum torque is observed at θ = 22°, beyond which a marginal decline occurs at 24°. This reduction may be attributed to increased resistive forces, misalignment, or flow-related losses at higher inclinations.

The efficiency vs. angle of inclination graph demonstrates a similar trend, where efficiency increases progressively with θ, reaching a peak at 22°. The subsequent decrease in efficiency beyond this angle suggests the onset of energy losses due to factors such as frictional resistance, turbulence, or reduced mechanical advantage.

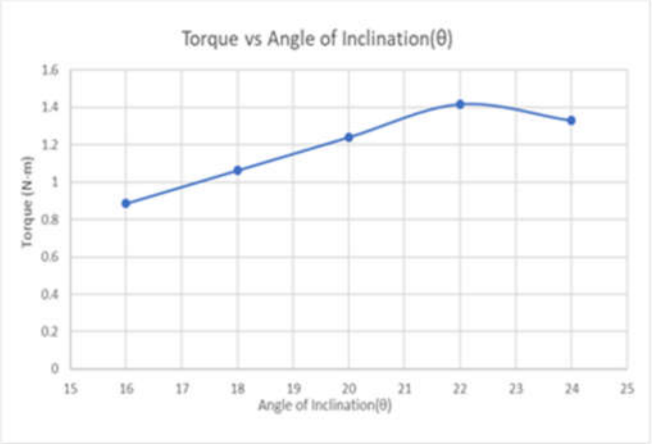

Fig. 8. Torque (N·m) versus angle of inclination (θ), illustrating an increase in torque with angle up to a peak at 22°.

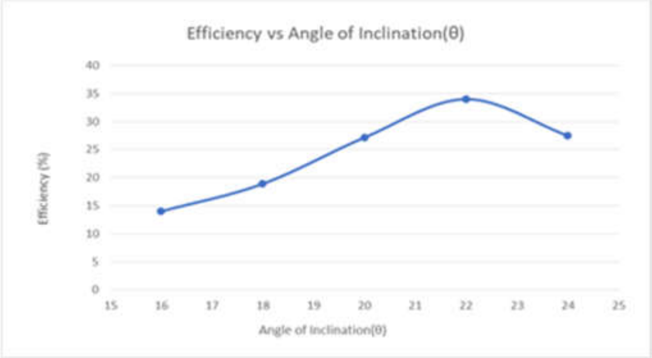

Fig. 9. Efficiency (%) versus angle of inclination (θ), showing an increase in efficiency with angle up to a maximum at 22°, followed by a decrease.

The observed trends indicate that both torque and efficiency are strongly dependent on the angle of inclination, with an optimal operating condition at θ = 22°. At this angle, the system achieves maximum energy conversion effectiveness and mechanical performance.

Thus, it can be concluded that 22° represents the optimal inclination angle for the system under the given experimental conditions, ensuring maximum torque output and efficiency.

VII. CONCLUSION

The experimental investigation of the Surface Hydrokinetic Turbine reveals that the performance of the system is highly dependent on the angle of inclination (θ) and flow conditions. The turbine requires a minimum stream velocity of 1.2 m/s to initiate and sustain operation.

The results indicate that the maximum efficiency of 34% is achieved at an inclination angle of 22°, corresponding to a torque of 1.4176 N·m at 68.3 RPM. Beyond this optimal angle, the efficiency decreases due to increased hydrodynamic losses, flow separation, and mechanical resistance. Similarly, the torque variation follows the same trend, confirming that θ =22° provides the most favorable operating condition.

The maximum power output obtained from the turbine is 8.9 W, demonstrating the feasibility of utilizing surface hydrokinetic energy for small-scale power generation. Overall, the study confirms that proper selection of inclination angle significantly enhances turbine performance in terms of torque, efficiency, and power output.

VIII. FUTURE SCOPE

India possesses a vast network of perennial rivers and irrigation canals, offering significant untapped potential for hydrokinetic energy generation. The developed Surface Hydrokinetic Turbine can be deployed at various scales in such water bodies to harness renewable energy without causing environmental degradation.

Future research can focus on improving the turbine design through advanced blade geometries, optimized inclination mechanisms, and enhanced structural configurations. The use of lightweight, corrosion-resistant, and high-strength materials can further improve efficiency and durability.

Additionally, computational analysis techniques such as CFD (Computational Fluid Dynamics) can be employed to better understand flow behavior and optimize performance. Integration with energy storage systems and hybrid renewable setups can further increase the applicability of the system.

Such advancements will not only improve the efficiency and power output of the turbine but also make it a viable solution for electrification in remote and rural areas, contributing to sustainable energy development.

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