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Design Process and Study of Pico Hydroelectric Floating Waterwheel Turbine

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ABSTRACT

Flowing and open streams can produce electricity using waterwheel or floating waterwheel turbines. Hydrokinetic energy from open streaming water in open channels has the potential to back neighborhood power needs since of lower administrative and capital speculation compared to customary seizing water implies. This research outlines key design parameters of interest, effective tools, and methods for the engineering characteristic rank arrange concurring to the customer's prerequisites in Quality Function Development (QFD). The higher action chart is the common data approximately the capacities performed by the item and useful modeling that depicted the detail work handle. For concept generation, a few methods used in a specifying the design by using the process and methodology such as Design analysis, Design for Assembly and Morphology analysis. The general design will be proposing in the finalize result. A new design of floating waterwheel prototype had been proposed and drafted with the purpose to generate electricity. Finally, this design had met the requirement and guidelines for the development process. In future, mathematical model and data survey should be formed to develop the product.

Key words: Design, waterwheel, floating water wheel, hydro power, stream and prototype.

1. INTRODUCTION

Today, the widespread concern is about authenticity and verification of renewable energy resources to provide power for electricity, where the concerns is in terms of electricity are widely utilized. A set of devices have been used for different renewable energy resources which is depended on the purposed of generating micro hydroelectric such as breastshot, pitchback, overshot and undershot water wheel turbine. In this project, the renewable energy from water resources is implemented by applying the waterwheel energy design into reliable characteristics to suit the environment condition which is known as hydropower.

The waterwheel technology is one of the forms of electric power generation machines that use river water resources where this technology is quite good for small-scale hydropower plants [1][1] and it is designed to deliver continuous electricity based on water stream source fund [2]. There are several types of water wheel turbines for renewable water and one of them is breastshot wheel.

There are three types of water wheels: overshot, undershot, and breastshot waterwheels [3]. For the watershot wheels, it can be used for very small head differences, 0.5-2.5 m, and flow rate in the range between 0.5-0.95 m^3/s per meter [3]. The normal undershot wheels are about 30% efficient. Others in terms of the waterwheel geometry have a curved blade tip where water will be discarded vertically and cleaner that leads to efficiency up to 77% [4]. Experiments conducted in connection with the performance of water wheels and theoretical models are evaluated by the experimental results review. The results shown at the end are the maximum value efficiency of undershot and overshot for the waterwheel.

Previous research was conducted on a micro hydro system, design and simulation of a generator model and hydraulic turbine for the implementation of a small hydro power in the waterfall, where solutions have contributed to the enormous potential for power generation [5]. Efficient use of water wheels as open channel flows, providing good power generation solutions have been discussed and concluded that water wheels as renewable energy aremost suitable for rural areas [6]. Meanwhile, the use of the tradition waterwheels system without any improvement produces synthetically output power that is not at maximum value.

The development of floating water wheel in use with new material such as wrought iron, allows it to be better than the form produced by the movement of the water wheel evolution into a fairly efficient energy exchange for a very low head [7]. The floating water wheel blade is part of a functional water turbine based on the water push [8]. When the turbine was pushed off by water, the blades were twisting. This water turbine is mounted to produce the kinetic energy from the free water wheel [9]. Based on the results of the analysis, an eight-blade water wheel is more efficient with the 1m/s speed variable (45.58% efficiency) and 5m/s (13.84%) efficiency [10]. In addition, water kinetic energy was not found to have an impact on the vitality transformation handle in the underwater wheel. It has been classified that underground water known as a response turbine.

In addition, due to its straightforward shape and formative changes, the undershot waterwheel is an economical turbine, and numerous private areas are mindful of this innovation making it appropriate for application in inaccessible zones [11]. Other research shows that the the specialized determinations for waterwheels, giving parameters for undershot waterwheeldesign [12]. In [13] paper shows the comparison of the effectiveness between blades number and blade configuration for an undershot waterwheel using an experimental method. A procedure for planning, designing, and installing a Pico-hydro power plant in a village using an undershot water wheel as the turbine was proposed [14]. The effect of immersing blade depth had been examined in the performance of an undershot waterwheel found that an immersed depth of 40mm was optimal compared than an immersed depth parameter used [15]. The flow behavior of the undershot water wheel had found which conditions that have the most force on the performance for designing [16]. An equation also has been developed to optimize the output power and efficiency of a hydrokinetic energy generation system using an undershot water wheel as its turbine [17].

Savonius waterwheel showed that the performance of the water's wheelSavonius with semi-curve where the number of blades was 4, 6, and 8 at the flow rate and the shaft load of 0.01587 m^3/s and 1000grams respectively was 9.945%, 13.929%, and 17.056% respectively [18]. Thus, high numbers of blades show good performance and high efficiency for Savonius waterwheel. This information is empirical, and in-depth analysis of other factors such as design parameters, working conditions, and important trend features affect the performance of the wheels is still in the preliminary stages of the study [19]. For breastshot water, design can be referred to as an alternative model with water head unsuitable for the overshot wheels [5]. In the previous study [8], where flow wheels were designed for water applications on the inside, the turbines with 12 blades gained the lowest efficiency compared to the turbines with 10 and 12 blades. Researchers [6] and [20] carried out experiments for the floating type flow wheel absorbs kinetic energy from the river. The wheels are equipped with a floating body with two side pontoons connected by the base plate and separator to improve the efficiency of the device. The small underwater wheels are higher than the water free of vortex turbines. It can be concluded that small underwater is more suitable at the head of water staff less than one meter [21].

For vertical water wheels, made from iron, have a design with excellent efficiency (80 to 90%) Low to medium head, and in the power range 10 to 50kW per unit, but the weakness of the remaining vertical water wheel is that it produces too much influence over downstream water levels, and it is impossible to use high runner-up [22]. Moreover, the under low water wheels are easily used in high ground areas with transportation, maintenance, and repair facilities. The average efficiency of this water turbine is between 35-40% [23]. More recent, advanced generators, free vortex rain water was found to have laboratory efficiencies of around 30-40% when the head of water is lower than a meter.

Therefore, the difficult part are to come out with a new design characteristics or parameters of waterwheel turbine that suit with the environmental condition of the research area especially in terms of reliability, flexibility and optimization to generate the power for electricity. The design should comprise design process and methodology including material type and cost. Therefore, objective of this study is to relate the patent search of waterwheel turbine designin order to overcome the problems faced by the past design. Aiming to come out with a new prototype for the waterwheel design turbine that floating on the water.

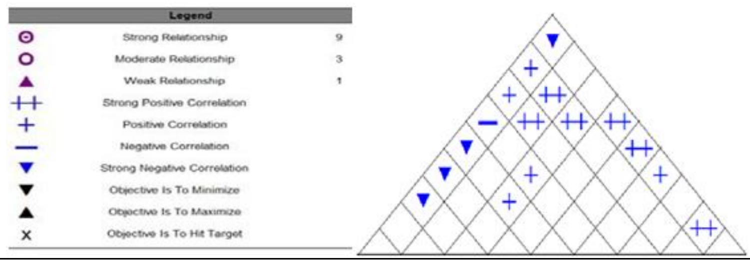
2. ANALYSIS QUALITY FUNCTION DEPLOYMENT (QFD)

There are a lot of reviews from the past design that had been made towards the waterwheel turbine to fulfill the customers need for supplying home electricity in the certain communities' area of the research. It will focus on the development of waterwheel design type and the application of the functionality of the product for the requirement needs. Despite a lot of design for waterwheel turbine that already applied, there are still some problems to be solved in the new generation of the design structure also considering a lot of factors to achieve the objective of floating waterwheel turbine.

A Quality Function Deployment (QFD) is additionally known as House of Quality where the most work to construct this chart within the item plan is to decide prioritized client requests and client needs, talked and implicit, deciphering these needs into activities and plans such as specialized characteristics and determinations. Moreover, to construct and provide a quality item or benefit, by centering on different capacities toward accomplishing a common objective of customer's fulfillment for the product developer.

3. HOUSE OF QUALITY

The House of Quality or QFD is a relationship between demand and characteristic of the product direct attention to those factors that matters most for a client when designing products. Figure 1 shows the priority of improvement where primary should be given to size, followed by cost, fatigue, environmental effect, toughness, type of material, and physical appearance.



Row #	Max. Relationship Value in Row	Relative Weight	Weight / Importance	Column	1	2	3	4	5	6	7	8	9	Competitive Analysis (0=worst, 5=best)	
				Direction of Improvement	▼	▼	▲	▲	▲	▲	▲	▼	▲		
				Quality Characteristic / Demanded Quality	Coating	size	Cost	Toughness	Hardness	Environment effect	Physical appearance	Fatigue	Type of material	Own Company	Competitor 1
1	9	7.0	3.0	Weight Consideration		O						O	Θ	4	2
2	9	2.3	1.0	Good in performance			O						O	2	3
3	9	7.0	3.0	Pressure Adaptability			Θ							4	2
4	9	11.6	5.0	Strength in material		Θ	O	Θ						3	2
5	9	7.0	3.0	Human Factors			Θ					Θ		4	1
6	9	11.6	5.0	System Reliability			O					Θ		4	1
7	9	11.6	5.0	Easy to maintain or service		Θ					▲			2	4
8	9	7.0	3.0	Easy to assembly		O								2	3
9	9	2.3	1.0	Suitable Location		Θ				O	O			3	2
10	1	7.0	3.0	Easy to operate		▲								2	4
11	9	7.0	3.0	Durability			Θ	Θ	Θ	O		Θ	Θ	2	3
12	9	11.6	5.0	Anti-corrosion						Θ	O		O	4	2
13	9	7.0	3.0	Environmental friendly	Θ					Θ	O	▲	▲	2	3
				Target or Limit Value											
				Max Relationship Value in Column	9	9	9	9	9	9	3	9	9		
				Weight / Importance	62.8	279	258.1	167.4	62.8	195.3	74.4	258	167.4		
				Relative Weight %	4.2	18.6	17.2	11.1	4.2	13	4.9	17.2	11.1		
				Rank order	6	1	2	4	6	3	5	2	4		

Figure 1: Quality Function Deployment

3.1 Concept Generation

This study using the Morphological Analysis to design and generate the concepts of floating waterwheel design. A morphological chart could be a visual way to capture the vital item design and investigate elective implies and combinations of accomplishing the right design. For each element of product design, a number of possible solutions need to be considered. The chart empowers these arrangements to be communicated and gives a structure for considering elective combinations. Below are the strategies to develop a Morphological chart.

i. List the design approach

This listing serves several capacities concurring to a foreordained arrange most vital, position within the structure, energy stream, data stream. Care ought to be taken to list capacities and not components.

ii. List the possible for reliable design

Think almost modern thoughts, as well as known arrangements or components and where conceivable thoughts ought to be communicated outwardly as well as in discourse. A few vital characteristics of the arrangements ought to be taped. Attempt to maintain the same level of sweeping statement for each potential arrangement.

iii. Chart partof plan and implies and investigate combinations

Draw up a chart with five columns containing all possible sub-concept as shown in Table 1. Typically the morphological chart which ought to speak to the whole arrangement space for the item. Attempt wherever conceivable to precise all alternatives outwardly as to recognize feasible combinations of sub- arrangements. The complete number of combinations may be exceptionally huge, so may have to be restricted to the foremost practical or alluring choices.

Table 1: Concepts Design Combination

Design Reliable		Concepts				
		A	B	C	D	E
1.1	Type of water flow	Direct Water Flow	Open Channel	Penstock	Streamlines	
1.2	Water Flow speed	Low speed	Medium speed	High Speed		
2.1	Position of Turbine	Fixed	Floating			
2.2	Place	Rivers	Open Sea	Waterfall		
3.1	Type of Waterwheel	Breastshot	Undershot	Pitchback	Overshot	
3.2	Type of Blade/Paddle	Flat	Bucket	Helical	Airfoil	
3.3	Number of Blade	Three	Five	Seven	Nine	Twelve
4.1	Shaft Material	Mild Steel	Stainless Steel			
4.2	Shaft Ability	Rigid	Can absorb rotation	Anti-corrosion		
4.3	Generator	5V	10V	12V		

3.2 Concept Assessment

Assessment includes comparison, taken after by choice making. To form a substantial comparison the concepts must exist at the same level of deliberation. There are numerous methods for concept assessment such as comparison based on supreme criteria, Pugh's Concept Determination Strategy, Weighted Choice Network. This investigate utilizing Pugh's concept selection strategy since it is nice strategy for choosing most promising plan concept as appeared in Table 2. It compares each concept relative to a reference or datum concept and for each model decides whether the concept in address is superior than, more awful than, or around comparative to the reference concept. The steps being taken to develop Pugh's concept.

Step 1: Generate an assortment of ideas or concepts
Step 2: Prepare a criteria list
Step 3: Pick a datum
Step 4: Evaluate each alternative by rating them with "+", "-" and "0"
Step 5 Rank the concept by referring the sums up scores
Step 6 Choose the best optimized concept
Step 7 Seek opportunities for improvement
Step 8: Apply more rigorous engineering disciplines

Table 2: Pugh's Method

Selection Criteria		Concepts															
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
1.	Manufacturing cost	-		0	0	-	0	-	-	0	0	0	-	0	0	0	DATUM
2.	Material	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3.	Weight	-	-	-	0	-	0	-	0	-	0	-	-	0	-	-	
4.	Design	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
5.	Durability	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
6.	Realibity	0	+	+	0	+	+	+	+	0	0	+	+	+	+	+	
7.	**Ability waterwheel to turn**																
	Water rotates the wheel	+	-	0	+	+	-	+	+	-	0	-	+	-	0	-	
	Wheel rotates at speed require	+	0	-	0	0	0	-	-	+	0	+	0	-	+	-	
8.	**Amount of rotation speed**																
	Rotational speed apply	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
	Gearing system application	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
	Generator application	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
9.	**System Efficiency**																
	Power efficiency high	-	0	0	0	0	-	0	-	-	-	-	0	-	-	-	
	Enough to supply current	0	-	-	0	-	-	-	-	0	0	-	0	-	-	-	
	Location is suitable	+	0	0	+	0	+	0	+	0	0	0	0	+	+	0	
	Water current speed low	-	-	-	0	-	0	-	0	-	0	-	-	0	-	-	
	Safe from environment	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
10.	**Maintenance**																
	Ease to service and repair	-	0	0	+	+	0	+	0	-		+	+	0	0	-	
	Sum of " + " (better than)	9	7	7	9	9	8	9	9	7	6	9	9	8	9	7	
	Sum of " - " (worse than)	5	5	4	0	4	3	5	4	5	2	5	3	4	4	7	
	Sum of " 0 " (similar as)	3	5	6	8	4	6	3	4	5	9	3	5	5	4	3	
	Net Score	4	2	3	9	5	5	4	5	2	4	4	6	4	5	0	
	Rank	7	13	12	1	3	3	7	3	13	7	7	2	7	3	15	
	Continue? (Yes = Y, No = N)	N	N	N	Y	Y	Y	N	Y	N	N	N	Y	N	Y	N	

3.3 Concept Comparison

The Pugh's concept determination strategy, the concepts are chosen for advance assessment. A few concepts are created and compared in terms of points of interest and impediments, where the comparison of concept #3 appeared in Figure 2. The visual see of concepts is additionally appeared through hand draws for superior understanding.

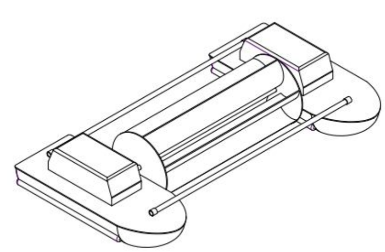


Figure 2: Concepts Design #3 of Floating waterwheel turbine

3.4 Concept Selection

Concept choice is the method of narrowing the set of concept choices beneath thought. This paper utilizing the Weighted Decision Matrix strategy which as well-known as concept scoring since it is straightforward to urge it and apply. Concept scoring is utilized when expanded determination will superior separate among competing concepts. In this organize, the weighted framework is the relative significance of the choice criteria and centers on refined comparisons with regard to each model. The concept scores are decided by the weighted entirety of appraisals. This approach can be great at demonstrating the front runners, but numerical strategies like this could be unsafe, as they tend to suggest as it were one 'right' reply. It ought to continually be recollected that both, the weighted and the appraisals are subjective. The methods to construct a Weighted Decision Matrix table are:

i. List the most important features

These ought to have been decided amid the item definition stage and shape the criteria against which equal arrangements will be judged.

ii. Determine weightings

Some features will be more critical than others. Assign weightings to each, so that their relative merits are accounted for. Ideally, the weightings should be determined in partnership with the target customers.

iii. Rating each option

Suppose the rating should be led by customer's relation to remove personal bias from amongst the design team or own idea.

iv. Calculate the weighted totals

Multiply the score by the weighting for each feature and sum the totals.

Table 3: Pugh's Method

			Concepts							
			(1)		(2)		(3)		(4)	
	Selection Criteria	Weighted (%)	R	S	R	S	R	S	R	S
1.	Manufacturing cost	25%	3	0.75	3	0.75	5	1.25	3	0.75
2.	Material	5%	4	0.20	4	0.20	4	0.20	4	0.20
3.	Weight	3%	4	0.12	2	0.06	4	0.12	2	0.06
4.	Durability	2%	5	0.10	4	0.08	1	0.02	5	0.10
5.	Safety	5%	3	0.15	2	0.10	2	0.10	3	0.15
6.	Reliability	10%	2	0.20	3	0.30	3	0.30	4	0.40
7.	Functionality	20%	5	1.00	4	0.80	3	0.60	4	0.80
8.	Human Factors	10%	4	0.40	2	0.20	4	0.40	4	0.40
9.	Easy to maintenance	10%	4	0.40	2	0.20	3	0.30	3	0.30
10..	Able to operate	10%	5	0.50	5	0.50	3	0.30	3	0.30
	Total Score		3.82		3.19		3.59		3.46	
	Rank		1		4		2		3	
	Continue		Yes		No		No		No	

R= Rating (1 = Inadequate, 2 = Weak, 3 = Satisfactory, 4 = Good, 5 = Excellent)
S =Weighted Score

3.5 Final Design

From the weighted decision matrix table, decided concept (#3) as the foremost ideal concept since it has the most elevated score among the other concepts. The remaining concepts will be changed and keep as reference as showed. In conclusion, the ultimate concept is concept (#3) which can be continuing to encapsulation plan and a few of the investigation is additionally based on the rules for item standard in Table 4.

Table 4: Guidelines for product standards

Guidelines	Application to product
No sharp edges in manufacturing	Floating Frame of the product do not have sharp edges
Easy for assembly, disassembly and move the parts	Parts attach with screws and also in and out mounting.
Device operation safety	Product build follow the standards to meet the required need in electricity not harm in overload power generated.

4. PROPOSED PROTOTYPE DESIGN

The engineering drawing of the floating waterwheel turbine design have separate parts which divided into three main sections namely Floating Frame, Waterwheel and Shaft. In this paper, the parts such as screws are not included in the drawing because they are standard parts. By Using CAD software, the product is being sketched in the 3D view as shown in Figure 3.

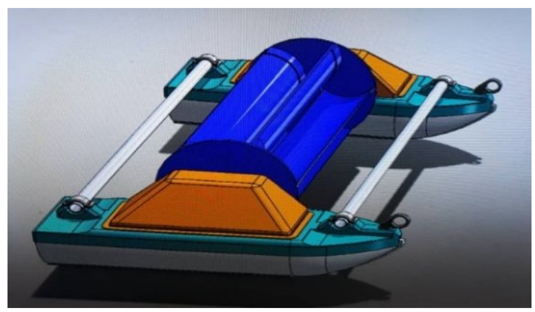


Figure 3: Model design of floating water wheel

4.1 Principle of Operation

The model will be installed near the open flow area as the water direction will be directly hit the waterwheel turbine. Force of water will pushing against the wheel and cause the wheel to rotate. The kinetic energy from the rotating wheel then is converted into mechanical energy. Meanwhile, the function of the generator is to convert the mechanical energy produced by the turbine into electrical energy. The generator is connected to the wheel by shafts and gear so when the wheel rotates, causes the generator to rotate also. The gear is designed to transmit motion from the turbine shaft to load shaft (generator) in order to avoid damage of the generator if overloading.

4.2. Constraint

A constraint has been set up in designing the floating waterwheel turbine. The power output of floating waterwheel turbine must be between 0.5 kW and 1 kW to ensure meet the power demand.

4.3. Product Requirements

Table 5 indicates guideline for product standards of desired criteria with its weighted percentage.

Table 5: Guideline for product standards

No.	Criteria	Weighted Percentage
1	Cost	25
2	Reliability	30
3	Weight	5
4	Safety	5
5	Performance	35
	Total	100

The most desirable criteria would be performance. This is followed by cost. Floating waterwheel turbine hydropower should cost less since it is designed for community in remote areas. Next is reliability where the product can perform its intended function satisfactorily without failure at given age. Since this design is based on water, thus the reliability of the product is one of the most important criteria that has to be considered. The least desired criteria are weight and safety.

4.4. Material Selection Analysis

Material selection will be based on product's requirement and function of each component based on Rating evaluation Table 6. Decision matrix in Table 7 is used in this analysis. The following steps show the process of choosing the best material for each component.

Table 6: Rating for Evaluation

5- point scale	Description
0	Inadequate
1	Weak
2	Satisfactory
3	Good
4	Excellent

Table 7: Decision Matrix for Wheel Material

Design Criterion	Weight factor	Material			
		Mild steel		Stainless steel	
		Score	Rating	Score	Rating
Reliability	0.30	3	0.90	4	1.20
Ease of fabrication	0.28	4	1.12	1	0.28
Cost	0.25	3	0.75	1	0.25
Weight	0.05	2	0.10	2	0.10
Availability	0.12	4	0.48	4	0.48
TOTAL	1.00		**3.35**		2.31

Table 7 shows that mild steel scored higher point compared to stainless steel. Mild steels are stiff and strong. Welding mild steels requires extraordinary safety measures be taken. However, welding mild steel presents fewer issues than welding stainless steels. Stainless steels corrosion resistance is better than mild still, but the use of protective coating may increase the mild steel corrosion resistance. Other than that, mild steel is easily available and less in cost.

Table 8: Decision matrix for Shaft

Design Criterion	Weight factor	Material			
		Stainless steel		Aluminum	
		Score	Rating	Score	Rating
Reliability	0.30	4	1.2	2	0.6
Ease of fabrication	0.28	2	0.56	3	0.84
Cost	0.25	3	0.75	2	0.50
Weight	0.05	2	0.10	3	0.10
Availability	0.12	4	0.48	4	0.48
TOTAL	1.00		**3.09**		2.52

Table 8 shows thatstainless steel scored higher point compared to aluminum. Stainless steel is better for shaft material because of its high modulus of elasticity. Besides, it also has a great corrosion resistance in oxidizing environments. Aluminum is generally less strong compared to stainless steel, but it is relatively high cost compared to steel at the same strength.

5. CONCLUSION

A new design prototype of floating waterwheel had been draft and proposed for this project as shown in Figure 4 and this require further research on mathematical model and data survey, where both should be conducted soon in order toproduce a real product. The system of the floating waterwheel turbine should develop generation of electricity. A gear system will be applied to this design and theoretical equation will be conducted to determine the type and size of gear for the system. Finally, this design should meet the requirement and guidelines for building process.

Figure 4: Prototype development

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