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Experimental Investigation and Optimization of Modified Blade and Conventional Blade for Savonius Hydrokinetic Turbine in Canal Flow

Sumukh S. Sumant[1,] Dr. Bhavesh Mewada[2] and Manish S. Maisuria[3]
[1] *Research Scholar, Mechanical Department, Parul Institute of Technology, Parul University, Vadodara, India*
[2] *Professor, Mechanical Department, Parul Institute of Technology, Parul University, Vadodara, India*
[3] *Associate Professor, Mechanical Department, Parul Institute of Technology, Parul University, Vadodara, India*

Abstract: - Today due to rapid growth of digitalization and inhabitants increases due to that the usage of energy is increasing to fulfill the demand of inhabitants because demand rising of energy the pollution of the nature is higher so this will create a global warning effects on nature to decrease this global warning renewable or green energy usage is essential for environment friendly nature this will save the exhaustible resources like (coal, petroleum) and save the nature against pollution. There are so many sources available in renewable energy like (air, water, sun rays) this all sources are remain till the existence of the world. Therefore in this research paper we are mainly focus on hydro power energy to produce electricity with the use of natural resources in hydro power sources have different method is used to utilize to convert water energy into useful electric power with the help of VAWT and HAWT type turbine but in this paper our main focus in on VAWT (vertical Axis Water Turbine) which includes Savonius and Darrieus turbine but in this research paper we have use 2-blade Savonius turbine using modified split blade mechanism to reduce negative thrust and increase the performance and efficiency of the turbine. In this article mainly focus on 2-blade turbine because 3-blade and 4-blade have lower efficiency than 2-blade turbine. From the results of the research paper Split blade type modified savonius turbine best performance and highest efficiency is noted in split blade turbine compare to conventional turbine in this Cp value is achieved 0.25 of the water speed of 62 rpm is achieved having velocity of water is 0.57m/s.

Keywords: Savonius Turbine, Hydro Kinetic Turbine, Renewable Energy, Modified Blade Design, Split Blade.

Nomenclatures

HAWT	Horizontal Axis Water Turbine	N	Angular velocity of the turbine (RPM)
VAWT	Vertical Axis Water Turbine	ρ	Density of water ($kg\ /\ m^3$)
Cp	Co-efficient of power	ω	Angular velocity (rad/s)
TSR	Tip Speed Ratio	Pmax	Available power in water (W)
CFD	Computational Fluid Dimension	$P_{turbine}$	Extract power by the turbine (W)
A	Frontal area of the turbine rotor (m^2)	D	Diameter of the turbine rotor (m

1. INTRODUCTION

Today as per increasing demand of the electricity is increases because of population of India is rising due to the digitalizing of country the usage of electric power is high so to fulfill the demand of public producing electric power with the natural resource is important energy is a valuable commodity in modern civilization. “The consumption of energy has evolved into an indicator of living standards and industrialization. At the moment, nearly 90% of the world's energy comes from the burning of fossil fuels such as petroleum oils, natural gas, coal and so on. Humans utilize fossil fuels to fulfil nearly all of their energy requirements, including driving cars, producing electricity for lighting and heating, and running factories.[1] On the opposite hand, the earth's fossil energy resources are limited, and world production of oil products will exceed its peak in the coming decades. Population growth will increase the demand for energy, as well as the cost of fossil fuels”.[2]

Simultaneously, we face a trouble with worldwide climate change resulting from carbon dioxide and sulfur-dioxide emissions from the burning of fossil fuels.[3] Using sustainable power as a cost-effective and dependable low-carbon energy source is becoming a major goal of global energy policy.[4] To use the pollution free green energy which is inexhaustible natural resource to use of the type of energy there are so much type of resource like wind energy, water or hydro energy etc. this all are the renewable type of energy resource.[5]

In the hydro type water energy have so many types of turbines like there are VAWT type turbine and HAWT type turbine in this VAWT type has two types like Savonius turbine and Darrieus turbine. In HAWT type turbine have wells turbine.[6] In this research article we mainly focus on VAWT type turbine in this we have use Savonius Hydro Kinetic Turbine to extract power from the water resource which is inexhaustible by nature gift to human beings. [7]

Sigurd J. Savonius invented the Savonius wind turbine in 1922 as a simple vertical-axis turbine machine. It was originally designed with two half-cylindrical blades arranged in a 'S' shape. As worldwide demand for energy increases, breakthroughs in energy conversion emerge, and changes to solar and wind energy sources such as solar, wind, and hydro become essential. The sunrays, air, and water are among nature's most valuable gifts. All living things on the planet rely on all three. Air and water are more than just simple fluids required for human survival because they are used as energy sources. [8]

It is also simple to install in a river or canal. This can operate with a small head and velocity and has a great self-capacity. Because water is a dense fluid, it is possible to derive more power from a water turbine than from a wind turbine of the same size when tried to apply to water power applications. However, the Savonius turbine concept has not been extensively investigated and practiced as a hydrokinetic turbine. As a result, the Savonius water turbine is best suited for canal conditions, as it can operate with a least fluid velocity of 0.5 m/s. [9]

Many HKT methods, whether for seawater or lakes, work according to the basic principle of converting free-flowing freshwater bodies' kinetic energy into mechanical power of rotor blades until trying to convert it into useful energy, primarily electricity. This same kinetic energy of a river current is transformed into mechanical power as the water rotates the turbine's rotor blades, as shown in Fig. 1. In turn, the turbine is linked to a shaft that drives a generator. To transform mechanical power into electrical power, a producing system, generally of the magnetic force type, is coupled with a gearbox unit. The energy generated is can then use to power sources or stored in batteries. [10]

Because water has a density approximately 800 times the same of air, a hydro - power turbine operates in a denser flowing fluid than a wind turbine. Like an outcome, a Savonius turbine trying to operate as a HKT system instead of a wind-based system experiences increased drag force, leading to greater torque production. A HKT system is approximated to retrieve or more than 61% more kinetic energy from streams and rivers than a similarly sized wind generator once applied to the same power input. [11]

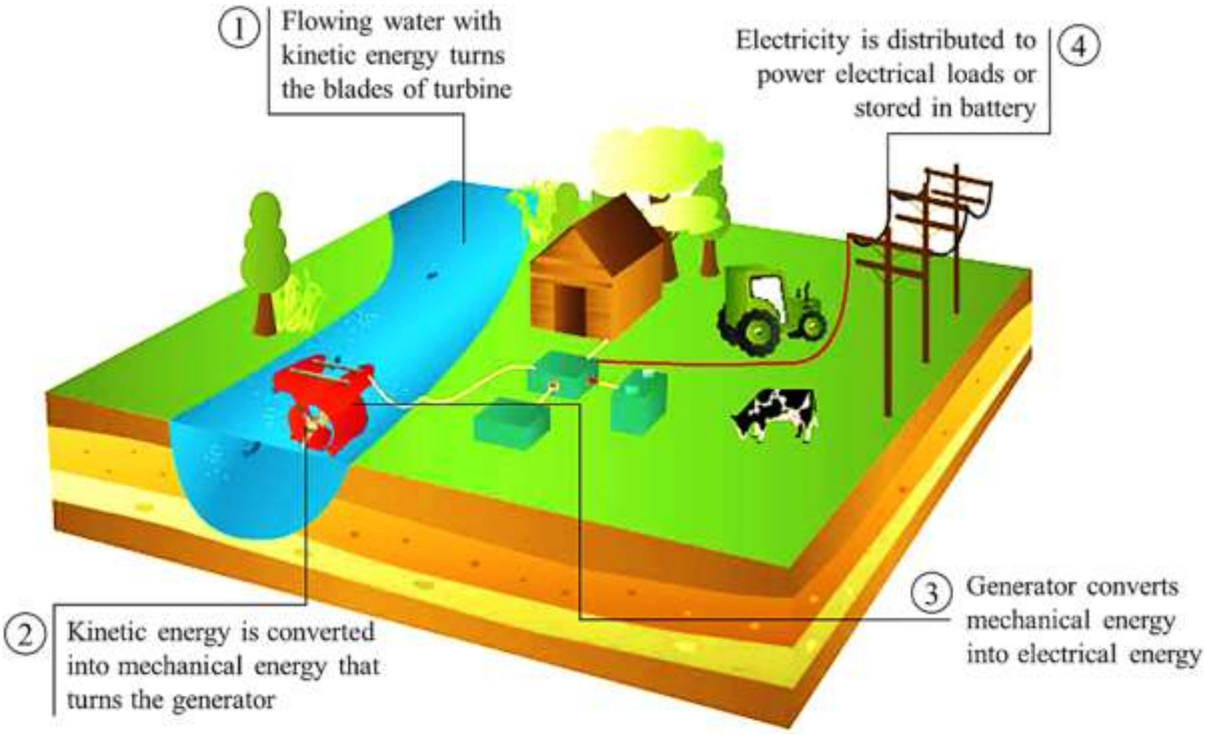

Fig. 1. "The working principle of the river current HKT system"[12]

2. Savonius Turbine Methods

2.1 Conventional Savonius Turbine

In the conventional type of Savonius turbine has simple construction of turbine and easy to use in this method 2-blade turbine is used to extract the water power to generate the energy in this turbine. Conventional Savonius turbine has negative thrust on the advancing blade which is reduced the turbine efficiency and also decreased the Cp.

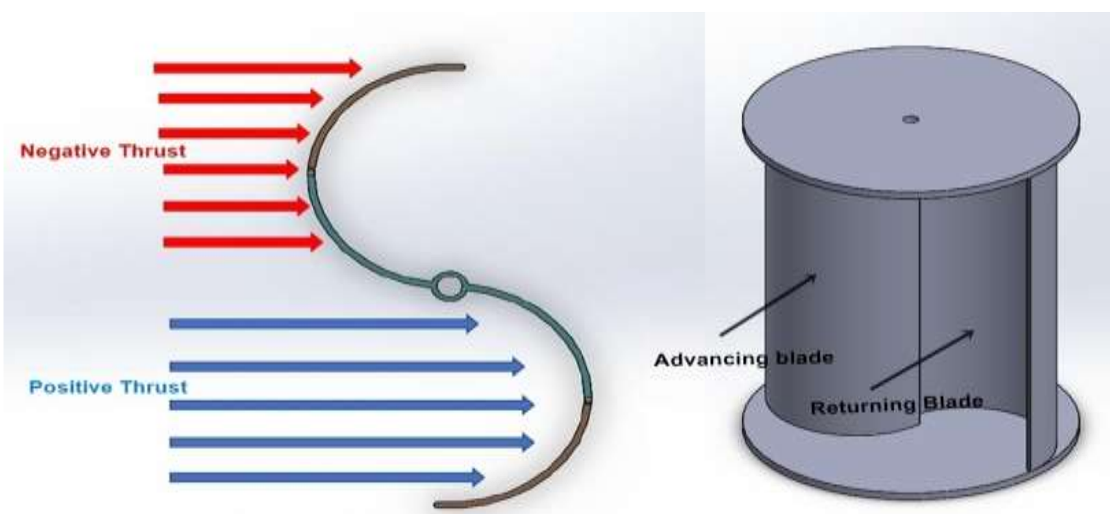

Fig 2. 2-blade Savonius Turbine's Blade and Flow Direction

"The savonius turbine's cross section is "S-shaped," with two semi-circular bucket shapes. The Savonius turbine operates by rotating around a central shaft, with fluid stagnation pressure acting on the concave side of the advancing blade. The drag force of the flow exerts a strong force on the advancing blade. During a similar moment, the convex surface of the returning blade experiences negative torque. Since a concave surface has a greater drag coefficient than a convex profile, the advancing blade experiences more drag force. This total drag difference on both surfaces generates a net positive torque, which aids turbine rotation. This turbine rotates at the speed of 43 rpm."

2.2 Split Blade Type Modified Savonius Turbine

In split blade type Savonius turbine has used split type mechanism to split the 2-blade Savonius turbine into 4 parts to minimize the negative thrust effect in Savonius turbine. To use this type of turbine for actual practical purpose this turbine gives 45% more power than the conventional turbine. In split blade type modified Savonius turbine having higher Cp value than the Conventional type Savonius turbine.

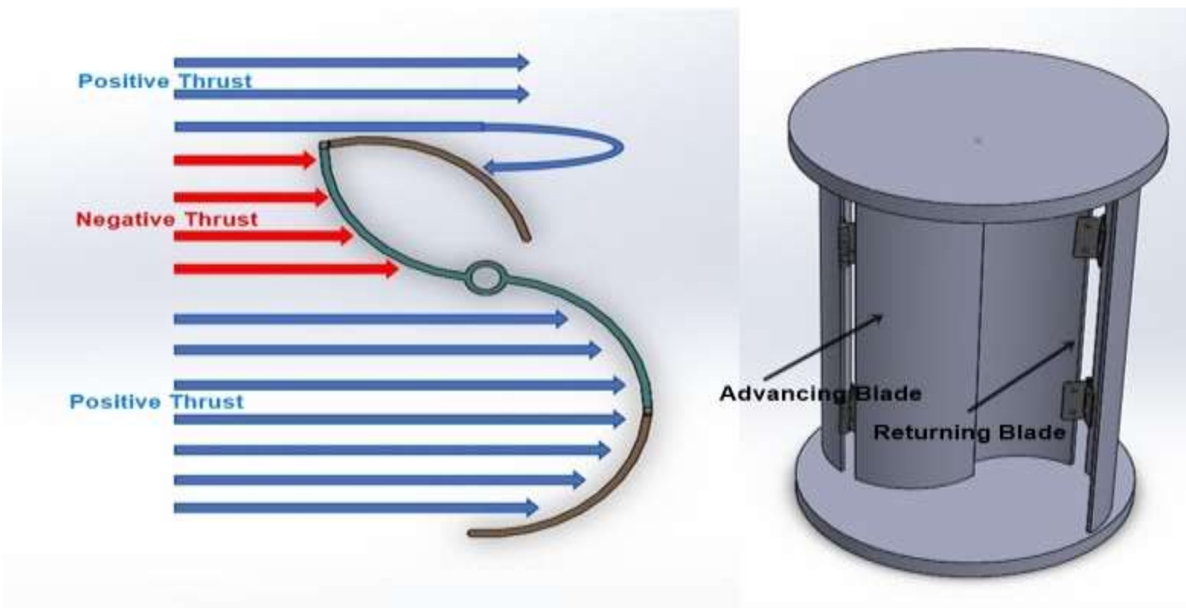

Fig 3. 2-blade Split Type Modified Savonius Turbine Blade and Flow Direction

This Savonius turbine have also same "S" type shaped with the four semi-circular bucket type shape in this turbine it should rotate the central shaft with fluid pressure applied on the advancing type of blade. When the pressure is applied on advancing central position the blade is used spring hinge mechanism to divert the fluid flow of water and minimize the negative thrust effect on the advancing side of blade this should be increase the positive thrust of the fluid and increase the value of Cp because in the above fig 3 when negative thrust is applied the spring hinge is rotate the split part into inside direction as shown in fig to eliminate the half negative thrust and increase the efficiency around 45% more than previous conventional Savonius turbine design.

During this similar moment the returning blade does not split because in opposite direction the blade is automatically open and make a rotation of turbine to generate net positive torque in this turbine is rotate around at the speed of 62 rpm.

This turbine is having higher co-efficient of power is produced due to split type mechanism is this Savonius modified turbine.

2.3 Actual method and Fabrication of Savonius Water Turbine

In the actual method of Savonius water turbine the its orientation is vertical axis type turbine is used in this paper it is used for the water application purpose so to run this type of turbine the water has minimum velocity of 0.4m/s to use this water energy into the useful work from the Savonius turbine.

The fabrication of Savonius turbine is used PVC pipe having cut from the center of the vertical axis having thickness of 5 mm this turbine is then fix on the wooden structure with proper bearing to rotate on the desired path of the structure.

Fig 4. Conventional Actual Turbine blade

Fig 5. Split Blade Modified Actual Turbine blade

Table 1. Actual parameter of Savonius Water turbine

Geometry parameters	Value
Shaft Radius (Rs)	8 mm
Rotor Diameter (D)	204 mm
Blade Angle	180°
Rotor Height (H)	150 mm

The below fig 6 have a schematic structure of the savonius water is shown with the 4 rectangle hollow pipe with MS material fix with 2 rectangle wooden sheet having 10 mm thickness is fix so that the structure is not moving with the water flow having 12 mm through hole on both the side of the wooden sheet to fix the turbine shaft is fix with bearing in the center so that the shaft is rotate freely.

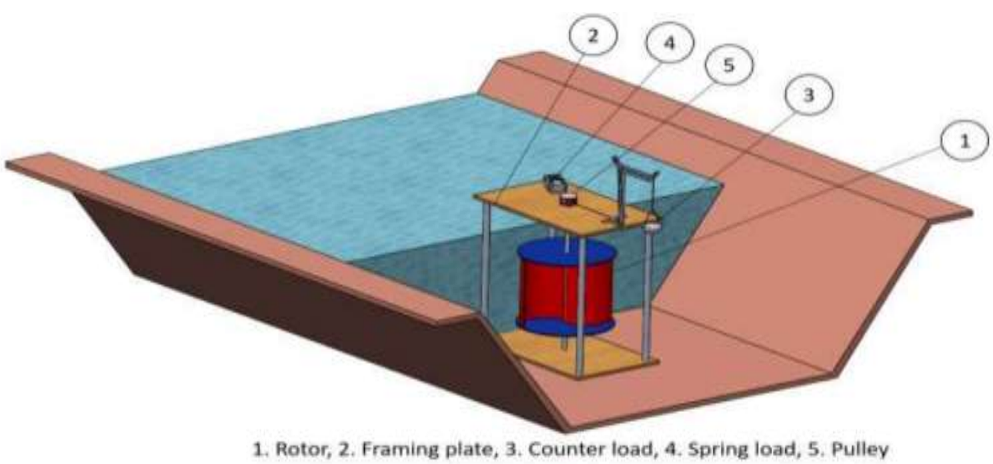

Fig.6 Schematic Diagram of Savonius water turbine [13]

3. Experimental procedure and performance

In the actual experiment performance is carried out at the canal to get proper flow of the water to run the actual turbine in the below fig 9 and fig 10 has shown the setup of the turbine in proper structure so that reading to be taken properly.

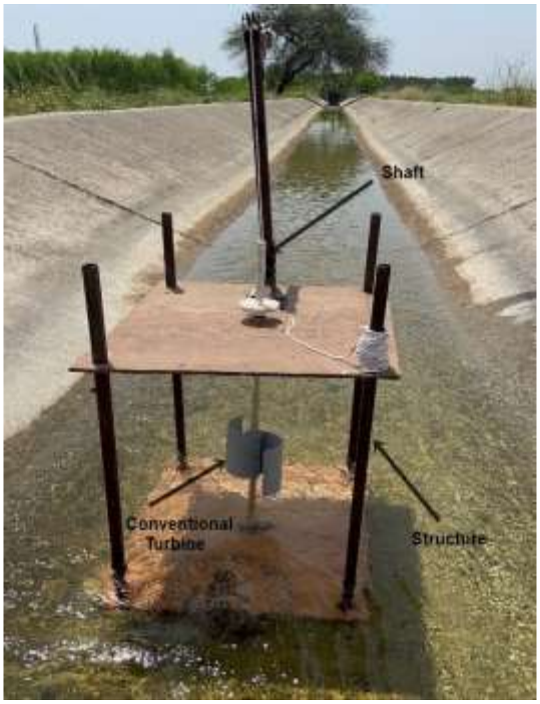

Fig 9. Experimental Setup of Conventional Turbine

Fig 10. Experimental Setup of Split type Modified Turbine

In this experimental setup of Savonius water turbine has tested on the 0.9 m depth of water canal and having water velocity is 0.57 m/s in this experiment the procedure of get the reading is simple firstly the turbine is have rotate freely without any load is applied rpm is to be noted in this 62 rpm is get for split blade modified and 43 rpm for conventional turbine and after this load is gradually increases up to turbine stop the rotation mean while takes the reading on every load increase and also calculate to get the torque of the Savonius turbine this process is continue till get the rpm up to 0 so that we should get the load value and spring meter value to calculate the Co-efficient of power (Cp) and Tip Speed Ratio (TSR).

To calculate the Cp and TSR value of the experimental method the following are the mathematical formulation is shown below to find different parameters for the comparison the energy carried out for the water current having velocity (v) is given under.

$$p_{\max} = \frac{1}{2}\rho A v^3 \tag{1}$$

The energy is available at the shaft of the turbine, torque generated shaft and rotor rotational velocity is represented by the Eq (2)

$$P_{turbine} = T\omega \tag{2}$$

The tip speed ratio (TSR) is defined as ratio of angular velocity of the turbine to blade velocity is given by below Eq (3)

$$TSR = \frac{\omega D}{2u} \tag{3}$$

The coefficient of power is the ratio of the $P_{turbine}$ to the $p_{\max}$ is given by the Eq (4)

$$c_P = \frac{P_{turbine}}{p_{\max}} \tag{4}$$

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4. Results and Discussion

Results of the conventional Savonius turbine indicates that relation between coefficient of power and tip speed ratio to the overall efficiency and performance is depends on this value like Cp has 0.15 and Tip speed ratio has around 0.80 so in that below fig11 is shown the water turbine model of 2-blade is more convenient than 3-blade or 4-blade turbine because in 2-blade turbine has less negative thrust as compare to 3-blade and 4-blade if water flow has higher rotation will results higher tip speed ratio. In this type of turbine has shown the Cp vs TSR for 2-blade conventional savonius turbine.

In Conventional Savonius turbine is shown in fig 11 is simple type of savonius turbine to get normal efficiency but if we get higher efficiency, we have to use new or modified turbine blade to fulfill the purpose.

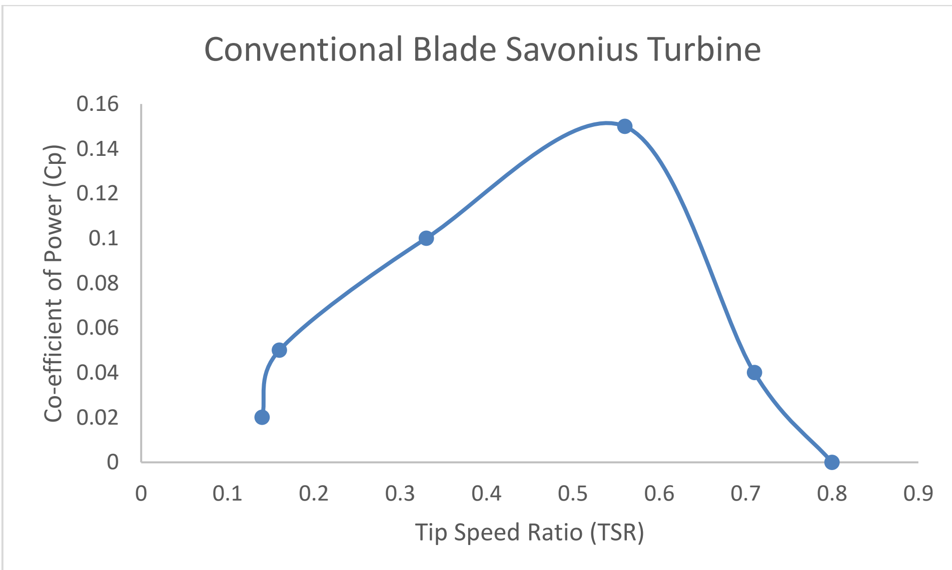

Fig 11. Conventional Savonius Turbine Cp vs TSR Chart for 2-blade

Results from the fig 12 is for the Modified blade savonius turbine having connection of the coefficient of power and tip speed ratio this will highly affect the performance and efficiency of turbine having Cp value is 0.25 and tip speed ratio is 1.16 if we can see that 2-blade split type savonius turbine has Cp and TSR value is gradually increasing to get the higher performance and efficiency than normal or conventional turbine.

As a result, this modified type of split blade savonius turbine is more useful than simple turbine hence it is fulfilling the purpose of the user and also both value is gradually increase therefore it is useful and it have simple and easy setup of the modified type split blade savonius turbine.

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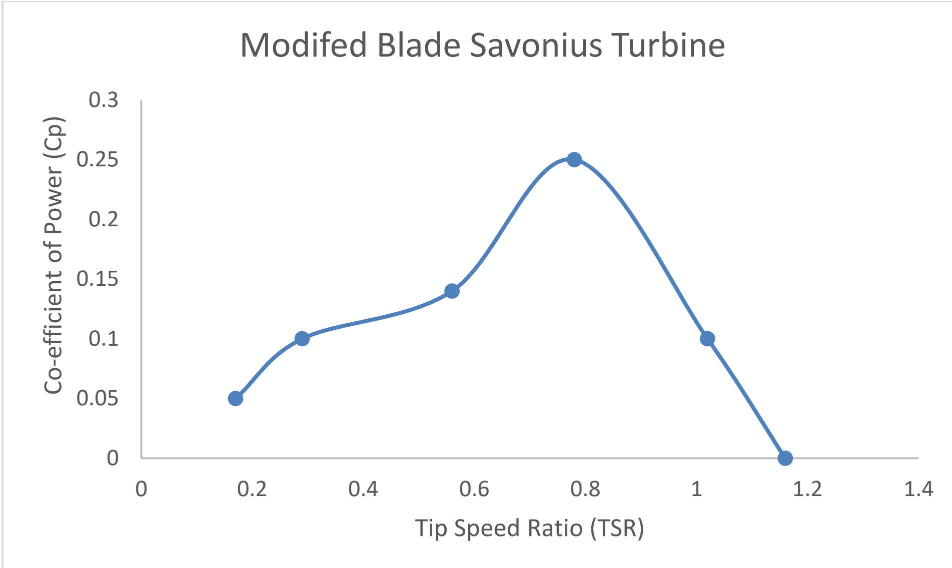

Fig 12. Modified Savonius Turbine Cp vs TSR Chart

In the comparison of both 2-bladed type conventional and split blade savonius turbine it is clearly seen in the fig 13 that in conventional turbine and split blade turbine the Cp and TSR both have difference this can be seen that the split blade type turbine is having more power and efficiency than the conventional turbine to compare the value of both turbine Cp1 is having 0.15 and TSR1 is 0.80 and Cp2 is having 0.25 and TSR2 is 1.16 so if we can see that when we comparing both the turbine we get better results in split blade type savonius turbine to minimize the negative thrust and increase the positive thrust to increase the performance and efficiency of turbine. This comparison is useful for researcher to get better idea of the numerical study of split blade savonius turbine.

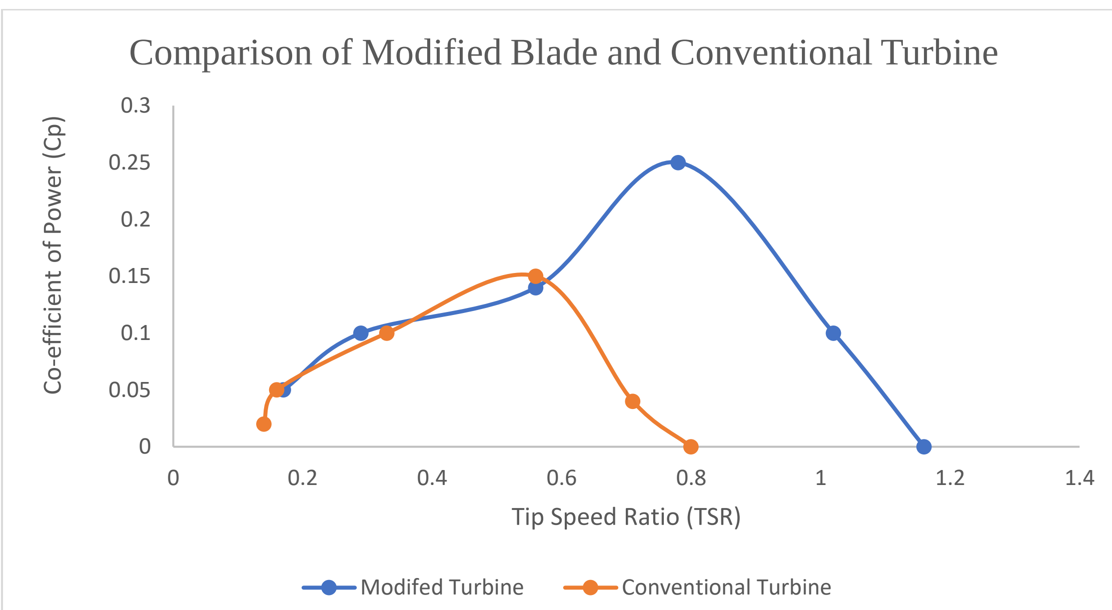

Fig 13. Comparison of Conventional and Split Blade Savonius Turbine for CP vs TSR chart

In the results of fig 13 is shown that the new modified type split blade turbine is useful to make research for researcher to make deep research in future.

Conclusions

The mainly aim of this investigation to increase the power coefficient of a conventional Savonius turbine to modified split blade savonius turbine to enhance its capacity the research was carried out for 2-blade turbine in that two type of design is used conventional and split blade using numerical method from the present results is available for both the turbine is Cp for conventional turbine is 0.15 and for split blade turbine is 0.25 this should improve the performance compare to conventional turbine so for the better efficiency and performance split type design give better output then conventional turbine. Therefore, its conclude that improvement of turbine is 45% higher in presently research is should be done compare to previous conventional turbine. So, this split blade savonius turbine research having 45% better performance and efficiency for the future scope of study it is helpful for the new researchers to achieve better Coefficient of power in split blade savonius turbine.

References

[1] F. Wenehenubun, A. Saputra, and H. Sutanto, "An experimental study on the performance of Savonius wind turbines related with the number of blades," in *Energy Procedia*, Elsevier Ltd, Apr. 2015, pp. 297–304. doi: 10.1016/j.egypro.2015.03.259.

[2] V. K. Patel and R. S. Patel, "Optimization of an angle between the deflector plates and its orientation to enhance the energy efficiency of Savonius hydrokinetic turbine for dual rotor configuration," *Int J Green Energy*, vol. 19, no. 5, pp. 476–489, 2022, doi: 10.1080/15435075.2021.1947821.

[3] N. H. Mahmoud, A. A. El-Haroun, E. Wahba, and M. H. Nasef, "An experimental study on improvement of Savonius rotor performance," *Alexandria Engineering Journal*, vol. 51, no. 1, pp. 19–25, 2012, doi: 10.1016/j.aej.2012.07.003.

[4] J. N. Goundar, D. Prasad, and M. R. Ahmed, "DESIGN AND PERFORMANCE TESTING OF A DUCTED SAVONIUS TURBINE FOR MARINE CURRENT ENERGY EXTRACTION," 2013. [Online]. Available: http://www.asme.org/about-asme/terms-of-use

[5] M. S. Maisuria and A. R. Patel, "Sustainable Energy Generation using Micro Hydro Turbine subjected to canal flow: Design, Performance and Validation using CFD Technique," 2021.

[6] I. Kougias *et al.*, "Analysis of emerging technologies in the hydropower sector," *Renewable and Sustainable Energy Reviews*, vol. 113. Elsevier Ltd, Oct. 01, 2019. doi: 10.1016/j.rser.2019.109257.

[7] N. R. Maldar, C. Y. Ng, and E. Oguz, "A review of the optimization studies for Savonius turbine considering hydrokinetic applications," *Energy Conversion and Management*, vol. 226. Elsevier Ltd, Dec. 15, 2020. doi: 10.1016/j.enconman.2020.113495.

[8] M. H. Mohamed, G. Janiga, E. Pap, and D. Thévenin, "Optimal blade shape of a modified Savonius turbine using an obstacle shielding the returning blade," in *Energy Conversion and Management*, Elsevier Ltd, 2011, pp. 236–242. doi: 10.1016/j.enconman.2010.06.070.

[9] F. Behrouzi, M. Nakisa, A. Maimun, and Y. M. Ahmed, "Renewable energy potential in Malaysia: Hydrokinetic river/marine technology," *Renewable and Sustainable Energy Reviews*, vol. 62. Elsevier Ltd, pp. 1270–1281, Sep. 01, 2016. doi: 10.1016/j.rser.2016.05.020.

[10] M. A. J. R. Quirapas, H. Lin, M. L. S. Abundo, S. Brahim, and D. Santos, "Ocean renewable energy in Southeast Asia: A review," *Renewable and Sustainable Energy Reviews*, vol. 41. Elsevier Ltd, pp. 799–817, 2015. doi: 10.1016/j.rser.2014.08.016.

[11] H. J. Vermaak, K. Kusakana, and S. P. Koko, "Status of micro-hydrokinetic river technology in rural applications: A review of literature," *Renewable and Sustainable Energy Reviews*, vol. 29. pp. 625–633, 2014. doi: 10.1016/j.rser.2013.08.066.

[12] M. Badrul Salleh, N. M. Kamaruddin, and Z. Mohamed-Kassim, "Savonius hydrokinetic turbines for a sustainable river-based energy extraction: A review of the technology and potential applications in Malaysia," *Sustainable Energy Technologies and Assessments*, vol. 36, Dec. 2019, doi: 10.1016/j.seta.2019.100554.

[13] M. S. Maisuria, D. Amit, and R. Patel, "Experimental Investigation of Savonius Hydrokinetic Turbine by Variation of Aspect Ratio," 2023.