FLUID DYNAMICS IN SAVONIUS TURBINES

Lappeenranta–Lahti University of Technology LUT

Bachelor’s Programme in Energy technology. Bachelor's thesis

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2024

Hongzhi Sun

Examiners: Professor Aki Grönman, Professor Jin Wang

ABSTRACT

Lappeenranta–Lahti University of Technology LUT

LUT School of Energy Systems

Energy Technology

Hebei University of Technology

Hongzhi Sun

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27 pages, 14 figures, 0 tables and 0 appendices

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Keywords: Savonius turbine, Vertical Axis Wind Turbine, Computational Fluid Dynamic, flow field

The Savonius turbines are vertical axis turbines, there are different from the horizontal axis turbines, which the principle of operation is drag. The Savonius turbines convert wind or water energy into electricity and other energy. Savonius turbines include the Savonius wind turbine and the Savonius water turbine. By studying the background and design of Savonius turbines, the advantages and disadvantages of Savonius turbine can be obtained. The main objectives of this thesis is to study the fluid dynamics behaviour of Savonius turbines and the flow field during operation. Computational fluid dynamics and simulation methods are used to study the flow field of Savonius turbine during operation. Under the condition of specific blade tip speed ratio, the pressure distribution diagram and velocity distribution diagram of Savonius wind turbines and Savonius water turbines can be obtained. These pressure distribution diagrams and velocity distribution diagrams can reflect the performance of the Savonius turbines during operation and intuitively understand the working principle of the Savonius turbines. This thesis can use to improve the Savonius turbines and study the fluid dynamics of Savonius turbines.

SYMBOLS AND ABBREVIATIONS

Roman characters

A	Cross-sectional area	m^2
R	radius	m
c	chord length	m
L	characteristic length	m
H	height of water turbine	m
U	speed of fluid	m/s
u	speed of fluid	m/s
P	power	W
U_∞	freestream velocity of the wind	m/s
C_T	torque	Nm
C_p	coefficient of performance	-
C_m	moment of coefficient	-

Greek characters

ω	angular velocity	rad/s
ρ	density of fluid	kg/m^3
ν	kinematic viscosity of fluid	m^2/s
μ	dynamic viscosity of fluid	Ns/m^2
λ	tip speed ratio	-

Dimensionless quantities

Re	Reynolds number

Abbreviations

VAWT	Vertical Axis Wind Turbines
HAWT	Horizontal axis wind turbines
TSR	Tip speed ratio
CFD	Computational Fluid Dynamics

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1 Introduction

The issue of natural resources is currently getting more and more important, due to advancements in science, technology, and society. In order to prevent the depletion of natural energy resources, people are researching renewable energy as a means of saving humanity in the future. The aim of this thesis is to study the fluid dynamics behaviours of Savonius turbine and the flow field of Savonius turbine during operation. The computational fluid dynamics method is used to study the above problems research into the Savonius turbine. This report provides an analysis of the Savonius turbines dynamic behaviour and flow field. It can be used as a wind turbine in addition to convert wind energy into electricity energy. And it is essential to the utilization of renewable energy. Because the Savonius water turbines can use the energy in the water flow to convert into electricity energy. And the Savonius wind turbines can use the energy of wind to convert into electricity energy.

It is essential to study the fluid dynamics behaviour of the Savonius turbine. In previous studies the researchers studied the influencing factors of the Savonius turbine, and the efficiency of the Savonius turbine, and conducted computational fluid dynamics simulations of the experiments to study how the Savonius turbine could be optimized and improved. Familiar with the fluid dynamics behaviour of Savonius turbine and the flow field under working conditions can better understand the operation of Savonius turbine, which can lay the foundation for future research on Savonius turbine, and also provide creative research for the increasingly severe energy problems.

The main objectives of thesis are studying the fluid dynamics behaviour of Savonius turbines and the flow field of these turbines during operation. It is necessary and important to study the fluid dynamics of the Savonius turbines. According to the current global energy situation, the development and research of renewable energy and its utilization are important. More research on the Savonius turbines could provide an effective solution to the serious problem.

2 Introduction of savonius turbines

This section will introduce the basic information of the Savonius turbine, the advantages, and disadvantages of the Savonius turbine, and the differences from other turbines.

2.1 Basic information about savonius turbines

The Savonius wind turbine was invented by the Finnish engineer Sigurd Johannes Savonius and was named by the Finnish engineer's name. Sigurd Johannes Savonius invented the turbines and patented it four years later in 1926. Savonius turbine is a vertical axis wind turbine(VAWT), the central axis of the Savonius wind turbine is perpendicular to the direction of the wind, so it can capture the energy in the wind. Because of its simple structure and design, consisting of two or more vertically arranged S-shaped blades, some Savonius fans are composed of shovel blades. Savonius turbine is a simple wind turbine. The Savonius turbine looks like a cylindrical barrel from the outside and looks like an S-shape above the Savonius turbine from an overhead Angle. Curved blade wind turbines have long been researched in Europe, and vertical axis curved blade prototypes exist. In 1616, Fausto Veranzio published a book about vertical axis curved blade turbines. Since then, such turbines have gained attention, and have been rapidly developed and widely used in the last century. (S. Mathew et al., 2012)

The Savonius turbine was originally designed as a wind turbine, but with the progress of the development of science and technology, the Savonius turbine can also be applied to water energy and other fields. Thus,the Savonius water turbine was born. Vertical axis turbine that is perpendicular to the direction of the fluid flow is the Savonius water turbine, so that energy can be extracted from the flow and used for purposes such as electricity generation. Savonius water energy turbines are also widely used today, but there is still a lot of room for improvement and progress compared to Savonius wind turbines. The Savonius water turbine is also one of the most popular turbines.

2.2 Operation principle and application of Savonius turbine

The Savonius wind turbine operates primarily on drag. Savonius wind turbines operate on the basis that when the wind blows in, the wind blows the curved blade or shovel blade, causing a pressure difference between the advancing blades and the returning blades, which causes the turbine blades to turn. This difference in drag pressure causes the turbine to rotate on its vertical axis. The Savonius wind turbine operates most efficiently in a specific wind direction, but it is made to function well in practically any direction of flow. The Savonius wind turbine can be started at lower wind speeds and is generally low in position, which means that the Savonius wind turbine can only extract energy from lower altitudes. (Salleh et al., 2020)

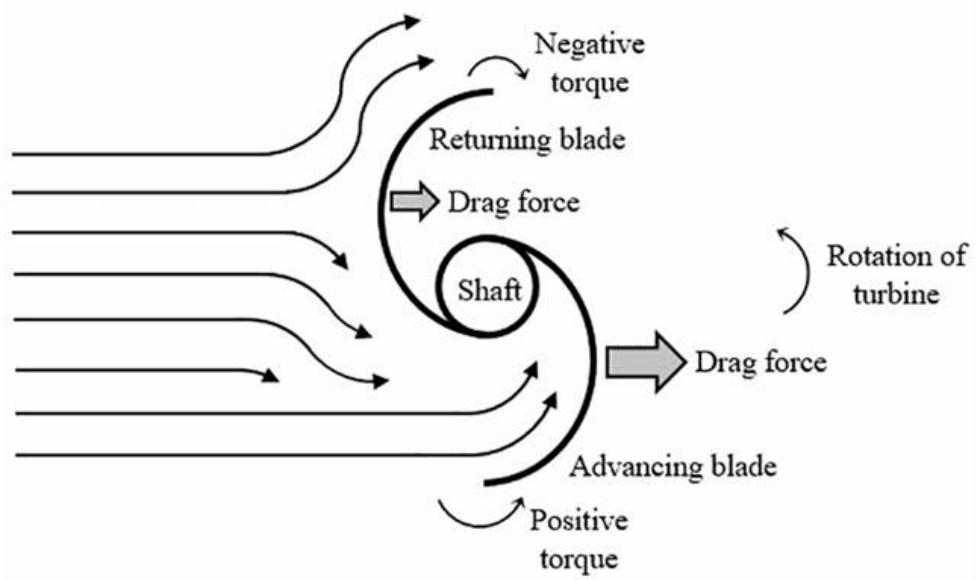

Figure 1. Diagram of how a Savonius turbine works (Salleh et al., 2020)

Savonius turbines are widely used at present, Savonius wind turbines are used in power generation, the conversion of wind energy into electric energy or other energy. Due to the characteristics of Savonius wind turbines, such generators are generally used in the case of low demand for electrical energy, such as home electricity, small-scale power generation, small-scale factory electricity and so on. Because of its superior self-starting qualities and

capacity to run at lower wind speeds, the Savonius wind turbine can also be used to measure wind speed.

Savonius water turbines are widely used, for example: Perfect for producing small amounts of electricity in isolated or rural locations with flowing water. To provide some houses or small settlements with electricity, they can be placed in tiny rivers or streams. This turbine is suitable for operation at low water flow rates, so this turbine should be used more widely. The Savonius turbine is special in that it can run smoothly in places without electricity and is used to pump water for agriculture or household water supply systems. The Savonius hydro turbine can be combined with other energy systems, for example, to form a hybrid energy system with solar panels. Savonius turbines—which also include wind turbines and hydroelectric generators—are already in widespread usage. Given the state of the energy industry, however, Savonius turbines will likely see more advancements and increased use as a result of the work of more academics. (Salleh et al., 2019)

2.3 Advantages and disadvantages of Savonius turbines

Savonius turbines are used as wind turbines and water turbine to capture energy of fluid in a wide range of fields. But at the same time Savonius turbine has advantages and disadvantages, in the face of some we will continue to use its excellent characteristics, so that Savonius turbine can better benefit mankind. Faced with the shortcomings, we should increase the research on Savonius turbine and make up for its shortcomings as much as possible. Technology can change people's lives, and people should improve and perfect the existing technology to make the Savonius turbine work better. (Ibrahim et al., 2018)

Savonius turbine advantages:

- Low speed operation. Savonius turbines are perfect for usage in locations with low wind or slow water flows because they start and run at low wind or water velocities.

- Simple structure and design. Compared with other turbines, the biggest advantage of the Savonius turbine is its simplicity of design and construction, so it consumes relatively little capital in construction and maintenance costs.
- Good self-starting ability. The Savonius turbine is able to self-start well and is able to operate well. This is also one of the important advantages compared to other turbines.
- Effective in all directions. The Savonius turbine works well in all directions, regardless of which direction the wind or water is coming from. It is not limited by the direction of the fluid and can operate in all directions.

Savonius turbine disadvantages:

- Low efficiency. Because Savonius wind turbines use drag rather than lift, its energy conversion efficiency is often low. It also operates at low speeds, limiting the efficiency of Savonius turbine.
- Space requirement. The Savonius turbine covers a relatively big area and requires more land resources for the same volume because of its vertical axis design, which may demand more floor space than the HAWT.
- Torque fluctuations. Because the design of Savonius turbine, there are torque fluctuations during operation. At the same time, there are also large torque fluctuations.

From the above description, the Savonius turbine has advantages and disadvantages. But for the shortcomings, researchers are working hard to overcome the technical problems that can be a good solution to the shortcomings of the Savonius turbine. Savonius turbines have bright futures in the realm of renewable energy development provided they are designed and made of innovative materials that increase their energy efficiency and lower their costs. Savonius turbines also provide virtually no environmental risks when in use, making them extremely eco-friendly. The Savonius turbine is a promising device that can produce hybrid energy using solar power and other energy sources. At present, the world is facing the problem of energy exhaustion, renewable energy is the clean energy that is currently developed and

utilized, wind energy and water energy are developed in renewable energy, and Savonius turbines can make good use of both aspects.

3 Fluid dynamic behaviour of Savonius turbines

This section will introduce the fluid dynamic behaviour of Savonius turbines and mainly study the design of Savonius turbines and the power coefficient of Savonius turbines. The Fluid dynamic behaviour of Savonius turbines can be analysed.

3.1 Design of savonius wind turbines

Savonius wind turbines are simple in design, consisting of one or more S-shaped or shovel-shaped curved blades. The figure 2 shows the Savonius rotor, this is a two-blades Savonius rotor. This shape design is essential for capture wind coming from any angles. And allows wind in any direction and the Savonius wind turbine can operate well. When the wind blows, the drag creates difference of pressure between the advancing blades and returning blades. Thus, creates torque and the Savonius wind turbine can operate. Taking the example of a traditional and simple two blades Savonius wind turbine, it is possible to get a good understanding of the operation principle of Savonius wind turbine. (Dewan et al., 2021)

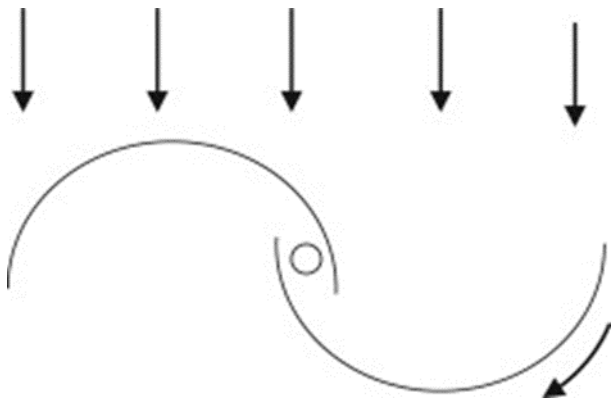

Figure 2. Diagram of the rotor of a Savonius wind turbine (S. Mathew et al., 2012)

The figure 3 shows the modelling of S-shaped blades from two blades to eight blades. Changing the number of blades can affect the flow dynamics behaviour of Savonius turbines. The number of Savonius rotor S-shape blades can affect torque fluctuation and power coefficient. Usually, by adding more blades from two improves the torque fluctuation but it can decrease the power coefficient. (Chen et al., 2023)

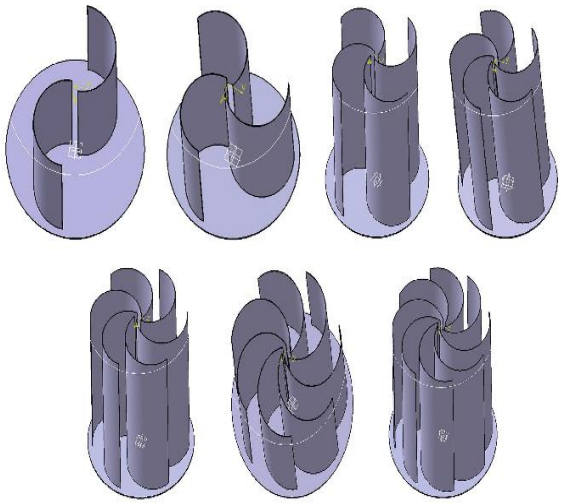

Figure 3. models of Savonius rotor from 2-8 blades. (Lates & Velicu, 2014)

The Savonius wind turbine's efficiency is an intuitive reference standard, but because the design of the Savonius wind turbine can use for low speed of wind and lower altitude conditions, the efficiency of the Savonius wind turbine is usually lower. This is also one of the problems that researchers are currently solving, how to reform the efficiency of Savonius wind turbine, it is possible to change the blade shape, parameters, and other further improvements to Savonius wind turbine. (Golecha et al., 2012)

3.2 Performance of Savonius wind turbines

Relevant parameters for data measurement can be introduced based on the performance evaluation of Savonius wind turbine. The coefficient of performance (C_p), blade tip ratio (TSR) and torque coefficient (C_m) can be used to measure the performance of the Savonius

wind turbine. A two S-shape blades of Savonius wind turbine in figure 4 can be introduced for the purpose of studying Savonius wind turbine performance. Some physical quantities are indicated in the figure 4. For calculate the TSR and power coefficient, mainly use the radius turbine rotor (R), the flow rate of the fluid (U) , the angular velocity (ω) and others. Then, using the parameters in the diagram, we can compute the relevant influence parameters. (Tian et al., 2019)

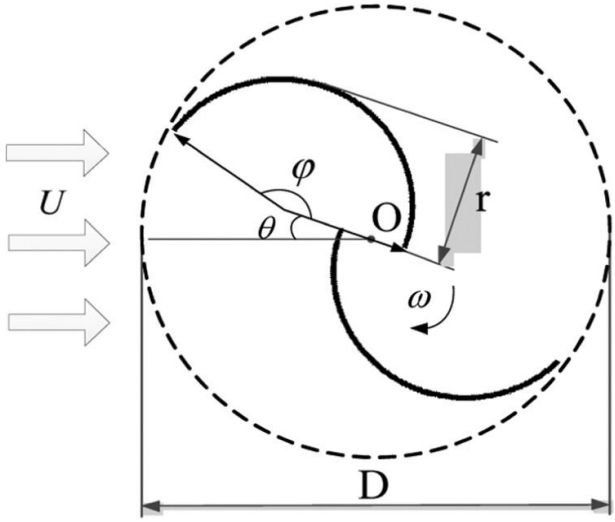

Figure 4. Two-dimensional diagram of the Savonius turbine. (Tian et al., 2019)

Reynolds number is dimensionless number in fluid dynamics, which describes the flow characteristics of fluids such as liquids or gases. The ratio of a fluid's viscous force to inertial force is Reynolds number. The size of the Reynolds number affects whether a fluid is laminar or turbulent, with a small Reynolds number being laminar and a large Reynolds number being turbulent. (Rehm et al., 2008)

$$Re = \frac{u*L}{\nu} = \frac{\rho*u*L}{\mu} \tag{1}$$

Where	u	is the speed of fluid	[m/s]
	L	is the characteristic length	[m]
	ν	is the kinematic viscosity of the fluid	[m^2/s]

ρ	is the density of the fluid	[kg/m^3]
μ	is the dynamic viscosity of the fluid	[Ns/m^2]

Reynolds number is very important in fluid dynamics, and the properties of fluid in fluid dynamics can be understood by calculating Reynolds number. The Reynolds number for vertical axis turbines can be obtained by searching the literature. (Whittlesey, 2017)

$$Re = \frac{c * U_\infty}{\nu} \tag{2}$$

Where	c	is the chord length	[m]
	U_∞	is freestream velocity of the wind	[m/s]
	ν	is the kinematic viscosity	[m^2/s]

Savonius wind turbines are VAWT and have a number of performance features that set them apart from HAWT. One metric used to assess the performance of Savonius wind turbines is the Power Coefficient (Cp), which is the maximum amount of wind energy can be used. (Yaakob et al., 2013)

$$C_p = \frac{P}{\frac{1}{2} * \rho * A * U^3} \tag{3}$$

Where	P	is the power by wind	[W]
	ρ	is the density of air	[kg/m^3]
	A	is the cross-sectional area of the rotor	[m^2]
	U	is the wind speed	[m/s]

The tip speed ratio in Savoinus wind turbine, which is the ratio between the speed of the blade tip and the speed of the wind. The torque coefficient (C_m) also affects the power coefficient. (Yaakob et al., 2013)

$$TSR = \frac{V_t}{U} = \frac{\omega * R}{U} \tag{4}$$

Where	V_t	is the blade speed of wind turbine	[m/s]
	ω	is the angular velocity of the rotor	[rad/s]
	R	is the radius of the rotor	[m]
	U	is the speed of wind	[m/s]

$$C_m = \frac{C_T}{\frac{1}{2} * \rho * A * R * U^2} \tag{5}$$

Where	C_T	is the torque in the turbine shaft	[Nm]

Through the above formulas and the results of literature review study the Reynolds number and performance of Savonius wind turbine, which can help to study the fluid dynamics behaviour of Savonius wind turbine. In the same way, these formulas also apply to the Savonius water turbine, because the operation principle of these turbines are same.

There has the relation between these physical quantities, in particular the TSR and the power coefficient. TSR is one of the main factors affecting the power coefficient of Savonius wind turbine. In this thesis, mainly study the relation between TSR and the power coefficient of two blades Savonius wind turbine. In the figure 5 below, it shows the relation between the TSR and the power coefficient. When the tip speed ratio changes, the power coefficient also changes as below figure shows.

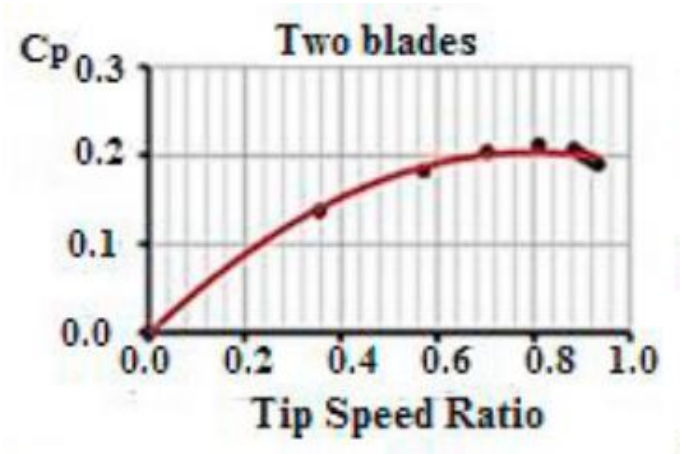

Figure 5. Power coefficient with the different TSR (Zemamou et al., 2017)

Savonius wind turbines have an optimal TSR to extract as much energy as possible from the fluid. The tip speed ratio is too high or too low, both of them cannot extract much energy from wind. And the tip speed ratio usually low. The reason is Savonius turbines use drag from its principle of operation. Through observation, it can be found that the power coefficient become maximum when TSR is 0.7. At this time the Savonius wind turbine is able to capture more energy in the wind, and this tip speed ratio can be used. In this thesis, mainly study the two blades Savonius wind turbine at the TSR is 0.7.

3.3 Design of the Savonius water turbines

The Savonius water turbine is based on the Savonius wind turbin. The vertical axis turbine can use water energy to convert into electricity. The working principle of the Savonius turbine is basically the same as that of the Savonius wind turbine, which use the drag to rotate the Savonius turbine. A rotating torque is produced as the water strikes the blade, the main principle of operation is same to the Savonius wind turbine. The Savonius water turbine mainly uses drag, which is also similar to the Savonius wind turbine. In the design, the Savonius wind turbine and Savonius water turbine have a lot in common. In the figure 6, a three blades Savonius water turbine working.

Figure 6. Savonius water turbine in operation (Zafar, 2018)

The operation principle of Savonius water turbine also use drag. And the fluid is water or seawater. The Savonius turbine has the same advantages and disadvantage of Savonius wind turbine. The Savonius water turbine will also have two and multi-blade designs, which will also affect the performance of the Savonius water turbine. Savonius water turbines also have good self-starting properties, suitable for areas with low water flow rates, and can be used for household power generation or other small-scale electricity consumption. Now, with the development of science and technology, the Savonius water turbine has been further improved and has been widely used.

3.4 Performance of the Savonius water turbines

For Savonius water turbine, it is different from Savonius wind turbine. Savonius Turbine include the depth of Savonius water turbine in figure 7, which will have a certain impact on Savonius water turbine. There are research literatures that have studied the effect of the depth of Savonius turbine blade on its performance. The depth of the Savonius water turbine isan factor affecting the Savonius water turbine. (Kumar & Saini, 2021)

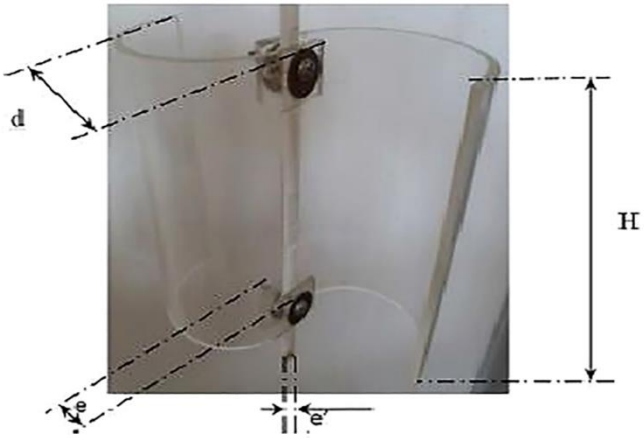

Figure 7. Two-blades Savonius water turbine (Zafar, 2018)

The formula can use to determine the tip speed ratio, power coefficient and torque coefficient. (Badrul Salleh et al., 2019)

$$C_p = \frac{P}{\frac{1}{2}*\rho*A*H*U^3} \tag{6}$$

$$C_m = \frac{T}{\frac{1}{2}*\rho*A*H*R*U^2} \tag{7}$$

$$\lambda = \frac{V_t}{U} = \frac{\omega*R}{U} \tag{8}$$

Where	H	is height of turbine	[m]
	λ	is the tip speed ratio	[-]

(Other quantities are described above)

The relation between TSR and power coefficient is obtained by consulting literature. As the below figure 8 shows, the Savonius water turbine also has an optimal TSR, which the TSR is about 0.7. Through the previous research results, it can be found that some differences between numerical CFD and experiment(Golesha et al., 2012). This thesis mainly study the two blades Savonius water turbine at TSR is 0.7.

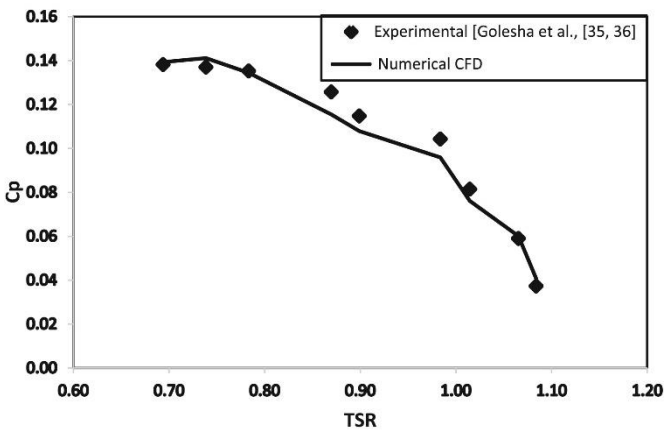

Figure 8. TSR and power coefficient of Savonius water turbine (Elbatran et al., 2017)

Understanding the fluid dynamic properties of the Savonius water turbine can be achieved by studying its performance. TSR affects the performance of Savonius water turbine and different TSR values have different effects on its performance. The amounts of blades and the angle of the blades are also factors that change the performance of the Savonius water turbine. Balancing the parameters of Savonius water turbine can help improve the performance of Savonius water turbine, which is very important for the study of the dynamics characteristics of Savonius water turbine.

4 The flow field during operation

This section describes the flow field of the Savonius turbine during operation. By reviewing the flow field of Savonius wind turbine and Savonius water turbine, the flow field of the Savonius turbine during operation can be studied.

4.1 Flow field of the Savonius wind turbines during operation

Firstly, the flow field is the distribution characteristic of fluid, including velocity field, pressure field and temperature field. Computational fluid dynamics can be used to simulate the characteristics of fluids and the distribution of flow fields.

The flow field of Savonius wind turbine during operation can be studied by using computational fluid dynamic. Through the study of data and literature review, the flow field distribution of Savonius wind turbine under specific TSR values can be obtained. Savonius wind turbines are affected by many factors, so in the case of studying the flow field distribution, it is important to study at specific values, such as the number of blades, TSR, etc. Taking the two blades Savonius wind turbine as an example, studying the flow field of Savonius wind turbine when the TSR is 0.7. (Kumar & Saini, 2021)

In the figure 9, it shows the basic operation of a Savonius wind turbine when the air is flowing, and the direction of the lines is represented by the direction the wind is blowing. For the Savonius wind turbine, every direction can accept the wind, it is not limited by the direction, and enables the Savonius wind turbine to operate in a state where the flow field can be studied simply.

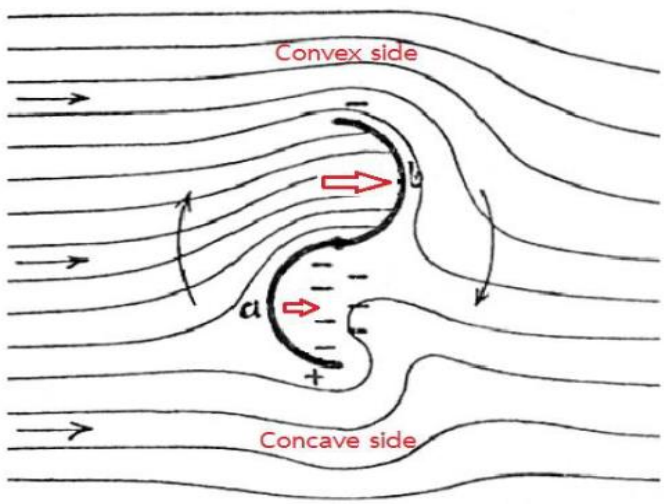

Figure 9. Two blades Savonius wind turbine in operation (Worasinchai & Suwannakij, 2018)

The figure 10 is pressure distribution of Savonius wind turbine and the figure 11 is velocity distribution of Savonius wind turbine. Study the flow field is generally select the velocity and pressure distribution. Computational fluid dynamics can simulate the pressure and velocity distribution of the Savonius wind turbine during operation. (Salleh et al., 2021)

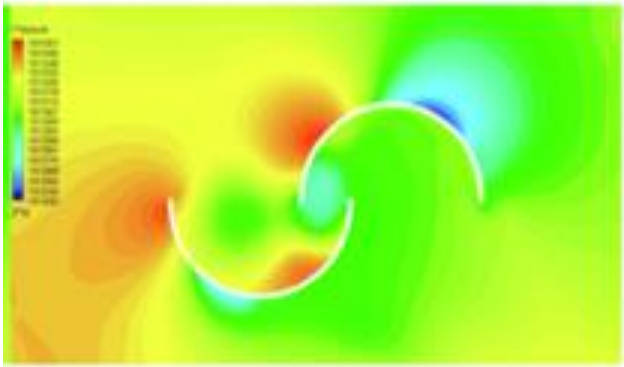

Figure 10. Pressure distribution of Savonius wind turbine during operation

(Badrul Salleh et al., 2021)

Through the pressure analysis of Savonius wind turbine during operation, at the condition of TSR = 0.7, the larger pressure zone distribute on the concave blade and tip of Savonius wind turbine. With the flow of the wind, the pressure of the fluid will also change, and the pressure change generally occurs at the concave. Compare the pressure of advancing blade, the pressure is usually lower at the returning blade.

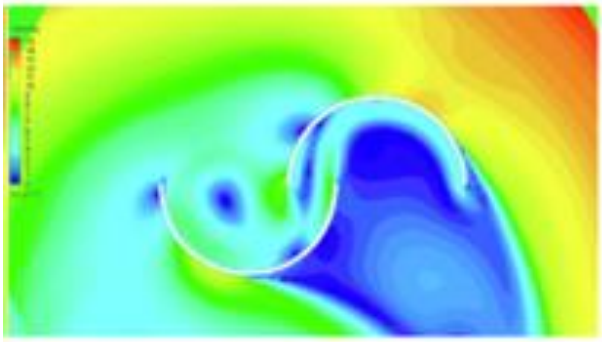

Figure 11. Velocity distribution of Savonius wind turbine during operation

(Badrul Salleh et al., 2021)

Based on the distribution of the speed during the operation of the Savonius wind turbine, we can get the results. Under a certain TSR value, the pressure is generally smaller at the blade position with high air flow rate, while the pressure is larger at the blade position with low air flow rate. Here we can give the reason why this phenomenon occurs according to Bernoulli's principle. For the Savonius wind turbine with TSR = 0.7, the velocity change occurs on the concave side of the blade.

In summary, much research shows that parameters of turbines make impacts on Savonius turbine, including TSR, blade shape, number of blades and other characteristics, influence the flow field of a Savonius wind turbine. For studying the flow field of Savonius wind turbine, choose a two blades Savonius wind turbine as sample, and considerable results can be obtained under specific TSR values. The flow field of a Savonius wind turbine is intricate, including the distribution of multiple parameters, and is more complex and influenced by more factors in real life. By studying the flow field of Savonius wind turbine, we can improve Savonius wind turbine better.

4.2 Flow field of the Savonius water turbines during operation

Research on the flow field look of Savonius water turbine in flowing water, experiments are carried out in the design model, simplified to two simple diagrams to research the flow field of Savonius water turbine during operation, mainly studying the distribution of pressure and velocity of Savonius water turbine under specific TSR values. In the figure 12, water flows through the blades of the Savonius water turbine, thus causing rotor to rotate. The direction of the streamlines are represented by the direction in which the water flows, create the torque as it passes through the Savonius water turbine. The pressure and velocity distribution of a Savonius water turbine is studied under a specific TSR.

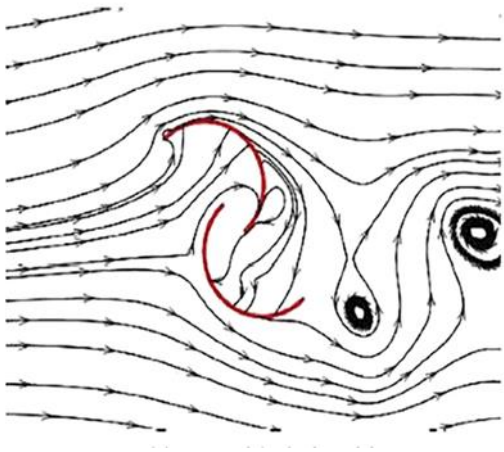

Figure 12. Two-bladed Savonius water turbine in operation (Golecha et al., 2012)

The figure 13 is pressure distribution of Savonius water turbine and the figure 14 is velocity distribution of Savonius water turbine. Both simulate by computational fluid dynamics (Kumar & Saini, 2021). These results are based on the TSR is 0.7 and the velocity of the water flow is constant. Mainly study the pressure and velocity of two blades Savonius water turbine and analyse the results of pressure and velocity distribution.

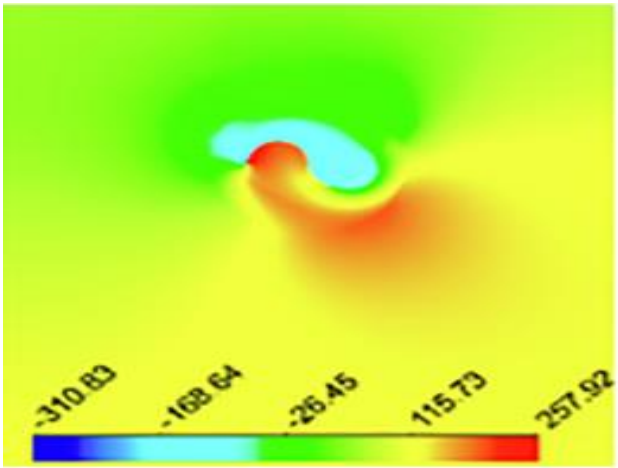

Figure 13. Pressure distribution of Savonius water turbine during operation (Kumar & Saini, 2021)

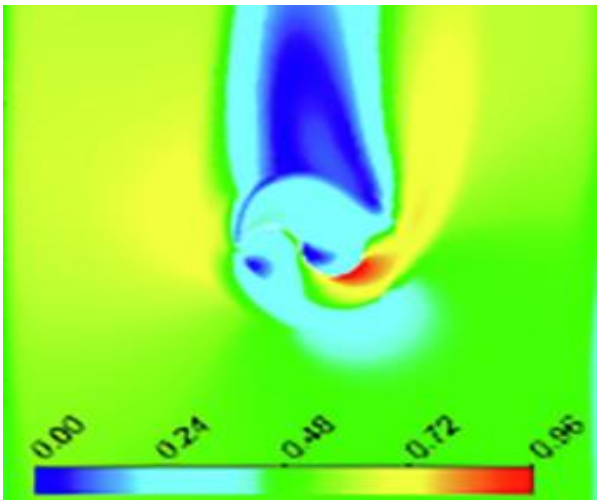

Figure 14. Velocity distribution in Savonius water turbine (Kumar & Saini, 2021)

When the water pushes the rotor with greater pressure, the larger pressure zone distributes on concave blade, and meanwhile lower pressure zone distributes on convex blade, thus create a pressure difference in figure 13. It’s same for speed. At a constant speed, the pressure is generally low and the water flow is comparatively high. The pressure and velocity of the Savonius water turbine will alter at the blade's tip. (Kumar & Saini, 2021)

The flow field of two blades Savonius water turbine is studied under specific TSR conditions. Select TSR=0.7, under which Savonius water turbine can achieve maximum performance and it can capture as much water energy as possible. It is convenient to study its pressure distribution and velocity distribution. The Savonius turbine operation principle and flow field condition can be seen in the distribution diagram of pressure and velocity. The TSR has influence on the flow field of Savonius water turbine. Besides, the blades amount, and the angle of blades will affect the flow field look of Savonius water turbine. More specialized experiments are needed to research how the flow field look of the Savonius turbine is affected.

5 Conclusions

This thesis mainly studies the basic information of Savonius turbines, the fluid dynamics behaviour of Savonius turbines and the flow field of Savonius turbine during operation. Collecting the relevant figures and some information through the literature about Savonius wind turbine and Savonius water turbine. The main method CFD used to study the flow field of Savonius wind turbine and Savonius water turbine. Savonius wind turbine and Savonius water turbine are vertical axis turbines. The operation principle is different from the horizontal axis turbine. Savonius turbines are drag design and use the drag. The fluid dynamics behaviour of Savonius turbines can be analysed through the basic information, design, operation principle and application of Savonius turbines. And the fluid dynamics equations are also used to explain the fluid dynamics in Savonius turbines. The TSR and power coefficient of Savonius turbine was obtained by searching the literature. The flow field of two blades Savonius wind turbine and Savonius water turbine during operation at tip speed ratio is 0.7 by literature review.

The results of this thesis can be mainly used for the improvement and application of Savonius turbines. Compare with earlier studies, this thesis studies the Savonius turbines. And analyse the fluid dynamics behaviour and flow field during operation of these turbines. However, there are still some limitations. When studying the flow field, the results were carried out under specific conditions, but the environment is more complicated, and the situation is more changeable in application. In the current situation of energy depletion in the world, the development and utilization of renewable clean energy is an effective way, and Savonius turbines can be applied to the utilization of wind energy and water energy. More and more researchers are improving the Savonius turbine, which also provides the foundation for the use of energy in the future. The Savonius turbine can benefit mankind with its advantages, make up for its disadvantages and improve in more research. In the near future, more Savonius turbines will be applied to solve the energy problems faced by mankind.

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