NUMERICAL STUDY OF TWO SAVONIUS TURBINES CONFIGURATION SIDE-BY-SIDE WITH DIRECT TURN

Ahmad Radix Dharma Cahyo[1*], Gunawan Sakti[2], Bambang Junipitoyo[3]

[1,2,3)] Civil Aviation Polytechnic of Surabaya, Jemur Andayani I/73 Wonocolo Surabaya, Jawa Timur, Indonesia, 60236
**Corresponding Author Email:* ahmadradix9@gmail.com

ABSTRACT

This study aims to optimize the performance of Savonius wind turbines in a side-by-side configuration using a two-dimensional numerical simulation method with a k-ε enhanced wall treatment turbulence model in ANSYS 18.2. The simulation was carried out with a wind speed of 5 m/s and a distance between the turbine shafts S/D = 5.5, with a blade diameter D = 60 mm. The results showed an increase in the power coefficient and performance of the Savonius turbine due to the flow interaction between the two turbines rotating clockwise, especially when the distance between the turbines is closer to the wall.

Keywords: Coefficient of Power, Coefficient of Moment, drag, speed torque flow wind , side-by-side,turbine Savonius.

1. INTRODUCTION

Energy wind is source energy friendly renewable environmental and safe for health. Wind turbine Savonius is one tool conversion energy the wind can used in the environment urban. This turbine own superiority like his abilities operate with direction varying winds and simple construction. However, efficiency turbine Savonius Still more low compared to with turbine wind horizontal pivot. Research by Jang et al. (2015) show that placement of two turbines Savonius side -by-side with configuration different rounds can influence performance turbine. Scenario with second turbine turn one way clockwork (CW) results coefficient more power tall compared to with scenario other.

research (2022) shows that integration turbine Savonius with wind-lens can increase performance turbine. Study This use simulation numeric with ANSYS-fluent 17.0 software for analyze influence rotor configuration and tip speed ratio. The results show that dual rotor configuration with direction round opposite and the ratio Lt/D=0.45 can increase coefficient Power turbine Savonius by 114%. Configuration This proven as the most optimal in study the, indicates that the addition of a wind-lens is possible repair performance turbine Savonius .

Principle Work turbine Savonius involve drag difference between side concave and convex of the turbine blade. Concave side produces negative torque, meanwhile side convex produces positive torque. Difference pressure between second side This create the effect of the nozzle on the gap between the blade and the wall, which increases speed flow and reduce pressure behind the concave blade. Effect This increases pressure drag on the concave blade, resulting in more positive torque big and improving efficiency turbine Savonius in a way overall.

Study This aim For develop results studies numeric on the turbine Installed Savonius side by side. Formulation identified problems covers a number of aspect important: first, how performance turbine Installed Savonius side -by-side at a distance of S/D = 5.5; secondly , how performance turbine Savonius with Reynolds number Re = 3.6x10^4; and third, how comparison performance turbine Savonius on the flow wind with speed 5 m/s. Focus study This is For understand efficiency and characteristics performance turbine in different configurations For get relevant information about optimization design and operations turbine Savonius .

The main purpose from study This is For compare performance turbine wind Installed Savonius side -by-side at speed flow air 5 m/s. Analysis This aim For know difference performance between turbine with single rotor and dual rotor when flowed wind at speed the. Study this is also purposeful For measure percentage coefficient on the turbine Installed Savonius side -by-side, as well For evaluate performance turbine with parameters such as Coefficient of Power, Coefficient of Moment, drag, torque, contour velocity, and pressure.

Study This will give base important in studies aerodynamics turbine Savonius side by side. The benefits covers provision outlook addition about performance turbine Savonius, who will enrich knowledge and understanding about technology This. Additionally, results study This will become development from study previous and working as reference for institution in learning aerodynamics. Study this is also expected become strong foundation For studies next will be explore variation configuration, speed, and turbine surface Savonius.

Proposed hypothesis in study This is that addition of a turbine rotor Savonius can be dual rotor side -by-side influence performance of Coefficient of Moment and Coefficient of Power, so potential increase torque. Side-by-side configuration is expected can influence flow air passing through gap between turbine rotors Savonius , so produce change significant in efficiency and performance overall . Hypothesis This based on setting behind study previous and theory underlying aerodynamics operation turbine Savonius.

Scope of problem set For focus research and avoid discussion that is not relevant. Study This use ANSYS 18.2 application for parameter analysis and reference from journal related. Configuration turbine wind Savonius used is side -by-side with speed flow air 5 m/s and distance S/D = 5.5. Limitations also include use performance turbine Savonius at a Reynolds number of 3.6x10^4 with temperature 25°C. Determination limitation This important For ensure that study still focused and results can implemented in a way appropriate in context under study.

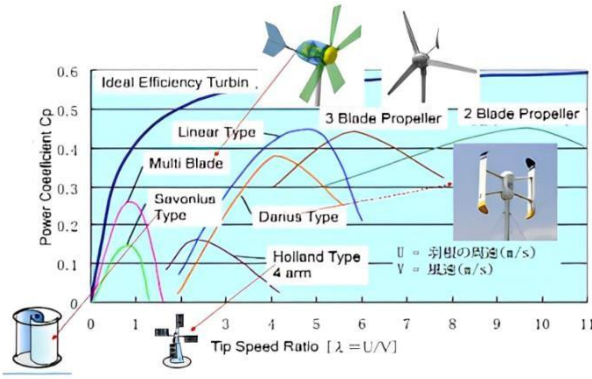
2. METHODS

2.1 Literature Review

a. Wind Turbine

Wind turbine is tools that change energy wind become energy mechanic, with energy wind obtained from half mass type air (ρ), area cross section turbine (A), and speed wind in number cubic (V^3). Difference small in speed wind can produce difference significant energy. As example, with fingers 1 meter turbine, mass type air 1.225 kg/m³, and speed wind 3 m/ s, energy produced is 52 W, while at speed wind 6 m/ s, energy produced increase to 415 W. Efficiency turbine, which is measured with the power coefficient (Cp), is factor important in design and operation turbine wind, decisive how much Good turbine can convert energy wind become energy useful mechanic.

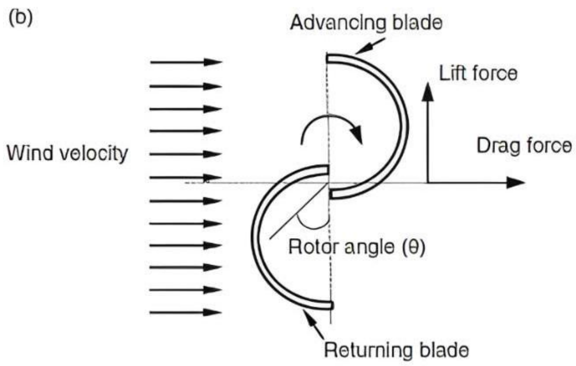
Wind turbine initially used as pinwheel wind For need agriculture like grind rice and irrigation, especially in European countries such as Denmark and the Netherlands. Now, turbines wind used in a way wide For fulfil need electricity public with use energy renewable. Wind turbine present in various size, from scale micro until large, where the size is more big generally produces a higher power coefficient tall. Development technology has possible turbine wind become source reliable and friendly energy environment, giving contribution significant to supply global electricity through conversion energy efficient wind.



b. Wind Turbine Savonius

Wind turbine Savonius discovered by Sigurd Johannes Savonius in 1922 and known Because The design is simple, composed from two spoons shaped half arranged circles in S shape. This turbine has two types of blade, namely the advancing blade shaped concave and facing direction coming fluid, as well as a shaped returning blade convex and back direction fluid. This design possible turbine Savonius For works with Good although in condition low windage, making it ideal for environment with speed the wind varies and does not stable. Apart from that, turbines Savonius easy installed, requires cost relative installation and maintenance low, and can built on more structures low, making it an economical and practical choice in Lots situation.

However, turbines Savonius also had a number of lack. One of weakness mainly is more efficiency low compared to with type turbine others, esp Because exists obstacle addition to the reducing blade ability turbine For catch wind optimally. Besides, because turbine This often installed on the structure low, ia No can utilise speed more wind normal height found at higher altitudes tall. Although I see, turbine Savonius still become interesting choice For application certain areas, especially in the regions urban or location with limitations space and budget, where its simple design and capabilities For spinning all over direction become superiority main.



c. Reynolds number

number (Re) is number not descriptive dimensions comparison between style inertia with style viscous in flowing fluid. Re often used For determine type flow fluid, whether laminar, transitional, or turbulent. The formula for Re is Re = (ρ.VL)/μ, where ρ is mass type fluid , V is speed flow, L is long characteristics field, and μ is viscosity dynamic. In context turbine wind, long characteristics often calculated with uses twice the turbine diameter minus the shaft diameter. The Reynolds number is very important in analysis flow fluid Because help predict condition flow and how fluid will interact with traversed surface.

In research involving turbine wind Savonius, a Re value of 36,000 is obtained from calculation with enter specific parameters like mass type air, speed wind, and dimensions turbine. With this Re value, flow surrounding air turbine Savonius can classified as turbulent, which affects performance turbine in catch energy wind and produce power. Turbulence in flow This usually produce more Lots vortex and exchange energy, which can increase or reduce efficiency turbine depending on design and conditions operation.

d. Drag Style

Drag style is inhibiting style movement a object congested moment move through fluid, like air or water. This style appear consequence pressure and tension slide on the surface object as well as interaction with flow surrounding fluid. Drag style works parallel with direction flow fluid and can calculated use equation F_D = C_D × 1/2 × ρ × V² × A, where F_D is drag force, C_D is the coefficient of drag (coefficient resistance), ρ is mass type fluid, V is speed fluid, and A is wide cross section affected object flow fluid. In context turbine wind Savonius, drag style plays role important in determine efficiency conversion energy wind become energy mechanic. The more big the resulting drag force increases big Obstacles are a must resolved turbine, which affects performance overall turbine in produce power.

e. Torque

Torque is descriptive quantity style that causes a object rotates on an axis certain or trend style For twist object the. On the turbine Savonius, the amount of torque is greatly influenced by the drag force acting on the blades and spokes blade turbine. With Thus, the turbine torque Savonius can formulated as results multiplication between drag force and radius spoon, which is mathematical stated with formula T = F_D × R.

f. Power Calculation

Savonius turbine operate with utilise energy kinetic and potential wind For produce energy mechanic through the rotor. Turbine performance This can measured through several parameters, one of them is the Coefficient of Moment (Cm). Cm describes connection between the torque produced by the turbine with the theoretical torque exerted by the wind. The Cm value is calculated with formula Cm = T / (1/2 × ρ × A × R × V²), where T is torque, ρ is mass type air, A is wide cross section turbine, R is fingers turbine, and V is speed wind. The more the larger Cm, the more effective turbine in change style wind become movement rotational.

Apart from Cm, the Coefficient of Power (CoP) also becomes indicator important in evaluate efficiency turbine Savonius. CoP shows ability turbine in convert energy wind become energy electricity, where CoP is calculated with formula CoP = (T × ω) / (1/2 × ρ × A × V³). Here, ω is speed corner turbine. CoP is number not indicating dimensions how much efficient turbine in change Power kinetic wind become Power mechanic. Connection between Cm and CoP is described by the equation CoP = Cm × λ, with λ as ratio speed end turbine to speed wind. The more the higher the CoP, the more efficient turbine Savonius in utilise energy wind.

g. Blockage Ratio

Blockage ratio is ratio between turbine diameters Savonius and canal diameter as explained by Willden & Schluntz (2015). In testing turbine wind, blockage effects are important parameters For analyze performance turbine Savonius. If speed wind low, blockage can occur impact negative on performance turbine. For calculating blockage on workstations, is used formula BR = A/B × 100, where A is the diameter of the test object and B is the wall diameter tunnel wind. In the example calculation, with A of 220 and B of 16,498.35, the blockage ratio value is 1.33%.

h. Computational Fluid Dynamics (CFD)

Completion equality fluid involve use equality differential partial (PDE) that combines law eternity mass, momentum, and energy For count variable important like speed, pressure, and temperature. Because of complexity problem fluid, modeling with help computer through Computational Fluid Dynamics (CFD) frequently used. CFDs are field mechanics the fluid used method numeric For predict and solve various related problems with fluid, like flow, displacement heat, and reaction chemistry. CFD simulation usually through three stages: pre-processing, processing, and post-processing.

Stage pre-processing involve definition that problem will be simulated, incl geometric modeling and computational domains. In stages In this case, the domain is divided into a grid or mesh consisting from elements small For increase accuracy calculation. More meshing fine used in geometry critical, temporary another part maybe requires more mesh rough. However, paradoxical appears where the increase amount element No always increase accuracy analysis and precisely Can add error. For the, grid independence test done For find amount optimal elements. Final step in stage This is define relevant physical and chemical boundary conditions.

At stage processing, calculation done with using data from stage pre-processing. Simulation done with finish equality turbulence in a way iterative until reach condition convergence and fulfillment error value that has been set. Stage post-processing involve analysis results visualized simulation in various form, such as a vector diagram, contour plot, or animation. Results This help represent and understand phenomenon that occurs in simulation, possible evaluation model performance or tested design.

2.2 Pre-processing stage

The pre-processing steps are stage beginning in simulation that uses device ANSYS 18.2 software . At stage this , creation geometry turbines and tunnels wind done For define the boundaries of the computing domain . Important parameters such as boundary conditions and meshing are also determined . In research here , two turbines Savonius placed in a way side by side with adjacent returning edges . This turbine be inside tunnel with a cross-sectional area of 500 mm × 490 mm, with flow air speed of 5 m/s. Modeling done use two-dimensional approach For analyze performance turbine , with various parameters that include density , viscosity , and dimensions turbine .

The meshing process in ANSYS is carried out with combining structured meshing in the stationary zone and unstructured meshing in the rotating zone. Structured meshing divides the area into surfaces small , while unstructured meshing allows flexibility in the rotating zone . Images show meshing results that include the entire mesh , rotating zone and turbine Savonius That Alone . Good meshing process ensure that simulation can done with accuracy high , however need adjustment more carry on For ensure optimal results .

Grid Independence Test (GIT) is method For ensure that results simulation No depending on quantity mesh elements used. In research this, GIT is done with vary amount element from 36,000 to 130,000. The goal is For reach stable results , where increases amount element No Again influence reults simulation , esp in calculate the Coefficient of Moment. This process important For get amount optimal elements that provide balance between accuracy and efficiency computing.

Stage validation aim ensure that arrangement simulation Already in accordance with standard existing research. Validation done with compare results simulation moment This with study previously , who also used turbine Savonius . Validation results This show suitability and consistency between research carried out , which is shown in chart validation . Validation This crucial For give trust that results obtained from simulation truly reflect condition actual physical.

2.3 Processing

Processing phase in simulation involve definition equations and conditions used For operate simulation in a way effective . One of element key in phase This is cell zone condition settings , where the rotating zone area is regulated For own speed rotation certain appropriate ones with tip speed ratio (TSR) against speed flow wind . Speed round turbine Savonius is strongly influenced by the TSR value , which is also decisive size step time or time step size in simulation . For example , on speed wind 5 m/s, TSR of 0.8 results speed rotation 3.636 rad/s and size step time of 0.004797 seconds , as presented in table study . Arrangement This important For ensure that simulation walk with accuracy high , reflecting condition actual dynamics of the turbine Savonius .

In addition , boundary conditions play a role role important in determine physical boundaries and appropriate conditions For simulation . In research This boundary condition includes various element such as inlet, outlet, wall, blade turbine Savonius , and the interface between these areas . With flow wind enter of 5 m/s, intensity turbulence 4.4%, and scale long 7.7 mm turbulence , simulation simulate condition real with using a pressure outlet of 0 Pa and no slip conditions (no There is friction) on the wall as well as blade turbine Savonius . Arrangement This ensure that condition physique from flow fluids and their interactions with turbine can replicated in a way accurate in environment simulation , provides close results condition Actually.

2.4 Post Processing

The post-processing step is stage end in the simulation process with ANSYS 18.2, where the data is generated taken after turbine Savonius turn as much ten times, use size step time as many as 3600. At stage This is the data obtained after round tenth chosen Because the result tend stable with less error from 5%. Collected data covers information quantitative such as coefficient of power (CoP), tip speed ratio (TSR), and coefficient of moment (Cm), which are important For analyze performance turbine Savonius . This data give description about efficiency and effectiveness turbine in change energy wind become energy mechanic .

For support study This , a laptop is used with Intel Core i7-9750H specifications , Nvidia Geforce GTX1650 GPU, 8 GB RAM and 512 GB storage . Software used includes ANSYS 18.2 for simulation geometry , Solidworks 2021 for planning geometry , Microsoft Word for writing reports , and Microsoft Excel for collection as well as data processing . This combination of hardware and software supports simulation processes and data analysis with efficient , ensuring results accurate and reliable research reliable.

2.5 Analysis Techniques

After the simulation process finished , result data simulation For each measurement parameter , especially Coefficient of Moment and Coefficient of Power, is collected in the (out) extension file which includes parameter values on each step time . This data Then served in form chart for each measured parameter to time flow every step time , and combined become a validated data set through grid dependency test and research reference . Analysis done with a results diagram simulation For evaluate impact of the twin rotors on the turbine wind Savonius on the Coefficient of Power and Coefficient of Moment. The maximum Coefficient of Power (Cp) is used For evaluate stability operational turbine , while the Coefficient of Moment is analyzed together with drag and torque. Simulation results also include discussion descriptive about pressure and contour speed ..

3. RESULT AND DISCUSSION

3.1 Research Result

Simulation results numeric For turbine Savonius show difference significant between turbine with one rotor and two inner rotors terms Coefficient of Moment (Cm). Table 4.1 reveals that turbine Savonius with double rotor have more cm tall compared to with turbine one rotor. On the turbine with a single rotor , Cm reaches 0.3885, while turbine with two rotors it reaches 0.7882, showing increase by 102%. Graph of Coefficient of Moment against azimuth angle illustrates Cm variation along rotation , highlighting more efficiency big from dual rotor configuration in handle burden wind .

In the Coefficient of Power (Cp) analysis , results simulation show that turbine Savonius with double rotors also more efficient compared to with single rotor . Based on Table 4.2, Cp for turbine with single rotor reached 0.4664, meanwhile For turbine with two rotors reaches 0.8335, showing increase by 78%. Graph of Coefficient of Power against azimuth angle depicts difference performance between single and double rotor configurations , with double rotors show increase clear performance in change energy wind become Power mechanic .

Coefficient of Drag (Cd) analysis was carried out For evaluate stability performance turbine Savonius with notice drag effect on conditions operational maximum . Drag graph against azimuth angle shows drag changes throughout rotation turbine , giving outlook about stability and efficiency turbine in various position corner . This data help in understand how drag affects overall performance turbine and efficiency conversion energy .

In the torque aspect , results simulation disclose difference between turbine with one rotor and two rotors. Table 4.3 shows that turbine with double rotor produce higher torque value tall compared to with turbine one rotor. Torque graph against azimuth angle shows Torque variations throughout rotation turbine , with double rotor show increase performance in produce style turn . Although there is decrease in internal torque a number of conditions , dual rotor configuration still show superiority compared to single rotor .

Validation numeric done with use contour pressure and speed For evaluate performance turbine Savonius . Figures 4.5 and 4.6 illustrate contour pressure and speed For turbine one and two rotors. Pressure contour show difference significant between the advancing blade and returning blade on the turbine double , with increase difference pressure that contributes to more torque big . The addition of a rotor improves speed flow and reduces drag on the returning blade, resulting in more performance good and more torque efficient on dual rotors .

3.2 Discussion

Simulation results turbine Savonius show difference significant between single and double rotor configurations in terms of Coefficient of Moment (Cm) and Coefficient of Power (Cp). Savonius turbine with two rotors showing increase clear performance compared to with turbine one rotor, fine in Cm or Cp. On the turbine double , Cm and Cp reach 0.7882 and 0.8335 respectively , which is increase significant of 102% and 78% compared with single rotor configuration . Improvement This show that dual rotor configuration more effective in convert energy wind become energy mechanics and handles burden wind . Analysis chart show how double rotor give more performance Good with produce more moment and power tall throughout rotation , which indicates more efficiency big in use energy wind .

Apart from that , drag and torque analysis also shows superiority turbine Savonius with two rotors. Drag data shows that turbine double produces more drag large on the advancing blade, which contributes to more torque height and increase performance overall . Validation numeric with contour pressure and speed show that addition of double rotors enlarge difference pressure between the advancing and returning blade, reducingdrag and increasing torque. With Thus , double rotor Noonly increase efficiency conversion energy but also deliver stability more operational OK , make it more choices effective For application turbine Savonius .

4. CONCLUSIONS

Based on results simulation and analysis , installation of two turbines Savonius side by side with round direction of speed wind 5 m/s indicates increase significant performance compared to with configuration turbine one rotor. Study show that this two rotor configuration can increase performance turbine Savonius up to 70% at a temperature of 25°C and a Reynolds (Re) value of 3.6 x 10^4. More efficiency tall This materialized through increase in Coefficient of Moment (Cm) and Coefficient of Power (Cp), as well as improvements to drag and torque. This result indicated that two turbine configuration give profit substantial operations , making it more effective in utilise energy wind and produce energy more optimal mechanics .

REFERENCES

[1] Agency for the Assessment and Application of Technology (BPPT). 2019. Indonesia Energy Outlook 2019: The Impact of Increased Utilization of New and Renewable Energy on the National Economy. Jakarta: Agency for the Assessment and Application of Technology (BPPT).

[2] Choon, MJ, Purnadiana, FR, Noor, DZ, Horng, TL, Chau, SW, & Odhiambo, E. 2015. Numerical study of flow past two counter rotating cylinders using immersed boundary method. Journal of Marine Scienceand Technology (Taiwan), 23(5), 761–773. https://doi.org/10.6119/JMST015-0617-1

[3] Hesami, A., Nikseresht, AH, & Mohamed, MH 2022. Feasibility study of twin-rotor Savonius wind turbine incorporated with a wind-lens.

OceanEngineering, 247. https://doi.org/10.1016/j.oceaneng.2022.110654

[4] Jang, C.M., Kim, Y.G., Kang, S.K., & Lee, J.H. (2016). An experiment for the effects of the distance and rotational direction of two neighboring vertical Savonius blades. International Journal of Energy Research, 40(5), 632638. https://doi.org/10.1002/er.3454

[5] Ministry of Energy and Mineral Resources. 2022. Data on fossil energy use in 2022. ESDM 2019. Jakarta.

[6] Sakti, G., & Yuwono, T. (2019). Performance Study of Installed an I-65o Type

[7] Cylinder at The Upstream of Returning Blade of Savonius Wind Turbine,

[8] Comparison With Conventional Savonius Wind Turbine. Science and Technology The Journal For Technology and Science, 30(2), 56. https://doi.org/10.12962/j20882033.v30i2.4991

[9] Sumner, D. (2010). Two circular cylinders in cross-flow: A review. Journal of Fluidsand Structures, 26(6), 849–899. https://doi.org/10.1016/j.jfluidstructs.2010.07.001.