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Simulation of Overlap Effect on Savonius Wind Turbine Performance by Varying Cylinder Distance in Front of Returning Blade

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Abstract— The performance of Savonius wind turbine was improved in the previous experimental studies that added overlap and variation of disruptive cylinder distances in front of returning blade. However, the study could not display flow visualization such as velocity contours, streamlined velocity, and pressure contours on turbines so further research is needed. This research is in the form of numerical study using 3-dimensional Computational Fluid Dynamics (CFD) method. The simulation is, determine visualize the turbine's flow like a velocity contours, streamlined velocity, and pressure contours. The turbine has the same diameter and height of 0.4 meters with overlap addition. The various distances of the disruptive cylinder used is S/d = 1.4; S/d = 1.7 ; S/d = 2 and S/d = 2.3. The final result shows that the visualization at a distance of S/d = 1.7 is the most optimal wake distance to cover the overall returning blade side so that the performance of the Savonius wind turbine at that distance is highest compared to other variations.

Keywords—Numerical, Computational Fluid Dynamics (CFD), Savonius Wind Turbine, Overlap, Disruptive Cylinders.

I. INTRODUCTION

Every element of human life cannot be separated from energy, especially electrical energy. Fossil fuels are mostly used to produce electrical energy. The use of fossil fuels as an energy source has the disadvantage of not being environmentally friendly. Therefore, solutions are needed to solve this problem so it is necessary to innovate environmentally friendly energy. One solution that can be done is to make a wind power plant.

Wind turbines are one of the tools used in energy utilization, especially the use of wind energy which is often used as one of the power plants, because the use of wind energy is one of the natural resources that will not run out [1]. The classification of wind turbines based on their axes is classified into 2 types, namely horizontal and vertical axes [2]. Wind turbine performance can be improved by varying the shape of turbine blades such as overlap [3], myring, and fin [4]–[7] or variations on the addition of a disruptive cylinder [8], [9]. Variations in the addition of cylinders can also be done in terms of stagger angle, cylinder distance, and cylinder diameter ratio that can be placed in front of the returning or advancing blade [10]–[12].

In previous studies to determine the performance of Savonius wind turbines, experimental studies were conducted by [13] by adding overlap ratio and varying the distance of the disruptor cylinder in front of the returning blade S/d = 1.4; S/d = 1.7 ; S/d = 2.0 ; S / d = 2.3 and speeds of 5 m / s, 6 m / s, and 7 m / s so that Savonius wind turbine performance is obtained in the form of Coefficient of Power (Cp). However, the experiment could not display flow visualization, so further research was needed.

TABLE 1.
DATA OF MODEL

DIAMETER (D)	:	400 mm
BLADE DIAMETER (D)	:	260 mm
HEIGHT (H)	:	400 mm
OVERLAP RATIO (E/D)	:	0,3
CYLINDER DIAMETER (DS)	:	160 mm

This study simulated a 2-blade savonius wind turbine [14] Overlap ratio profile 0.3. Variations are made to variations in the distance of the disruptive cylinder in front of the returning blade [15] to derive the value of the coefficient of torque and flow visualization with the Computational Fluid Dynamics (CFD) method [16].

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II. METHOD

A. Savonius Overlapping Wind Turbine Dimensions

The dimensional data of the savonius wind turbine to be tested using numerical simulation are represented in Table 1.

B. Tip Speed Ratio (TSR), Ct, and Cp

Tip speed ratio or often referred to as TSR is a comparison of the speed between turbine rotation to wind speed [17]. The Tip Speed Ratio equation can be defined as follows :

$$\mathrm{TSR} = \frac{\omega \cdot R}{v} \quad (1)$$

The Coefficient of Torque or Ct can be defined as the ratio between the actual torque produced by the turbine and the theoretical torque possessed by the turbine. The greater the value, the greater the comparison. The Coefficient of Torque equation can be defined as follows [18] :

$$\mathrm{Ct} = \frac{4\mathrm{T}}{\rho v^2 D^2 H} \quad (2)$$

Coefficient of Power is a calculation that determines the magnitude of wind turbine performance. The value of the Coefficient of Power is directly proportional to the performance of the wind turbine. The value of the Coefficient of Power can be determined through the following equation [18]:

$$Cp = TSR.Ct \quad (3)$$

C. Number of Time Step and Time Step Size

Time size step (TSS) is the desired time for the blade to travel an angle in degrees. While the number of time steps is how many time steps will be calculated. Here are the equations of NTS and TSS [19] :

$$\mathrm{NTS} = \mathrm{N}\frac{360}{\theta} \quad (4)$$

$$\mathrm{TSS} = \frac{\mathrm{N}}{0{,}15915\ \omega \times NTS} \quad (5)$$

D. Simulation Schema

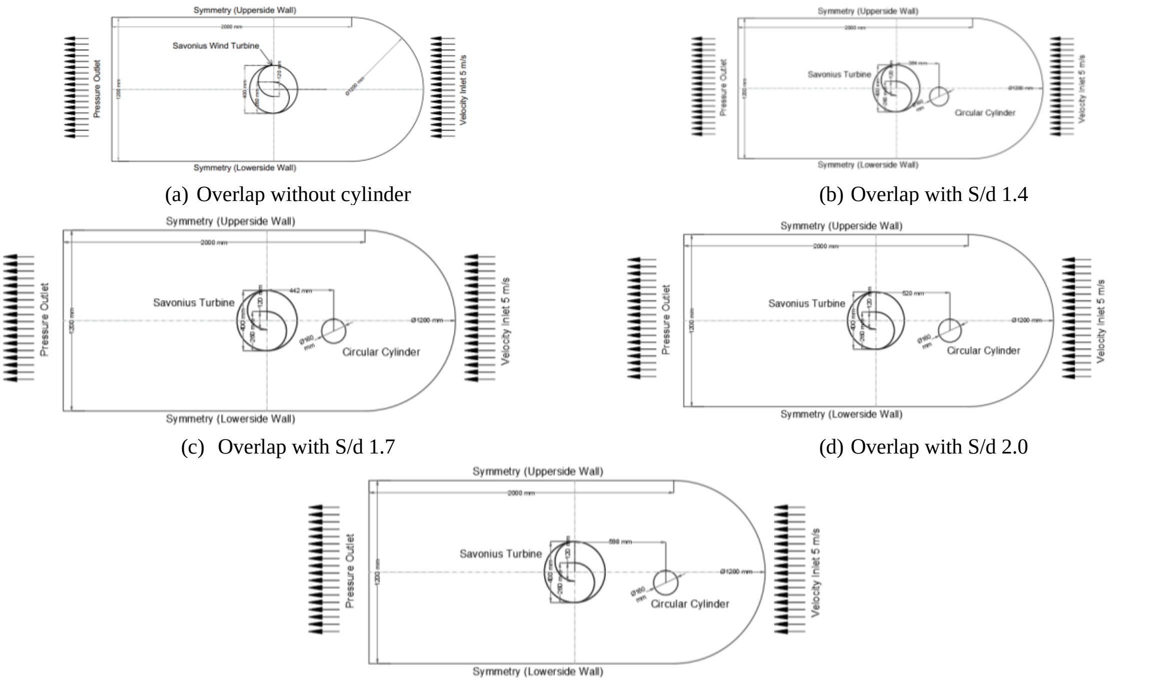
At this stage the simulation is carried out using a model with variations in the distance of the disruptor cylinder in front of the returning blade, namely S / d = 1.4; S/d = 1.7 ; S/d = 2.0 ; S/d = 2.3 and the Savonius wind turbine overlaps without cylinders.

TABLE 2
INPUT DATA FOR NTS AND TSS

TSR	NTS	TSS (s)
0,4	3437	0,01745
0,6	5156	0,01164
0,8	6875	0,00873
1	8594	0,00698
1,2	10313	0,00582

TABLE. 3
BOUNDARY CONDITIONS

NO	Surface	Specify Boundary Types
1.	Inlet	Velocity
2.	Outlet	Pressure
3.	Turbine Blade	Wall
4.	Wall	Symmetry
5.	Rotation and static	Interface



(a) Overlap without cylinder
(b) Overlap with S/d 1.4
(c) Overlap with S/d 1.7
(d) Overlap with S/d 2.0
(e) Overlap with S/d 2.3

Figure. 1 Savonius wind turbine simulation scheme distance variation

E. Boundary Conditions

The purpose of creating a boundary condition domain is to define the set volume to be calculated numerically. There are 2 domains created in this simulation, namely the static domain and the rotating domain. All domains that have been created are mesh to see the density of each domain.

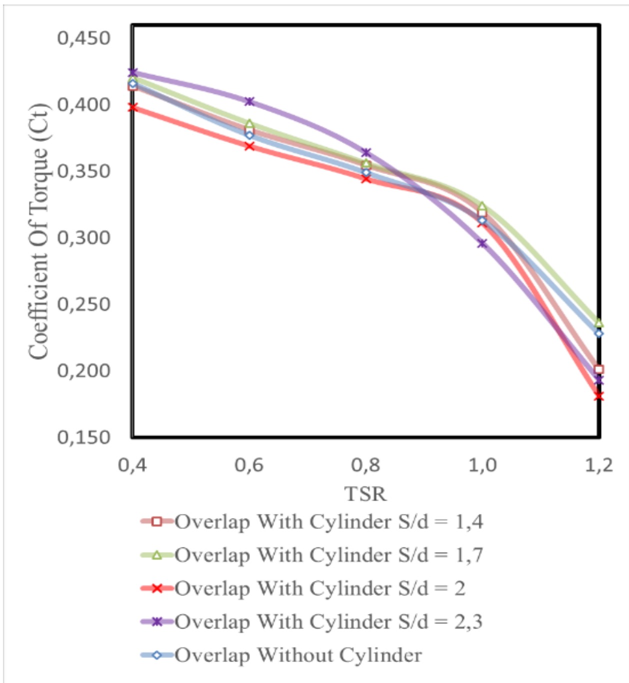


Figure 2 Graph of coefficient of torque (Ct) to TSR at distance variation (S/d)

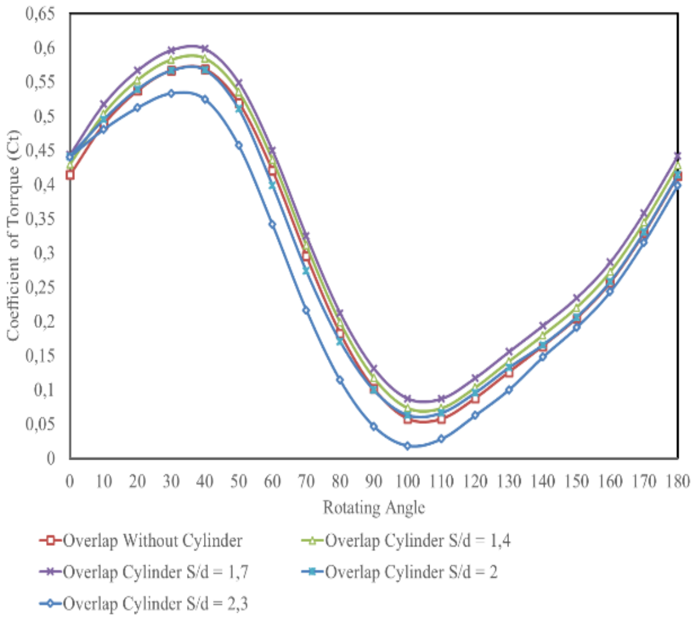


Figure 3 Graph of the pattern of coefficient of torque (Ct) over half a turn of the Savonius wind turbine

III. Result and Discussion

A. Torque Coefficient

From the simulation results, Savonius overlapping wind turbines with various variations in the distance of the disruptor cylinder in front of the returning blade has a coefficient of torque (Ct) value that is higher than the value of the coefficient of torque (Ct) of the Savonius overlapping wind turbine without cylinders. Figure 2 is a graph of the coefficient of torque.

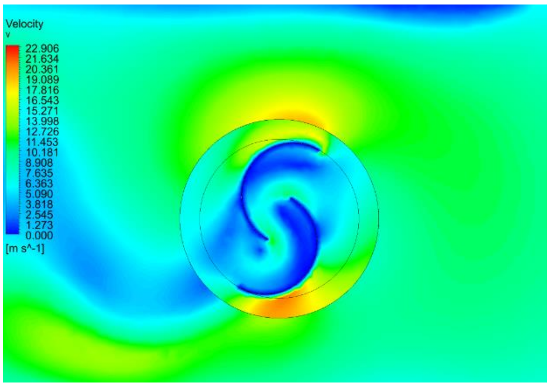
B. Pattern Curve Coefficient of Torque (Ct)

In this study, simulations were carried out under transient conditions so that a pattern of coefficient of torque (Ct) was obtained at the rotating angle during the turbine rotating half a rotation (180 °). The pattern of coefficient of torque (Ct) produced by the turbine in each variation at wind speed conditions of 5 m/s. The coefficient of torque (Ct) at each rotating angle has the same groove, which forms a sinusoidal pattern. The highest coefficient of torque (Ct) value is found at a turning angle of 40°.

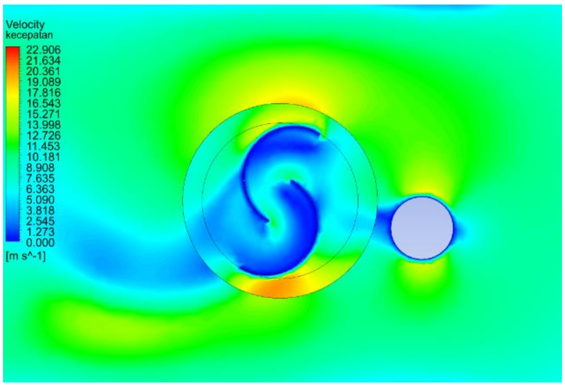
From the fig. 3 turbine at a turning angle of 40° produces the highest coefficient of torque (Ct). In this condition, flow visualization planning will be carried out to determine the flow contours, pressure contours, and speed streamlines on the Savonius wind turbine.

C. Velocity Contour

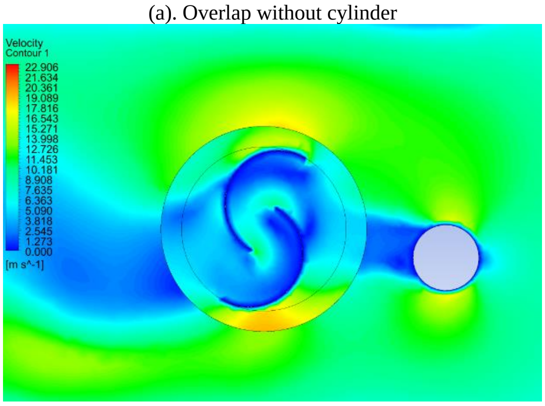
The function of the flow velocity pattern is to see the shear layer formed from the interaction of vortex when it hits the blade of the Savonius wind turbine.



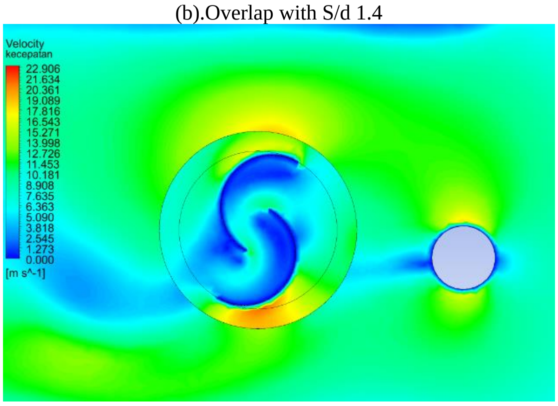
(a). Overlap without cylinder



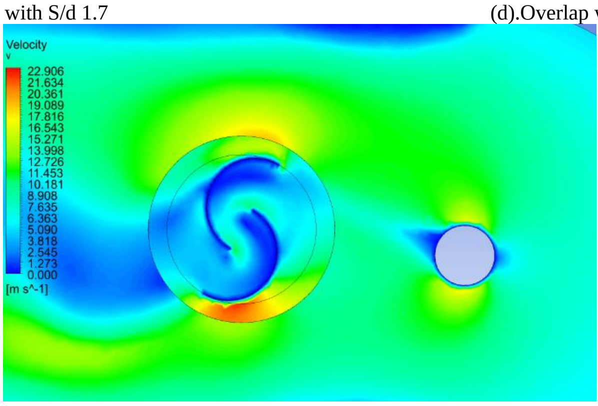
(b).Overlap with S/d 1.4



(c).Overlap with S/d 1.7



(d).Overlap with S/d 2



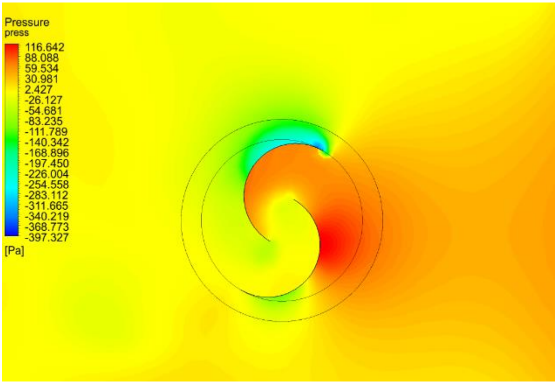
(e).Overlap with S/d 2.3

Figure. 2 Velocity contours savonius wind turbine overlap

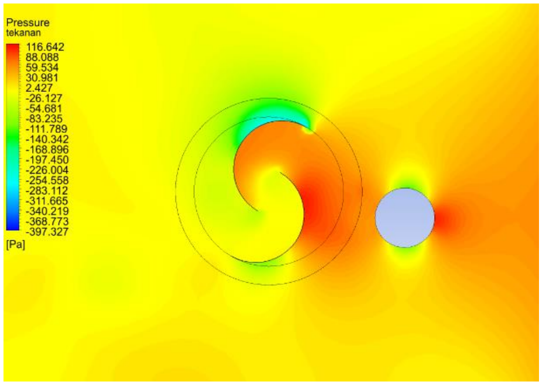
In the variation of overlap without cylinders, the distance S/d = 1.4, S/d = 1.7, S/d = 2.0, S/d = 2.3 shear layer formed a flow that has low speed on the advancing blade side so that the drag force generated on the advancing blade side decreases. While on the returning blade side, a flow is formed that has high speed so that the drag force generated on the returning blade side increases. This causes the net drag (the difference between the advancing and returning blade drag forces) to increase and the turbine performance to increase. However, the best variation occurs in the variation S/d = 1.7 because at a distance of S/d = 1.7 the disruptor cylinder causes the formation of a wake that covers the returning blade side as a whole so that the flow is evenly distributed.

D. *Presure Contour*

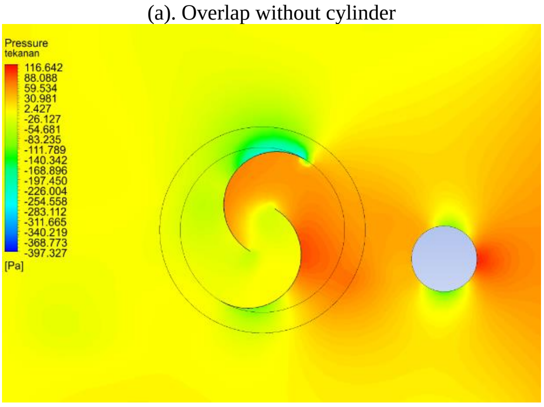
Figure 5 is the pressure contours of savonius overlapping wind turbines.



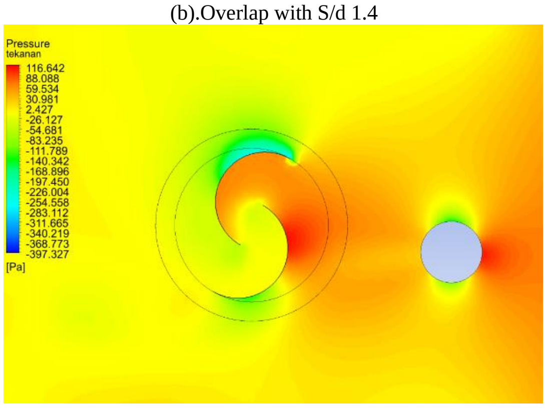
(a). Overlap without cylinder



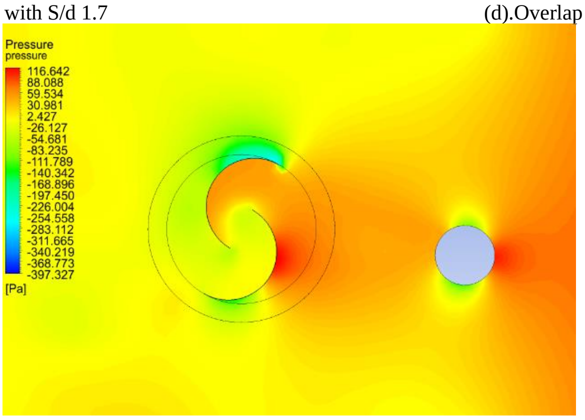
(b).Overlap with S/d 1.4



(c).Overlap with S/d 1.7



(d).Overlap with S/d 2



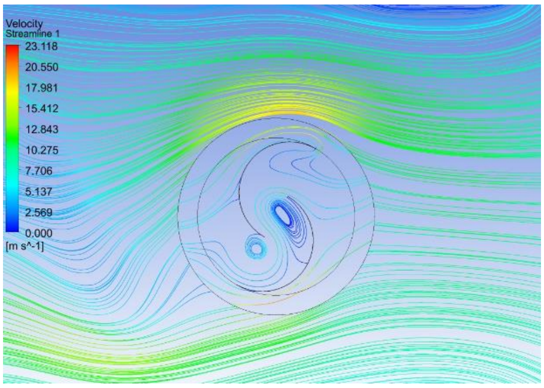
(e).Overlap with S/d 2.3

Figure. 3 Pressure contours savonius wind turbine overlap

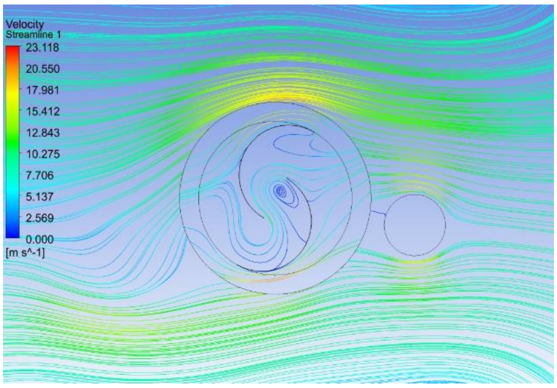
In the variation of overlap without cylinders, the distance S/d = 1.4, S/d = 1.7, S/d = 2.0, S/d = 2.3 shear layer a flow is formed that has low pressure on the advancing blade side so that the drag force generated on the advancing blade side decreases. While on the returning blade side, a flow is formed that has high pressure so that the drag force generated on the returning blade side increases. This causes the nett drag (the difference between the advancing and returning blades) to increase and the turbine performance to increase.

E. *Streamline Velocity*

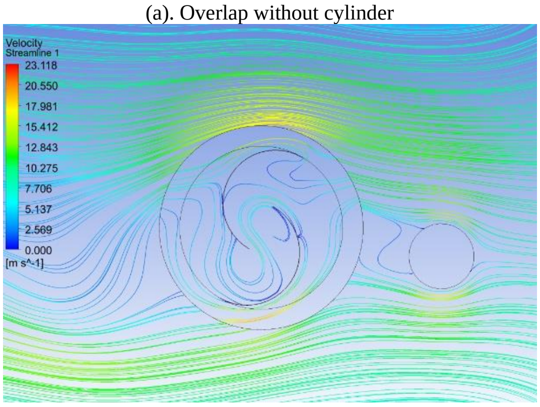
The following are the streamline velocity of savonius overlapping wind turbines :



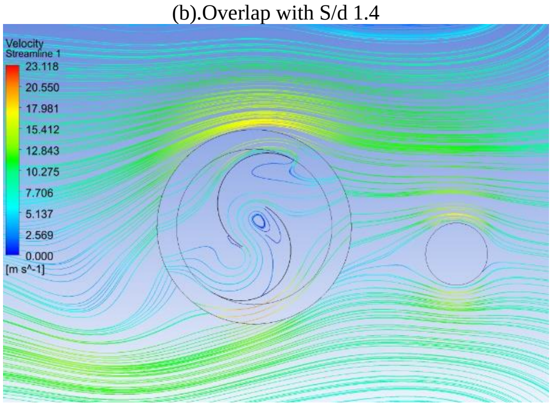
(a). Overlap without cylinder



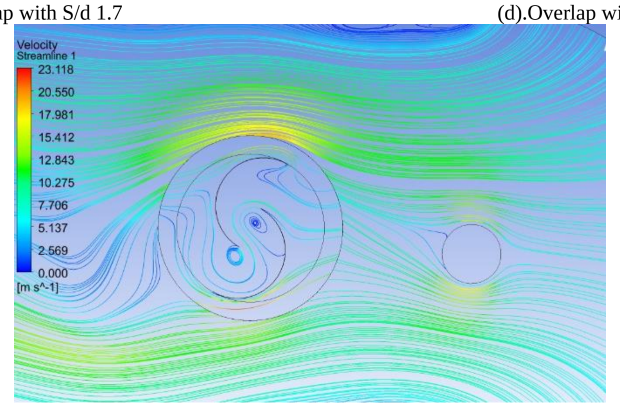
(b).Overlap with S/d 1.4



(c).Overlap with S/d 1.7



(d).Overlap with S/d 2



(e).Overlap with S/d 2.3

Figure. 4 Streamline velocity savonius wind turbine overla

At a blade turning angle of 50°, the disruptor cylinder causes a wake to form that covers only part of the returning blade. In addition, vortex changes are visible in the center of the turbine.

At a blade turning angle of 50°, the disruptor cylinder causes a wake to form that covers the entire returning blade side. In addition, vortex changes are visible in the center of the turbine.

At a blade turning angle of 50°, the disruptor cylinder causes a wake that does not cover the returning blade side. In addition, vortex changes are visible in the center of the turbine.

At a blade turning angle of 50°, the disruptor cylinder causes a wake that does not cover the returning blade side. In addition, vortex changes are visible in the center of the turbine.

IV. Conclusion

1. The value of the coefficient of torque (Ct) from the simulation results can be concluded that the Savonius wind turbine overlaps with the addition of variations in the distance of the disruptor cylinder has a higher performance than the Savonius wind turbine overlap without cylinders.
2. In the contour of flow speed and pressure, it can be concluded that the speed of flow passing through the blades on the turbine is influenced by drag forces. The lower the flow speed, the lower the drag force and the nett drag produced is higher.

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