International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Savonius Vertical Axis Wind Turbine Design and Analysis with Dimples and Fins

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Submitted:24/03/2023 **Revised:**26/05/2023 **Accepted:**13/06/2023

Abstract: As a solution to the worldwide energy dilemma and growing global emissions, innovative work in the field of environmentally friendly power, eminently wind and sun oriented, has expanded rapidly as of late [1]. A horizontal axis wind turbine is not suitable for residential use. With its ability to produce energy even in low-wind conditions, the Savonius vertical-pivot wind turbine might be a more dependable other option. [2]. The motivation behind this model is to exhibit the upsides of the upward hub wind turbine over the more conventional even pivot plan under an extensive variety of wind conditions and to energize its far reaching reception as a reasonable method for creating power not long from now. [3].

Keywords*: Vertical Axis Wind Turbine, Savonius Wind Turbine, CFD, Aerodynamic Performance, Dimples and Fins.*

1. Introduction

Recently, there has been a lot of focus on the topic of alternative or renewable energy. People are increasingly interested in finding contemporary and innovative energy alternatives to complement conventional fuels as a result of technology advancements [4]. In the production of electricity and other types of mechanical energy, wind power has emerged as one of the most cutting-edge energy sources in recent years. Wind turbines are one tool that may be utilised to harness the power of the wind.

Attempts are made in this assignment to increase performance, Changing the size of the wind's sharp edge and the topography of the surface are two examples. [5]. Dimples, then again, are exceptionally acceptable at lessening grinding, as demonstrated by the diminished drag and expanded lift found in golf balls. Balances in the sharp edge likewise increment the positive drag on the cutting edge, permitting it to create more force. For a wind turbine to function properly, lift and drag must be optimized, which, respectively, must be increased and decreased. Dimples and balances of varying sizes and designs are applied to the outer surfaces of wind turbine blades in an effort to increase their efficiency. CFD is used to determine the optimal dimple and balance combination. [6].

A. VAWT Wind Turbine

A VAWT is characterised by a vertically oriented main rotor shaft and a few blades. We came up with a plan that slightly modifies a regular "Savonius Turbine" to go around the limitation of low wind speeds. Similar in capacity and design to a cup anemometer, Savonius Turbines are a sort of vertical pivot wind turbine. [7]. It can move independently of the wind's direction and has a powerful initial acceleration even in light breezes. Several types of wind turbines are seen in Figure 1.

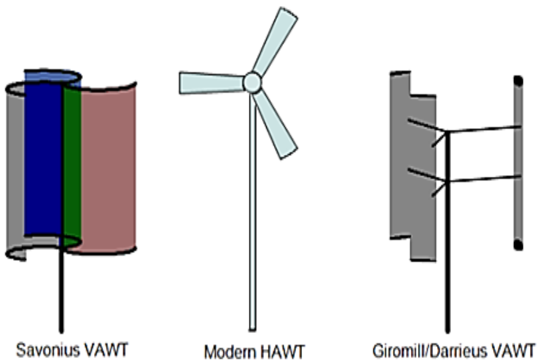

Fig. 1. Types of wind turbines

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B. Dimples

Little permanent depressions, or dimples, may be seen all over the surface of a golf ball. As can be seen in Figure 2, the dimples on a ball support the energy and maverick power open to moving fluid particles in the breaking point layer, a dainty locale near the ball's surface. [8]

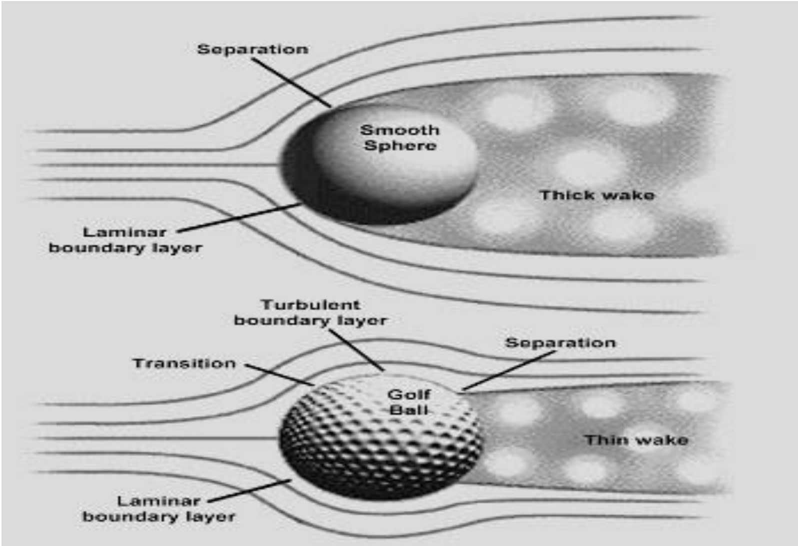

Fig. 2. The Impact of Dimples on Golf Ball Performance

Among the many possible effects of displaying dimples, this one demonstrates two main points:

- As the velocity increases, Both the active energy and the straight force in the limit layer are constantly growing throughout the length of the stream.
- Compared to laminar flow, turbulent flow has higher kinetic energy and shear force. If you rap on the door quickly enough, you could disrupt the smooth flow of air in the boundary layer.

C. Dimple Structure

Dimples may reduce the amount of blockage by up to half compared to a flat surface. The findings explain why dimples cause a decline in opposition. The dimples on a surface operate as a terrible cutoff layer, reducing the surface's ability to haul in a base. Since the layer stream contains more energy than even the furthest layer stream, it may be put to good use. [9]

D. Fins

The balance of a turbine is an extra or altered portion of the blade's edge that distributes stress more evenly throughout the blade's length. According to the research, having more balance at the pointy end may affect how the breeze turbine displays its potential to generate electricity. Adding a blade to a wind turbine's rotor may change the amount of energy it generates, according to studies. [10]

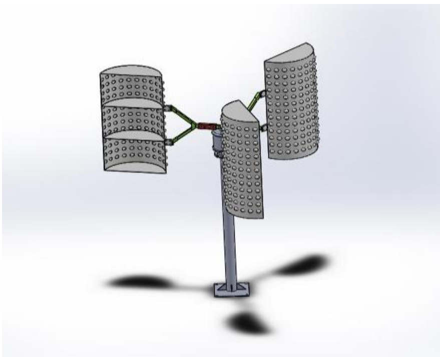

Fig. 3. Savonius Variable Area Wingtip with Dimples and Fins

2. Metheodology

A. Mathematical calculations

To calculate the power and efficiency of Savonius VAWTs, one may use the following formula:

The total quantity of attainable wind power, P, equals

$$P_\omega = \frac{\rho \times A \times V^3}{2} \quad \text{…. (1)}$$

Where,

ρ = a measure of the weight of the air

A = turbine's sweeping area, and

V = wind velocity.

C_P, or the power coefficient, is the relationship between how much energy created by a wind turbine P_O and the amount of energy it can harvest P_ω from the wind.

$Cp = \frac{Po}{P\omega}$ (C_P, max = 0.59) …. (2)

The most effective wind turbine design can only capture around 59% of the notional energy carried by the wind and convert it into useful electricity. Variables such as wind turbine construction quality and atmospheric conditions (such as air thickness and turbulence) all contribute to the Cp value, making each configuration unique. As a result, Cp is often essentially lower than 0.59, and although additional planning systems used in a wind turbine installation may increase overall efficiency, (such as a gearbox, generator, or guiding system) are included, productivity reduces even more. Cp is a representation of the breeze turbine's streamlined output, which accounts for losses due to choppy air and other environmental factors but not mechanical failures. So, using Eq. (), we can calculate how much power Po the turbine gained by converting the wind into rotational energy (3) [11].

$P_O = \frac{\rho \times A \times V^3 \times C_P}{2}$ …. (3)

Also,

$P_O = \frac{2\pi NT}{60}$ …. (4)

In which,

ρ = Density of air, kg / m^3

T = wind turbine's Nm of torque

N = The rotations per minute of the wind turbine.,

A = area of wind turbines i.e. A = D x H,

V = what is considered to be the top speed, m/s

H = Windmill Height, m

The value of C_P varies depending on the operating conditions of the turbine, i.e., at various turbine rotational speeds. That means the Tip Speed Ratio (TSR) λ, defined as, influences C_P.

TSR = $\frac{Tip\ Speed\ of\ the\ Blade}{Wind\ Speed}$

$= \frac{V_{tip}}{V_{air}}$ …. (5)

$= \frac{(\omega \times R)}{V}$

Where,

$V_{tip} = \frac{\pi DN}{60}$ …. (6)

D = Diameter of wind mill, m

B. Tool Used:

Power output is determined using a CFD study, with pressure distribution, velocity profile, and torque calculated using Ansys CFX 19.2 and Ansys Design Modeler, respectively.

With ANSYS CFX, you can examine liquid stream, heat move, and pressure in perplexing calculations including incompressible and compressible fluids. You can bring in meshes, set materials, boundary conditions, and solution parameters, run computations, examine the outcomes, and generate reports with the help of in-built features.

ANSYS CFX is a multi-purpose Computational Fluid Dynamics (CFD) software package that includes a state-of-the-art solver in addition to robust pretreatment and post-processing tools. The following amenities are included into it:

- A dependable and robust state-of-the-art coupled solver.
- The defining of the issue, its analysis, and the presenting of the findings are all seamlessly combined.
- A configuration procedure that is both straightforward and engaging, with the aid of menus and sophisticated visuals.

C. The Mathematics of CFD

Force, heat, and mass transmission are like a revolving door, and this is best shown in the Navier-Stokes conditions. Inferred in the middle of the nineteenth century, these fractional differential circumstances can only be discretized and dealt mathematically since there is no realised universal scientific structure for them. In addition to the Navier-Stokes conditions, other conditions depicting cycles, such as combustion, may be addressed. Disturbance models are a common kind of approximation model used to find these supplementary requirements. [11]

Many different kinds of organisation methods are used in CFD codes. As mentioned earlier, CFX is built on top of the limited volume method, which is the most well-known of its kind. In this strategy, the premium area is broken down into more manageable bits called "control volumes." The circumstances in every control volume are discretized and settled iteratively. The approximation of each component at certain foci may then be obtained for the whole area. Thusly, one determines a full image of the conduct of the stream.

3. Results and Discussion

A. Results

Settings for SAWTs

- Mill's Floor Space = 6,667 Sq. Ft.
- The blade diameter of the wind turbine is 2.866 m
- Windmill height is 2.325 metres
- Wind turbine blade width = 0.477 metres
- Assume a molar mass of 28.96 kilogrammes per mole
- The formula for density is:
- Indicative Temperature: 25 degrees Celsius
- For reference, the average wind speed is 5 metres per second.
- 1 atmosphere is equal to 1 bar

1) Result of a CFD study without dimples and fins

The Savonius wind turbine produces 3.64E4 kW and 115619 N-m of power and torque, respectively.

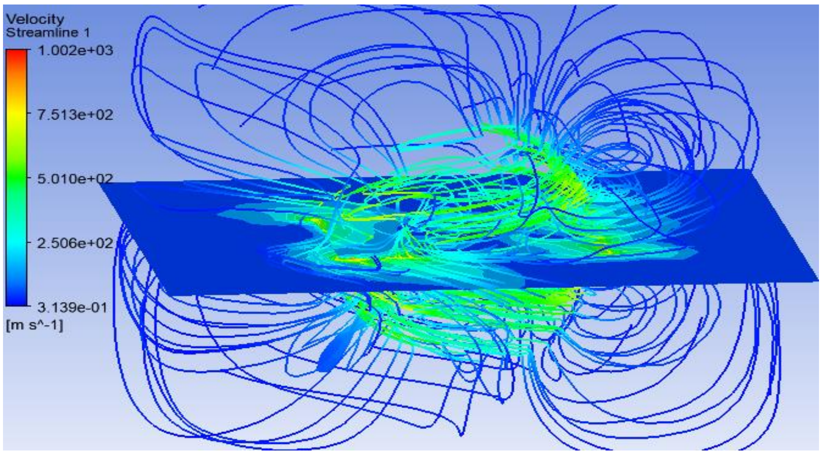

Fig. 4. Wind velocity distribution

- **The velocity plot:** Besides aiding in the comprehension of the evolution of flow within the domain, this figure demonstrates that the flows at high speed near the inlet, validating the turbulent flow assumption.

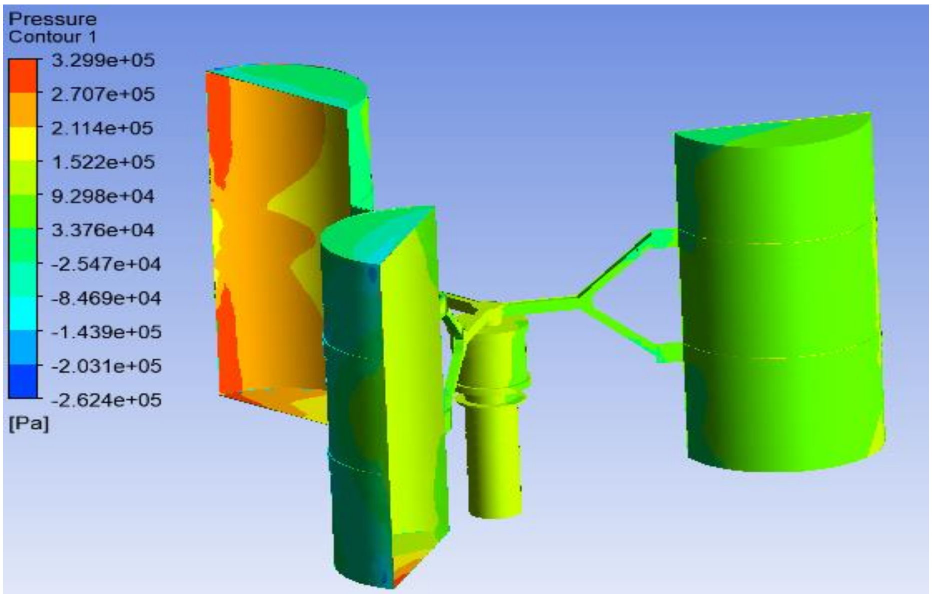

Fig. 5. SAWTs without dimples and fins have a different pressure profile on the blade.

2) Dimpled and finned CFD findings

The Savonius wind turbine can produce 5.46E4 kilowatts (kW) and 173708 Newton-meters (N-m) of torque.

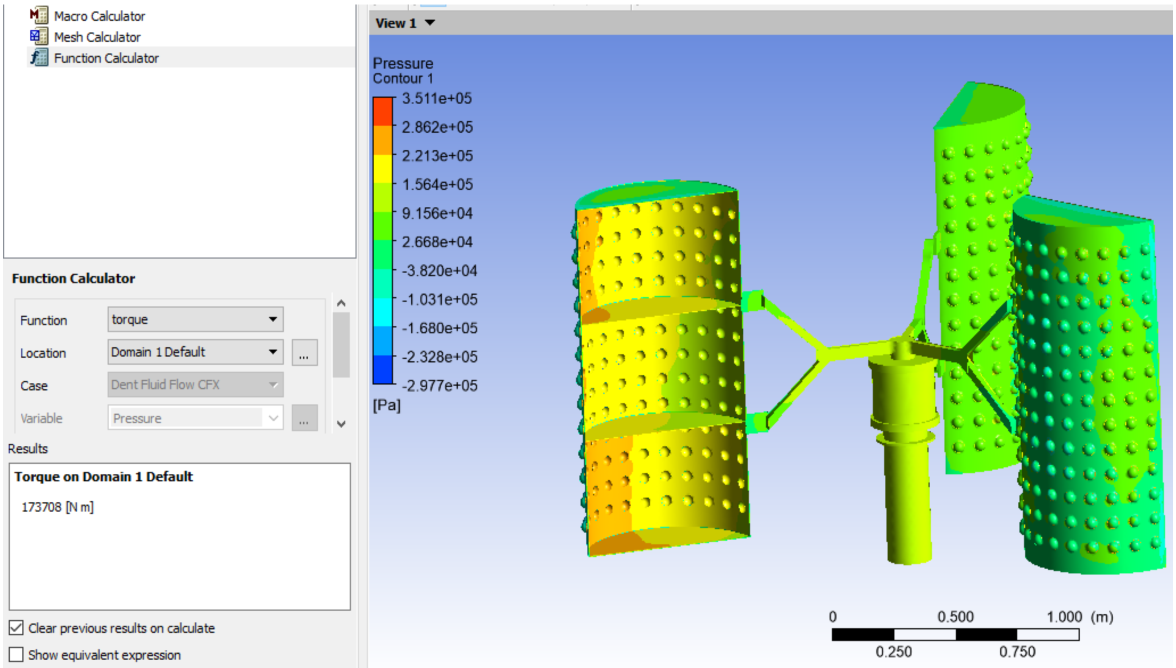

Fig. 6. CFD model with dimples and fins on a Savonius wind turbine.

B. Discussion

When comparing dimpled and non-dimpled Savonius VAWTs, the wind turbine with dimples and fins was more efficient and produced more electricity. When compared to a conventional wind turbine, the output of one with dimples and fins is 5.46104 kilowatts (KW). Also, the power coefficient and efficiency is also high with dimples and fins windmill.

4. Conclusion

The investigation centers on the streamlined impacts which came about because of the incorporation of dimples and balances, adding to force and in the long run improved execution levels. The reason for this examination is to decide how successful a breeze turbine with dimples and edges would be in lessening wind obstruction. This work is being done with the hope of making wind turbines more effective and powerful. Dimples and blades, which are used to alter the surface topography of golf balls, were the original inspiration for their usage in wind turbines.

The following goals are derived from the results:

i. Savonius As compared to conventional wind turbines, VAWTs generated much greater thrust and power.

ii. Better results were achieved using a Savonius wind turbine that had dimples and rotor blades.

iii. Electricity might be produced using dimpled wind turbines even when the wind is too feeble to drive conventional turbines.

iv. The evaluation of the velocities and circulations of the pressing factors will be influenced by the sharp edge balance number. Where two balances on the cutting edge delivered the higher pressing factor circulation and speed appropriation

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