Tikrit Journal of Engineering Sciences (2025); 32(1): 1748
DOI: http://doi.org/10.25130/tjes.32.1.32

IRAQI Academic Scientific Journals

ISSN: 1813-162X (Print); 2312-7589 (Online)

Tikrit Journal of Engineering Sciences

available online at: http://www.tj-es.com

TJES Tikrit Journal of Engineering Sciences

Empirical Investigation Study of Impeller Wind Turbine

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Keywords:
Vane; Wind turbine; Energy; Power; Design.

Highlights:

- *Novel vertical-axis vane turbine enhances drag coefficient (Cd=1.6–2.3) for low-wind efficiency.*
- *Four-frame design outperforms three-frame, yielding 27% higher torque at 10 m/s wind speed.*
- *Wind tunnel tests validate theory with 7% power variance, Cp peaks at low wind speeds.*
- *Simple, cost-effective vane turbine operates effectively in turbulent, low-velocity winds.*

ARTICLE INFO
Article history:

Received	01 Oct.	2023
Received in revised form	17 Jan.	2024
Accepted	22 Feb.	2024
Final Proofreading	20 Oct.	2024
Available online	28 Mar.	2025

Citation: Alwaise AMA, Alrashedi MA, Rajab RH. **Empirical Investigation Study of Impeller Wind Turbine**. *Tikrit Journal of Engineering Sciences* 2025; **32**(1): 1748.
http://doi.org/10.25130/tjes.32.1.32

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Abstract: According to the latest research, renewable energies currently take precedence because they used to make up 1% of the global energy supply but now account for a higher amount. In order to develop a new wind turbine design that is more effective than existing designs, the inventors were forced to construct a wind turbine. The wind turbine described in this article utilizes the wind's energy more efficiently and only depends on the vanes' active surface. A vane wind turbine maximises a wind turbine's kinetic energy harvesting capacity. Due to their shape and construction, ordinary three-blade propellers practically have an efficiency of wind energy utilisation of about 20%. Renewable power sources are leading the way toward a more democratic energy distribution system, and they are increasingly competing with fossil fuels on an equal footing without government support. Renewable energy is considered cost-effective in many applications, ensures its ongoing availability and presence, produces fewer heat emissions associated with power generation, and does not contribute to gaseous emissions that degrade the environment.

دراسات تجريبية استقصائية لتوربين الرياح الدفعي

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الخلاصة
وفقاً لآخر البحوث، فإن مصادر الطاقة المتجددة تحظى حالياً بالأسبقية لأنها كانت تشكل نسبة ١ في المائة من إمدادات الطاقة العالمية ولكنها تمثل الآن مبلغاً أكبر. ومن أجل تطوير تصميم تربيني هوائي جديد أكثر فعالية من التصميمات الحالية، اضطر المخترعون إلى بناء تربينات ريحية. وتستعمل التوربينة الريحية الوارد وصفها في هذه المادة طاقة الرياح على نحو أكثر كفاءة ولا تعتمد إلا على سطح الطواحين النشط. وتُصنع توربينات رياحية زائفة لزيادة ناتج التوربينات الريحية التي تسخر الطاقة الحركية للرياح. ونظرا لشكلها وبنائها، فإن المراوح العادية ذات الثلاثة المظلات لها عمليا كفاءة في استخدام طاقة الرياح تبلغ نحو ٢٠ في المائة. وتقود مصادر الطاقة المتجددة الطريق نحو نظام أكثر ديمقراطية لتوزيع الطاقة، وهي تتنافس بشكل متزايد مع أنواع الوقود الأحفوري على قدم المساواة دون دعم حكومي. ويُنظر إلى الطاقة المتجددة على أنها فعالة من حيث التكلفة في العديد من التطبيقات، وتكفل توافرها ووجودها المستمرين، وتنتج انبعاثات حرارية أقل مرتبطة بتوليد الطاقة، ولا تسهم في الانبعاثات الغازية التي تتحلل البيئة.

الكلمات الدالة: الزعانف، تربينات الرياح، الطاقة، القدرة، التصميم.

1.INTRODUCTION

The conversion of wind energy into a form that can be harnessed and used for practical purposes through the installation of wind turbines is known as wind power, such as mechanical or electrical energy. The development of wind turbine technology has continued. Currently, a single unit's capacity ranges from 250 to 500 KW. Wind energy's cost effectiveness and environmental benefits are undeniable [1,2]. The concepts of aerodynamics and the construction dynamics of rotary system's must be thoroughly understood in order to design a wind generator system that can produce energy with peak of performance. Many wind turbine technologies have been suggested and constructed for catching and transferring the kinetic power of winds. There are now three main types of wind turbines in use in the field of wind energy. The vertical axial Darrieus and Savonius turbine and the horizontal axial propeller are examples of related devices, and each model has numerous variations. The vertically oriented turbine is usually used in small- and moderate-sized setups, but a propeller-kind turbine is more frequently employed in large-scale uses, making up virtually the whole turbines on the world mart. There are several sources for information on wind turbine technical specifications [3, 4]. However, a basic evaluation of these wind turbine concepts exposes that they are not ideal and that wind power cannot be used at full capacity due to numerous engineering factors. A flat vane whose plane is normal to the wind flow will only be subject to one aerodynamic force: that of the flow of the wind., or air force. The drag coefficient C_d has a variable quantity, and depends on several variables, including the arrangement of the vanes, the wind velocity, the angle of attack of the vanes' wind, etc. A tangential force, as well known as "skin friction," is present [5,6]. Many complex equations are employed to calculate the power of wind turbines. For evaluating the power of various wind turbine designs, fluid dynamics theory provides a single formula with a few minor modifications. The primary equation that controls a wind turbine's power output [7]. These definitions may lead to the powering of turbines at their rated efficiency. As a result, before comparing the effectiveness of various turbines, efficiencies must be evaluated with considerable care. The hardest aspect of this process is figuring out the C_d drag factor. The final C_d can be affected by a wide range of factors, making it very variable. A few factors that might affect C_d are shape, height, inclined of wind destination and velocity, surface smoothness, spin, and nose rudeness. The drag factor has been the subject of numerous studies, and the findings are very diverse. For a straightforward 2D flat plate, the drag element can change from $C_d = 1.0 - 2.0$ [8, 9] The new wind turbines should have reduced geometrical sizes within the blades', vanes', or other parts' engaged area. The presented issue can be resolved by a novel design of a vertical axis vane-type wind turbine that utilizes the drag force through the active region of the working elements, has a simple structure, and is technologically simple to produce. In an industrial setting, simple mechanisms such as chutes, tranches, etc. are used to slide or roll prismatic or disk-shaped pieces. The majority of basic devices use one chute to transfer the pieces by gravity. The parts that are being transported frequently need to be divided into two groups for the flow chute branches and then moved to various processing devices [10]. The study focuses on the use of wind turbines as a clean, renewable energy source in Kirkuk City. A 400W horizontal turbine that is connected to the electrical system supply was built on a construction site. Electric current and voltage differential measurements were made in the study, and they were contrasted with actual power generation. The data showed that summer is the greatest period to operate wind turbines, with a ten-fold boost in energy production over the winter [11]. The study examines the use of wind energy for irrigation projects in the Al-hawija district of Iraq. According to the study, wind speed is appropriate for producing energy, particularly at 3.5 m/s at a height of 10 m and acceptable for towers up to 50 m . The windiest months on record were June, July, and August [12]. In order to address the energy issue and meet climate change objectives, renewable energy sources are being deployed. The goal of this project is to capture energy by turning solar panels towards the direction of the sun. Sun azimuth and altitude are determined using astronomical calculations, increasing daily power generation by 17.3% [13]. The aim of the study is to obtain the best efficiency of turbine engines, then improve the drag factor for turbine has been fabricated.

2.ACTUAL WIND ENERGY EFFICIENCY

Any wind turbine design's theoretical maximum power efficiency is the Betz Limit of $C_e = 0.59$ [1, 2]. With values of $0.345 - 0.44$ being typical in even the best-designed wind turbines, the real-world limit is significantly lower than the Limit of Betz. Other than this one, the wind turbine, bearings, transmission of power, etc., in a wind turbine system result in energy losses, and only more than 9% to less than 31% of the energy of wind's is ever truly turned to useful electric. The lift force of aerodynamic and forces of drag operating on the outer layers of the fins, or vanes, are primarily used by wind turbine generators. According to current studies, wind turbines with flat axes (lift force design) should potentially have greater energy efficiency than those with vertical axes (drug force design). In spite of their decreased efficiency, vertical turbines are nevertheless capable of producing a significant amount of electricity when the wind is turbulent and rapidly changing directions. However, the following crucial information exists: the operating areas for the wind turbine and generator are inversely correlated with each other and with the wind speed, cubed. When designing a new type of wind turbine, these peculiarities should be considered as the primary output power factors.

$$\boldsymbol{P = \frac{1}{2} A \times \rho \times V^2 \times \lambda} \qquad \textbf{(1)}$$

The coming wind to the turbine is perpendicular to the projected area, and P is the power generated by the wind turbine. ρ is the air of density. V is the wind velocity approaching the wind turbine, λ is the efficiency of wind turbine for the usual scenario. λ is the wind turbine efficiency, which is determined by the formula below and depends on the following factors:, $\lambda = C_p \times N_g \times N_b \times C$w here $C = C_d \; or \; C_l$ (or deriving from them) are variables that determine lift and drag, respectively, and are influenced by the configuration of the blades or vanes as well as the direction of the wind flow relative to the object; Coefficient of performance, or ($C_p = 0.3495$ for a well design); N_b: bearings efficiency/ gearbox (around for an ideal layout); N_g: generation performance (eighty% or perhaps higher in the case of an electrically linked induction source or a permanent-magnetic device). Modern wind turbines are known to be developed using extremely complicated optimality criteria that go beyond aerodynamic efficiency. The primary goal is to increase the coefficient c. In general, the shape of the turbine component, the Reynolds numeral, the Froude variety, and the Mach value has an impact on everything. the drag aspect C_d. A is Sweep region with spinning blades for a propeller wind turbine, but the real size of the swept area is four to five times larger than the blades. Between propellers, a wind flows plain and has no impact on the blades. The actual power produced of a wind turbine with propellers is four to five times lower than its potential power. Instead of using the swept area of the complete turbine assembly, the producer of a Darrieus-type turbine bases its definition of performance on the actual area of the blades. Ducted turbines only employ the rotor's projected surface area, not the duct's surface area. But out of the three ways of determining C_d (experimental, theoretically simplified, and numerical CFD), employing a wind tunnel is the most practical and simple approach. This involves figuring out equation One for cap C sub d and putting a pattern in a tunnel of wind (known values for cap V and cap A The force applied to the apparatus holding the model is measured using test results, and $C_d = F/A$ is calculated. The quantity of electricity that can be realistically extracted from the wind also has physical restrictions. Theoretically, it has been demonstrated that any windmill can only ever capture a maximum of 59.3% of the wind's energy (known as the Betz limit) [14, 15]. Due to losses like viscosity loss, three-dimensional losses, and transmission loss, the maximum power coefficient of traditional horizontal axis wind turbines with a single rotor is typically between 40% to 50% in practice. To increase the maximum power coefficient of a wind turbine, a variety of concepts and blade designs have been put out during the past few decades [16]. The velocity variations across the rotor are 4/6 of the total energy, the greatest power that can be collected from the wind is around 59% of the total energy. However, in reality, the energy left in the aftermath of a single rotor is not negligibly little. A second rotor can be added to the wake to further extract some of this energy [17]. The maximum energy that two rotors of equal diameters may extract simultaneously increases from 59% to 64% of the available energy, which is the Betz limit for two rotors. Since the first rotor's wake rotates in the opposite direction from the rotor's direction of rotation, to efficiently extract the available energy in the wake, it is advised that the second rotor rotate in the same direction as the wake [18]. Based on this finding, the counter-rotating wind turbine has recently undergone intensive research in an effort to harness more wind energy than is possible with a typical wind turbine with a single rotor [19,20].

3.THEORY-BASED APPROACH

The numerical methods of computational fluid dynamics should typically be used to handle the extremely challenging challenge of mathematical modeling the power of wind turbines. Lastly, actual testing conducted in an aerodynamic wind chamber should validate the conclusions of theoretical modeling. Simple mathematical representations of the design and operation of wind turbines can provide starting knowledge and the capability to assess the planned construction for this contribution range. For ease of analysis, two flat-vane wind turbine types are used. Vane-kind of wind turbine shown in Fig. 1 Plan view. The initial design of vane kind turbines consists of 4 parts of assembled vanes mounted on structures that are parallel to one another, connected by a primary produced shaft. The next one is made up of 3 separate vanes that are spaced 1200 apart and fastened to the main output shaft.

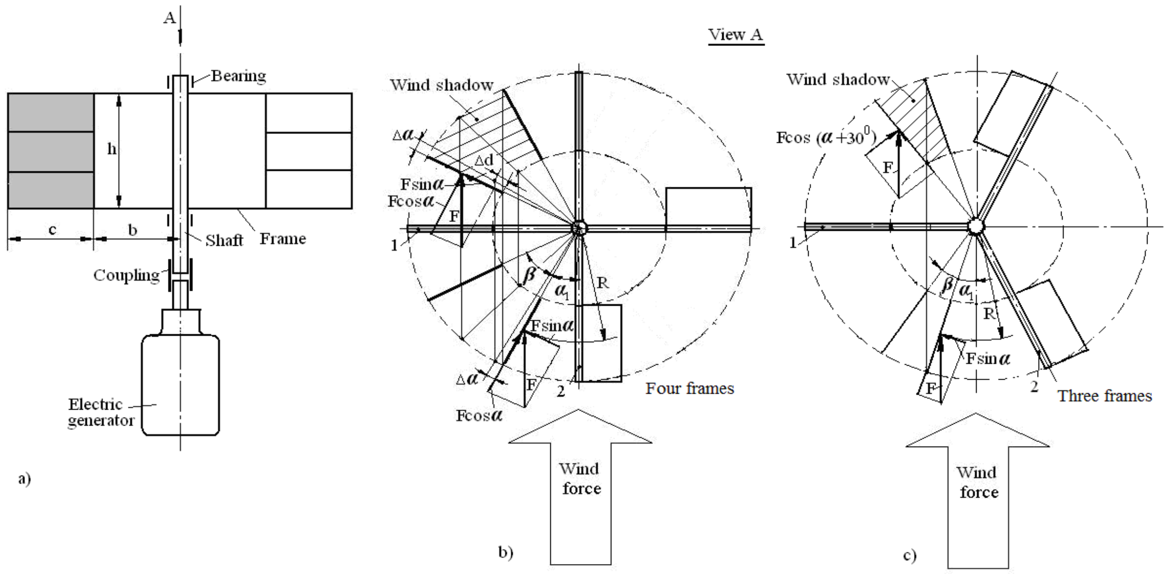

Fig. 1 (a) Vane Kind for Turbine of Wind (b) 4 Frames (c) 3 Frames**.**

Vanes' acting surface area A and location at one of the output shaft's sides determine how much power is produced. Known approaches can consider the link among the physical variables operating on the vane. Acting forces, the position of the vanes in relation to the wind, the shadow of the wind, and the force of the wind on the vanes are all inversely related to the velocity of the wind. The force that the vanes are being subjected to due to the air's changing momentum as it impinges on them must first be calculated. An analytical approach requires the last modification of the force operating on stationary vanes. Depending on the assumptions used, this simplification produces various outcomes. Several important presumptions are made:

a) The air turbine's vanes are streamlined.

b) The air that strikes vanes is viscous-free. Furthermore, it is expected that after hitting the vanes, the air travels away from the substrate, avoiding generating an angle of friction.

c) There is no difference in the drag force acting on the left and right frame components.

The expression below is used to define the force element F operating on the left side frame's stationary vertical vanes [1, 3].

$$F = (0.5)\, C_d \times V^2 \times \rho \times A \times \cos\vartheta \qquad (2)$$

where every one of the elements mentioned before and in Fig. 1. The entire vanes area, as well as the space between the shaft that produces the electricity to the center of the wind pressure, must be specified to be able to determine the turbine's wind vane's initial torque (T). The equation then has the expression that follows.

$$T = (0.5) C_d \times V^2 \times \rho \times A \times R \times \cos\alpha \qquad (3)$$

wherein R is the separation among the pressure measurement center of the wing surface and the shaft's center point., in addition to the other previously mentioned variables. The following formula calculates the result of power.

$$P = T\omega = (0.5) A \times C_d \times \rho \times V^2 \times R \times \frac{V}{R} \times \cos\alpha = (0.5) A \times C_d \times \rho \times V^3 \cos\alpha \ (\text{Watts}) \qquad (4)$$

wherein the other factors listed above and the turbine's rotational angular velocity, denoted by ω, are involved. The next stage is to create a mathematical model of the force that results and acts on moving vanes. This requires figuring out.

d) The airflow velocity in relation to the vanes' front surface in the initial frame, and

e) Impact of the wind on the second structure vanes' surface.

Pressure increases along to the outer layer of the object when the frames with vanes rotate. Higher pressure is usually seen on a surface that is perpendicular to the direction of the wind. By estimating the pressure spread over the variable vanes position and then integrated it, the specific center of pressure is where the resultant force acts. Due to the small surfaces on the faces of the frames, the forces operating on their sides can be disregarded. An effective vane design that integrates the aerodynamics, mass characteristics, and vane spin allows the projectile to be oriented end-forward along the whole air stream line. However, very placement of the frames with the vanes makes the acting forces on the vanes unstable, as well as the rotation of the output shaft. A typical scenario for loading air force on the vane is represented by airstream of flat vane with its normal plane. Calculating the drag factor is a very difficult theoretical problem. Practically, to determine the power produced by wind turbines, it is crucial to have the drag factors determined experimentally by testing turbines in a wind tunnel. Because the rotation of vanes has moved azimuthally from 90° to 0°, for the vane type turbine, the drag factor ranges from highest to minimum. The mean drag factor $C_d = 0.8$ is generally recognized for the vane form turbine to make the computation of the torque simple. The vertical axis wind turbine is one of the appealing solutions to these issues since it can harness wind energy even at low wind speeds and at a reasonable cost. A symmetrical airfoil performs well when used with a vertical axis wind turbine, according to the literature review [21]. The construction of many Darrieus turbine prototypes by both Canada and the United States during the 1970s and 1980s brought vertical axis machines back into the public eye. The prototypes turned out to be highly dependable and efficient [22]. The Darrieus patent also mentioned the creation of the straight-bladed VAWT [23]. Although it has also been referred to as giromill or Cyclo-turbine (different conceptions of the same invention), this turbine is more commonly known as the straight-bladed Darrieus turbine or the H-rotor [24]. peak power coefficients for the three rotor designs that were studied. The four-bladed design has a 5% performance decline using the power coefficient of the three-bladed turbine as a benchmark, whereas the five-bladed architecture experiences 14.9% performance decline. For the four-bladed configuration and 20% for the five-bladed architecture, the value of the tip speed ratio to get the peak power is reduced [25].

3.1.Four-Frame Blade Form Turbine

Two frames sit to one side of the longitudinal shaft of the four-frame vane form wind turbine in order for it to function. Another a 2 frames' vanes are not closed, so the air does not affect their acting area Fig. 1 (a, b). According to the air turbine's layout, the structures with the vanes are positioned diagonally to one another. Due to the turbine's rotating motion, the active vanes' location is variable, which makes a torque produced by the wind force likewise changeable. To compute the output power, it is crucial to understand how the torque produced to the shaft varies. The computation of the forces effected on the vanes, which allows one to determine delivered torque of the wind turbine shaft, is shown schematically in Fig. 1(b). The torque is produced by the wind force through two working frames located on the left edge of the vane turbine. Two frames' vanes operate under various conditions. At certain rotational angles, the secondary frame's blade interacts with the vanes of the first frame to create wind shadows. The vanes in the following one frame Fig. 1(b), four frames function absent a wind shadow. According to air shadow at a particular angle of the frame's turning, the produced toque by the first vane has some drop. Beginning at angle α1, the shadow's angle extends till angle a $\alpha_1 + \beta$. The subsequent equation was used to compute the angles shown from the position of the vanes' shape.

$$(C+b)\sin\alpha_1 = b\cos\alpha_1 \qquad \beta = 90^o - 2\alpha 1$$

After transformations and substituting $\alpha_1 = \tan^{-1}\frac{b}{b+c}$

The half diameter of the produced air force is $R = b + {}^{C}/_{2}$, while the radius of the shadow of air $R = (b + \Delta_d) + (C - \Delta_d)/2$. The increase in size Δ_d is variable with increasing vane rotation angle Δα in wind shadows area. The dependency of Δ_d and Δ_α has expression $\Delta_d = K\Delta_\alpha$, where $K = {}^{b}/_{({}^{\beta}/_{2})}$

A following formula are used to compute the generated torque by the 1,2 frames with an arrangement of vanes:

1- The initial vanes' torque at an angle of rotating between 0° to α1 absent an air shadow.

$$\boldsymbol{T_1 = C_d \times F\left[h_c\left(b + {}^{C}/_{2}\right)\right]\cos\alpha}\ \Big|_0^{\alpha_1} \qquad \textbf{(5)}$$

when the drug factor is C_d.

2- Whenever the wind shadow is initially generated by the second vanes, the initial vanes' thrust is generated at a rotational angle. α_1 to $\alpha_1 + {}^{\beta}/_{2}$.

$$T_2 = C_{d1}\mathrm{F}h(C-\Delta d)\left[(b+\Delta d)+\frac{(C-\Delta d)}{2}\right]\cos\alpha + C_{d2}F\left[(h\Delta d)\left(\frac{\Delta d}{2}+b\right)\right]\cos\alpha\ \Big|_{\alpha_1}^{\beta/2}, \text{ or}$$

$$T_2 = C_{d1}\mathrm{F}h(k\Delta\alpha - C)\left[(k\Delta\alpha+b)+\frac{(C-K\Delta\alpha)}{2}\right]\cos\alpha + C_{d2}F\left[(hK\Delta\alpha)\left(\frac{K\Delta\alpha}{2}+b\right)\right]\cos\alpha\ \Big|_{\alpha_1}^{\beta/2} \quad (6)$$

In which Cd2 is the drug factor that determines the zone of wind shadow for the vanes.

3- The torque produced when the additional vanes' wind shadow ends and the initially vanes' degree of rotating changes from ${}^{\beta}/_{2} + \alpha_1$ to $\beta + \alpha_1$.

$$T_3 = C_{d2}\mathrm{F}h(C-\Delta d)\left[(b+\Delta d)+\frac{(C-\Delta d)}{2}\right]\cos\alpha + C_{d1}F\left[(h\Delta d)\left(\frac{\Delta d}{2}+b\right)\right]\cos\alpha\ \Big|_{\beta/2}^{\beta} \quad (7)$$

4- The initial vanes' torque at an angle of rotating between $\alpha_1 + \beta\ to\ 90^0$lacking a wind shadow.

$$T_4 = C_{d1}\mathrm{F}[hc(b+{}^{c}/_{2})]\cos\alpha\ \Big|_{\alpha_1+\beta}^{90^0} \quad (8)$$

5- The 2nd frame's torque vanes at a degree of rotating between $0^o\ to\ 90^0$ avoid creating a wind shadow.

$$T_5 = C_{d1}F[hc(b+{}^{c}/_{2})]\sin\alpha\ \Big|_{0^0}^{90^0} \quad (9)$$

The subsequent equation determines the total torque produced by the two frames of all four sections of the wind turbine.

$$T = \sum_{i=1}^{5} T = C_{d1}F\left[hc\left(b+\frac{C}{2}\right)\right]\cos\alpha\ \Big|_{0}^{\alpha_1} + C_{d1}Fh(\Delta d - C)\left[(\Delta d + b) + {}^{(\Delta d - C)}/_{2}\right]\cos\alpha + C_{d2}F\left[(h\Delta d)\left(b+\frac{\Delta d}{2}\right)\right]\cos\alpha\ \Big|_{\alpha_1}^{\beta/2} + C_{d2}Fh(\Delta d - C)[(\Delta d + b)(\Delta d - C)/2] + \cos\alpha + C_{d2}F\left[(h\Delta d)\left(b+{}^{\Delta d}/_{2}\right)\right]\cos\alpha\ \Big|_{\beta/2}^{\beta} + C_{d1}Fh(b+C/2)\ \cos\alpha\ \Big|_{\alpha_1+\beta}^{90^0} + C_{d1}F[hC(b+C/2)]\sin\alpha\ \Big|_{0^0}^{90^0} \quad (10)$$

3.2.Turbine of the Vane form with Tree Frames

Additional frames that are situated on the left edge of the vertically shaft of the three-frame vane form wind turbine also function. The right-side vanes of the frames are not closed, so the air does not exert any force on their surfaces Fig. 1 (a, c), three frames. The two initial frames vanes' torque equation is identical to the four-frame turbines. The second frame vanes rotate on 30° following the first frame vanes, which is the sole variation. Another distinction is the wind shadow region. Using distinct angular coordinates for the rotary motion of the vanes and the wind a shadow, Eq. (10) calculates overall torque produced via both frames of the wind turbine's three frames of vanes.

4.A WORKING EXAMPLE

The vane form turbine measures $C = 1.0\,m$ in vane width, $b = 1.0\,m$ in not close frame section length, and $h = 2.0\,m$ in height of the structure. The standard drag factor for rotating vanes is $C_{d1} = 0.8$. At wind shadow, the standard drag factor is $C_{d2} = 0.5$. the vane is being forced by: When the air velocity $V = 10\ m/s$, the wind force F is equal to $100N$. The density of the air is $\rho = 1.25\ kg/m^3$. Efficiency of a wind turbine $\lambda = 0.3$. The most torque a single frame can produce is:

$$T_1 = C_{d1} \times F[hC(b + C/2)]\cos\alpha = 0.8 \times 100[2 \times 1(1 + 1/2)] = 240Nm$$

Using Eq. (10), the greatest torque produced by two frames is computed. Eq. (1) is used to determine the theoretical power produced by a vane-type wind turbine.

4.1.Air Turbine with a Four Propeller and Framework

α1 - beginning of wind shadow formula

$$\frac{b}{b+c} = \frac{\sin\alpha_1}{\cos\alpha_1}.\ \alpha_1 = \tan^{-1}\frac{b}{b+C} = \tan^{-1}\frac{1}{1+1} = 26.5^{\circ}$$

The value for β, or the wind shade angle is $\beta = 90^{\circ} - 2 \times 26.5^{\circ} = 36.88^{\circ}$

The inclination angle of the end of air shade is $\alpha_1 + \beta = 26.5^{\circ} + 36.88^{\circ} = 63.44^{\circ}$

If take factor of air shadow $C_{d2} = 0.5$, so the torque of the first blade of air shade at $\alpha_1 + \beta/2 = 26.5^{\circ} + 36.88/2^{\circ} = 45^{\circ}$, the second vane torque at 45° is

$$T_2 = C_{d1}F[hc(b + C/2)]\cos 45 = 0.8 \times 100[2 \times 1(1 + 1/2)]\cos 45 = 169Nm$$

Overall torque with the wind shadow acting on 2 vanes calculated by Eq. (10)

$T = T_1 + T_2 = 106.4 + 169.8\ Nm$

The torque of the two-vanes turbine at the beginning of the wind shade αs = 26.56°

$$T = C_{d1}F[hC(b + C/2)\ \cos\alpha + C_{d1}F[hC(b + C/2)]\sin\alpha$$

$$T = 0.8 \times 100[1 \times 2(1 + 1/2)\ [\cos\alpha 26.5^{\circ} + \sin\alpha 26.5^{\circ} = 321.9\ Nm$$

The torque of the turbine of two vanes at the end of wind shadow αs = 63.44°

$$T = C_{d1}F[hC(b + C/2)\ \cos\alpha + C_{d1}F[hC(b + C/2)]\sin\alpha$$

$$T = 0.8 \times 100[1 \times 2(1 + 1/2)\ \cos 63.4 + 0.8 \times 100[1 \times 2(b + C/2)]\sin 63.4 = 321.98\ Nm$$

4.2.The Wind Turbine with Three Frames

Beginning of wind turbine equation $\alpha_s = \alpha_1 + 30^{\circ}$. $\frac{b}{c+b} = \frac{\sin\alpha}{\cos(30^{\circ}+\alpha_1)}$

In which the trigonometry identity cos $(\alpha_1 + 30^{\circ})$ $=\cos 30^{\circ} \times \cos\alpha_1 - \sin\alpha_1 \times \sin 30^{\circ}$ and following mathematical transformations.

$\alpha_1 = \tan^{-1}\frac{0.866}{[(C+b)/b]+0.5} = \tan^{-1}\frac{0.866}{[(1+1)/1]+0.5} = 19^{\circ}$, then $\alpha_s = \alpha_1 + 30^{\circ} = 49.1^{\circ}$

Formula for β – the angle of wind shadow is

$$\beta = 90^{\circ} - 30^{\circ} - 2 \times \alpha_1 = 90^{\circ} - 30^{\circ} - 2 \times 19.1 = 21.8^{\circ}$$

Model for αe1 – the angle of ending wind shadow for the first vane is

$$\alpha_{e1} = 30^{\circ} + \alpha_1 + \beta = 30^{\circ} + 19.1^{\circ} + 21.8^{\circ} = 70.9^{\circ}$$

Equation for α_{e2} – the angle of ending wind shadow for the second vane is

a) The initial frame vane's torque for a complete wind shade at $\alpha_1 = 30^{\circ} + \alpha_1 + \beta/2 = 30^{\circ} + 19.1^{\circ} + 21.8^{\circ}/2$

$$\alpha = 30^{\circ} + \alpha_1 + \beta/2 = 30^{\circ} + 19.1^{\circ} + 21.8^{\circ}/2 = 60^{\circ}$$

$T_1 = C_{d1}F[hC(b + C/2)\ \cos 60^{\circ} = 0.5 \times 100[2 \times 1(1 + 1/2)\ \cos 60^{\circ} = 75.0\ Nm$

The torque of the second frame vane at 60° turn of first frame

$T_2 = C_{d1}F[hC(b + C/2)\ \sin 30^{\circ} = 0.8 \times 100[2 \times 1(1 + 1/2)\ \sin 30^{\circ} = 120\ Nm$

Calculated overall torque when two vanes are subject to a wind shadow by Eq. (10)

$T = T_1 + T_2 = 75.0 + 120.0 = 195.0\ Nm$

b) The maximum torque of initial vane at starting of wind shadow at $\alpha_s = 49.1$

$$T = C_{d1}F[hC(b + C/2)\ \cos 49.1^{\circ} + C_{d1}F[hC(b + C/2)\ \sin 19.1^{\circ}$$

$$T = 0.8 \times 100[2 \times 1(1 + 1/2)](\cos 49.1^{\circ} + \sin 19.1^{\circ}) = 225.6\ \ Nm$$

The maximum torque of second vane at starting of wind shadow at αs = 19.10

$$T = C_{d1}F[hC(b + C/2)\ \sin 19.1^{\circ} = 0.8 \times 100[2 \times 1(1 + 1/2)\,sin 19.1^{\circ} = 78.53\ Nm$$

Total torque at the starting of air shade

$$T = T_1 + T_2 = 78.53 + 98.21 = 176.74\ Nm$$

c) The maximum torque of two vanes at ending of wind shadow at αe1 = 70.90, αe2 = 40.90

$$T = C_{d1}F[hC(b + C/2)\ \cos\alpha_{e1}{}^{\circ} + C_{d1}F[hC(b + C/2)\ \sin\alpha_{e2}{}^{\circ}$$

$$T = 0.8 \times 100[2 \times 1(1 + 1/2)\ \cos 70.1^{\circ} + 0.8 \times 100[2 \times 1(1 + 1/2)\ \sin 40.9^{\circ} = 238.82\ Nm$$

The torque computations for all vane type turbines are displayed in the Table 1.

Table 1 The Torque That Vane-Kind Wind Turbines Produce on Their Output Shaft.

Four Frames Turbine											
α°	0	10	20	26.56	45	63.44	70	80	90		
T_1 N	240	236.35	225.52	214.67	106.4	107.31	82.08	41.67	0		
T_2	0	41.67	82.08	107.31	169.68	214.67	225.52	236.35	240		
T	240	278.02	307.60	321.98	276.08	321.98	307.60	278.02	240		
Three Frames Turbine											
α°	0	10	20	30	40	49.1	60	70.1	80	90	100
T_1	240	236.35	225.52	207.84	183.85	157.13	75.0	81.69	41.67	0	0
T_2	0	0	0	0	41.67	78.53	120.0	157.13	183.85	207.84	225.52
T	240	236.35	225.52	207.84	225.52	225.66	195.0	238.82	225.52	207.84	225.52

As a result, the four- and three-frame turbines' mean torque outputs are $T_{av} = 286\ and\ 225\ Nm$

The formula that follows is used to determine how much power the vane wind turbine produces.

$$\boldsymbol{P = (T_{av}V/R)\lambda} \qquad \textbf{(11)}$$

1) A four-frame turbine with the formula $P = (T_{av}V/R)\lambda = \left(286 \times \frac{10}{1.5}\right) \times 0.3 = 572\text{ W}$

where the mean torque from the Fig. 2 is $T_{av} = 286\ Nm$.

2) A three-frames turbine using the formula $P = (T_{av}V/R)\lambda = \left(225 \times \frac{10}{1.5}\right) \times 0.3 = 450\text{ W}$ P=

where the average torque from the diagram.

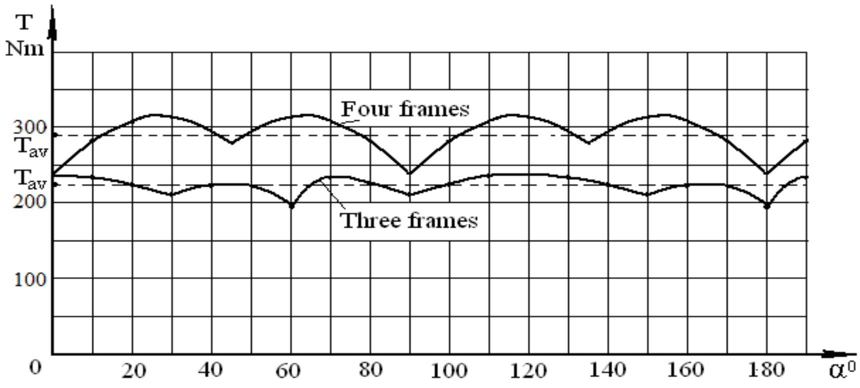

Fig. 2 Torque Vs Output Shaft Rotational Angle.

Fig. 2 is T_{av} = 225 Nm.
The diagrams in Fig. 2 make it simpler to use Eq. (10) to determine the torque. The mean torque for a four-frame turbine is Tav≈1.19Tn, and for a three-frame turbine is $T_{av} = 0.93T_n$, respectively $(r = \frac{T_{av}}{T_n} = 1.19)$, if the wind turbine's normal torque $T_n = 240\ Nm$ is accepted. The importance of the values presented in Fig. 2 for the torques $T_{av}.T_n$, and other quantities. Then, Equation will contain the following expression.

$$\boldsymbol{T = C_{d1}F[hC(b + C/2)} \qquad \textbf{(12)}$$

For frames vane form wind turbines, the schematic Fig. 2 and Table 1 according to illustrate energy fluctuations that may be mathematically estimated using the following formula: where the wind turbines' r coefficients are 0.93 for the three and 1.19 for the four frames. A four-frame wind turbine produces about 27 percent more torque than a three-frame turbine.

$\delta = \frac{T_{max}-T_{min}}{T_{max}} \times 100\% = \frac{320-240}{320} \times 100\% =$ 25%

$\delta = \frac{240-195}{240} \times 100\% = 19\%$

The four frames turbine and the three frames one. The torque fluctuation of the four frame turbine is 6% larger than that of the three frame turbine. The power produced by the quartet of vane kind air turbine is produced by using the existing Equation.

$P = 1l2\ A \times\ \rho\ \times V^3 \times \lambda\ = 1l2\ \times 1.25 \times\ 2.83 \times 10^3 \times 0.3 = 531\text{W}$

where A is the combined maximum active area of two acting vanes and equals $A = \frac{4}{2} \times C \times h \times cos45^{\circ} = 2.83\ m^3$. With $P = 572\ and\ 531\ W$, respectively, and $C_{d1} = 0.8\ and\ C_{d2} = 0.5$ for Eq. (11), These equations get similar results for the power values produced by the four frame turbines. With a 7% difference, the results of the two theoretical approaches are essentially equal.

5.VANE-TYPE TURBINES ARE TESTED IN AN EXPERIMENTAL WIND TUNNEL.

The wind turbine test's objective is to validate the design's performance capability, collect actual data for comparison with theoretical predictions, and assess the effectiveness of product testing. The dynamo of bicycle Golden Model Cat 6V, 8P-5, and 3W with vane-type air turbine approach mounted on, it is situated in the centre of the measured area for the wind tunnel. Wind speeds of $5\ m/s\ to\ 30\ m/s$ are frequently used. We used a version HV935 TF tool INC electronic anemometer to test the wind velocity. To quantify the angular velocity for the shaft of air turbine, a sheet of white paper with a reflecting surface was attached to a tachometer of the Compact Instrumentation Advent Tachopole type. Experimental data analysis demonstrates that four vanes are faster than three. In both test configurations, with and without a dynamo connected to the wind turbine, the scenario takes place. The results established the theoretical claim that a four-frame wind turbine is more efficient than a three-frame one Fig. 4. When the shaft of a turbine is linked to the dynamo, a two types of turbines' revolutions per second decrease by $0.6\ to\ 0.7$. However, the dynamo was utilized whenever the wind velocity passed $12\ m/s$ since the rotational area of the turbine vanes did not allow the turbine to rotate steadily, producing unstable electricity.

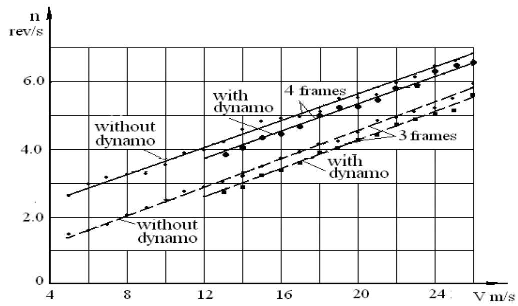

Fig. 3 Number of Shaft Revolutions Per Minute and The Wind Speed.

Fig. 3 can be used to compute the efficacy coefficient, drug coefficient, and performance of vane-kind wind turbines. The bearing efficiency is given by the equation $N_b = 0.998$ and the coefficient of performance is calculated using the following equation: $N_b\ C_p = V_t/V$, where $V_t = 2\pi(b+c)n. b$ and c are the geometrical parameters of the turbine Fig. 2(a), n is the number of shaft movements, and V is the velocity of the wind in the tunnel Fig. 3. Fig. 4 displays the results of the efficiency coefficient C_p calculations for vane-type wind turbines. The performance coefficients for turbines with four and three frames differ and decrease as wind speed increases, as seen in the following image. At the low wind speed ($V = 5.0$ to $10.0\ m/s$), the performance coefficient of four frame turbines is about twice as high as three frame turbines. For vane-type turbines, this information is essential. Vane turbines work better when the wind velocity is little value, according to averages of the natural magnitudes of wind speed that have been scientifically proven [2]. This discovery reveals other advantageous traits of vane turbines that call for further research.

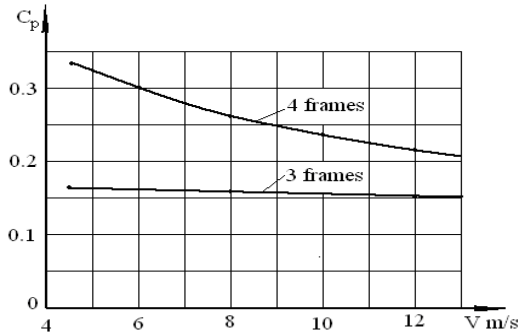

Fig. 4 Coefficient of Performance Vs the Wind Velocity.

The drug factor evaluated using equation $C_p = F/A$ where is the wind pressure power, A is acting space of the vanes and $V = \pi\, d\, n/(1000 \times 60)$ is actual tangential speed of the vane of turbine, $d = 2(b + c/2)\ (mm)$ is diameter of the wind pressure force used, $n\ (rev/s)$ is the plenty of revolution of the shaft. more of the earlier identified factors. Fig. 5 displays the outcomes of drug coefficient C_d estimates for vane form wind turbines. The drug factor varies between four and three frame turbines and increases when wind speed increases, as seen in the diagram.

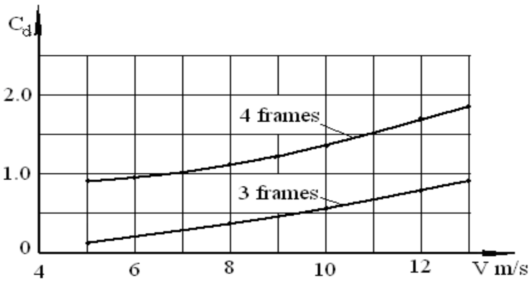

Fig. 5 Comparing the effects of drugs and wind speed.

Using the equation $C_p \times C_d \times N_g \times N_b$, Eq. (1) the results of the wind turbine efficiency estimate are displayed in Fig. 6, along with the average statistical range of the wind speed. The efficiency parameters for wind turbines are shown in Figs 4 and 5, assuming that $N_g = 0.8$ and $N_b = 0.998$ are acceptable.

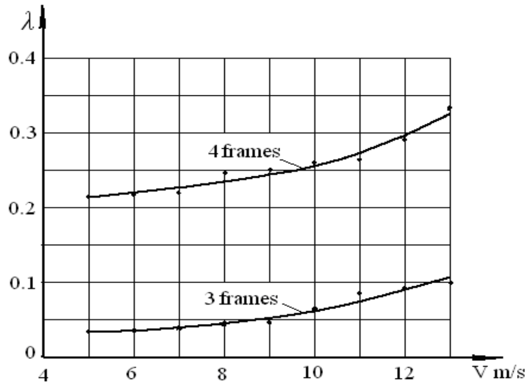

Fig. 6 Performance of Wind Turbines of the Vane Type in Relation to Wind Speed.

The vane-style wind turbine's theoretical power output, as calculated by equation:

$P_{th} = (0.5)A \times C_d \times \rho \times r \times V^3 = 0.5 \times 1.25 \times 1.16 \times 0.05 \times 0.06 \times 8^3 = 1.11\ W$

with $V = 8\ m/s$ of wind speed and the other parameters specified above. Using Eqs. (2)-(12) as well as the schematics in Figs. 3, 4, and 5, absolute power is calculated.

$P_{\alpha c} = T\omega = 0.5\ C_d \times \rho \times r \times V^2(b + C/2) \times 2\pi \times n = 0.5 \times 1.15 \times 1.25 \times 1.19 \times 0.003 \times 8^2 \times 2\pi \times 3.3 = 0.256\ W$

where $r = 1.19$ is the torque correction factor for the four frame turbine Eq. (12), n = 3.3 rev/s is the number of turbine rotations accepted from Fig. 4, $\omega = 2n/60$ is angular velocity, $C_{d1} = 1.15$ is the acceptable drug factor Fig. 6, and other parameters as previously specified. When the previously indicated characteristics are present, vane form wind turbine performance is presented by using $\lambda = P_{\alpha c}/P_{th}$ for the given dimensions and wind velocity $V = 8\ m/s$, obtaining $\lambda = 0.256/1.11 = 0.23$. The turbine with flat vanes of the vane type that was tested. However, it is ease to build the structure so that the crevices created by the vanes permit to an improve in the drag coefficient ($C_d = 1.6 \ldots 2.3$), or the power produced of the vane type turbines, as well as an increase in $C_{dp} = 0.4 \ldots 0.5$ and the turbine performance ($\lambda = 0.3 - 0.5$). Findings allow us to conclude that further research is necessary and that vane type wind turbines have a strong chance of producing more electricity than existing wind turbines."

6.FINDING AND DISCUSSIONS

Based on experiment data, the outcomes are consistent with the theoretical approach Eq. (12). Four-frame wind turbines are more highly efficient than three-frame turbines. This is so that more wind energy may be captured by the surface area of wind turbines with four frames. The wind turbine's rotational speed shows a modest drop when the wind speed is the same with and without the dynamo. In a wind tunnel, both test models were exposed to the same wind speed. The results show that as wind speed grows the drug factor increases and the performance coefficient falls. Even in light winds, vane-type turbines display amazing efficiency. Despite the little wind velocity, the specific kind of air turbine has strong technical characteristics and can be used to generate power more effectively. By altering the frames' form vane type turbines' performance can be greatly boosted, wherein can produce the vanes crevice and improve the drug coefficient. The vertical portions of the frames could be made to look like Darriues-style wind turbines, increasing the output and efficiency of the vane turbine. New data on the drag factor and efficiency coefficient that may be used in computational models was obtained from the tests of the vane type turbine in the wind tunnel. The recommended vane turbine is extremely economical to produce and may be built with cheap components. There are no restrictions on how the vane turbine can run. When there is high velocity of wind, it is feasible to build vane turbine with a smaller amount functioning vanes. The propensity for the vanes to flip due to the force of the wind can be prevent with ease beneficial measures.

7.CONCLUSIONS

The novel vane kind wind turbine, which offers a number of benefits, can address the issue of rising wind energy demand. The excellent efficiency of the vane kind air turbine allows for the growth of the surface region and drug factor of vanes, which can increase output power. The novel vane kind of wind turbine can compete with existing wind turbine designs and has all the benefits of both vertical as well as horizontal turbine models, especially when wind is blowing slowly. The innovative turbine has an uncomplicated design and can be produced using simple tools and low-cost components. It is feasible to create a new turbine that can run under any wind condition.

Future research should simulate the operation of wind turbines mathematically using computational fluid dynamics and validating it with actual tests in a wind tunnel. Research on the most effective new turbine design is also necessary (power as a function of the vanes' geometry, the weight of turbine, its aerodynamic form, the wind velocity, etc.). Reliable data for the design of a vane type wind turbine can be obtained by examining the turbine in a wind tunnel and modifying the mathematical model.

ACKNOWLEDGEMENTS

In a research paper about the effects of climate change, the acknowledgment section might include thanks to the scientists who provided data and expertise, the funding agencies that supported the research, and the participants who agreed to be interviewed or observed. By reviewing and editing this section, the author can ensure that no one is accidentally left out and that all contributors are properly recognized. The authors are very grateful to the University of Mosul, College of Petroleum and Mining Engineering, Mosul, Iraq, for their support, which helped to improve the quality of this work.

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