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A SCIENTIFIC STUDY ON ANGULAR TORQUE AND ITS RELATIONSHIP TO THE MECHANICAL PROPERTIES OF TURBINE BLADES

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Abstract

The general trend now in all countries of the world and all sectors is to achieve sustainability. One of how this sustainability can be achieved is to develop and improve the properties of raw materials, and in the field of turbine-powered power plants, sustainability must be achieved in light of the global crisis facing the energy sector, in this study, which aims to study the effect of angular torque on Mechanical properties of turbine blades, so that we can develop and improve the properties of those blades Angular torque is very important in turbine blades because it drives the turbine to rotate. Angular torque results from a force acting on a rotating body. In the case of turbine blades, the force of the gas flow produces angular torque. Turbine blades typically consist of thin, curved metal sheets. When gas passes through the blades, it exerts a force on the blades. This force forces the blades to rotate around its axis the greater the angular torque it produces. The greater the angular torque, the faster the turbine rotates. This study provides a mathematical model to calculate the angular torque resulting from turbine blades. The model was used to study the effect of various factors on the angular torque, including the gas flow speed, the shape of the blades, and their mechanical properties. Then, a simulation was run using the

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ANSYS program to determine the relationship between the angular torque and the mechanical properties of the turbine blades. The results indicated a large deviation of the flexible blades and unstable rotation of the rotating blade systems, due to the coupling effect of rotation and vibration, where the mechanical properties of mass/inertia distributions, damping, and stiffness are related to changes in rotational speed and local deformation in rotor blade systems, thus, the harmonic balance must occur and the mechanical properties of the blades be improved.

Keywords: Angular Torque, Mechanical Properties, Raw Materials, Turbine blades, mathematical model, flow speed, ANSYS, rotation and vibration, harmonic balance.

دراسة علمية حول العزم الزاوي وعلاقته بالخصائص الميكانيكية لشفرات التوربينات

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الملخص

الاتجاه العام في جميع دول العالم وفي كافة القطاعات هو تحقيق الاستدامة، حيث يمكن تحقيق الاستدامة بتطوير وتحسين خصائص المواد الخام، وبالتالي من الضروري تحقيق الاستدامة في ظل الأزمة العالمية التي يواجهها قطاع الطاقة وخاصة في مجال محطات توليد الطاقة التي تعمل بنظام التوربينات.

تهدف هذه الورقة إلى دراسة تأثير العزم الزاوي على الخواص الميكانيكية لشفرات التوربينات، حيث يعتبر العزم الزاوي مهم جداً في لدفع التوربين إلى الدوران وبالتالي إمكانية تطوير وتحسين خواص تلك الشفرات. ينتج عزم الدوران الزاوي نتيجة القوة المؤثرة

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على أي جسم يدوار كما في حالة ريش التوربينات فان قوة تدفق الغاز تولد عزماً زاويا، تتكون شفرات التوربينات من صفائح معدنية رفيعة ومنحنية، وعندما يمر الغاز عبرها، فإنه يؤثر بقوة عليها تجبرها على الدوران حول محورها، فكلما زاد عزم الدوران الذي تنتجه، كلما زاد العزم الزاوي وبالتالي زادت سرعة دوران التوربين. تقدم هذه الدراسة نموذجا رياضيا لحساب العزم الزاوي الناتج عن دوران شفرات التوربين.

النموذج استخدام لدراسة تأثير عدة عوامل على عزم الدوران الزاوي من ضمنها سرعة تدفق الغاز، وشكل ونوع الشفرات، وخواصها الميكانيكية. بعدها تم إجراء محاكاة باستخدام برنامج ANSYS لتحديد العلاقة بين عزم الدوران الزاوي والخواص الميكانيكية لشفرات التوربين. وقد بينت النتائج انحراف كبير في الشفرات المرنة، ودوران غير منتظم لأنظمة الشفرات الدوارة نظرًا لتأثير المزدوج للدوران والاهتزاز، حيث ترتبط الخواص الميكانيكية لتوزيع الكتلة، القصور الذاتي، التخميد، والصلابة بالتغير في سرعة الدوران والتشوه في أنظمة شفرات الدوار، وبالتالي يجب خلق التوازن التوافقي وتتغير الخواص الميكانيكية للشفرات الدوارة وتحسين الشفرات.

الكلمات الدالة: العزم الزاوي، الخواص الميكانيكية، المواد الخام، ريش التوربين، النموذج الرياضي، سرعة التدفق، ANSYS، الدوران والاهتزاز، التوازن التوافقي.

1. Introduction

Angular torque is an important physical quantity and makes a fundamental difference to many physical phenomena and industrial applications. It’s also a result of the way things move energy-wise. It is a Macroscopic production process. It caused an absolute Industrial Revolution in that close world we could only feel but never quite reach through technology up to that time or just for once saw. “Angular torque is the driving force behind any object that revolves, from a tiny gear to giant wind turbine blades." Determines the rate of change in angular velocity, causing objects to turn faster or slower [1]."Energy Transfer Mechanism: It helps to pass energy on from one object to another using rotation. For example, the

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torque generated by an engine is transmitted through a car's transmission to its driving wheels, thus making sure it goes forward. It is applied in numerous practical and engineering fields. Instead of simple electronics, there are many uses borrowed from the industry. From tools like wrenches, screwdrivers, hammers, and others to elaborate machines such as motors, pumps, robots, etc., they all depend on the angular torque in their operation. It happens that angular torque changes the direction of movement [2]. As the shaft turns, so do gears and other components, leading eventually (as power gets passed down through domestic animals until it finally produces something useful: wind turbines, hydroelectric turbines (and to a lesser extent). Even aircraft engines use the principle of angular torque to convert the kinetic energy in a flowing fluid (wind or water) into rotational energy. This energy is then used by generators or heaters, depending on whether it generates electricity or heat [3]. Turbine blades are made of thin, curved metal sheets. When gas passes through those blades, it exerts a force on the blades. This force drives the blades to rotate around their axis. The stronger the gas, the greater the angular torque it produces. The greater the angular torque, the faster the turbine rotates. The angular torque generated by the turbine blades is used to power a variety of machines, including electricity generators, ships, and aircraft. One of the most important factors affecting the angular torque in the turbine blades is the speed of gas flow: the greater The speed of the gas flow, the greater the angular torque it produces, the cross-sectional area of the gas: the greater the cross-sectional area of the gas, the greater the angular torque it produces, the shape and material of the blades, as the shape of the blades affects the way the gas interacts with the blades, which affects In turn on the angular torque they produce, higher-strength materials allow stronger blades to be created, resulting in greater angular torque. Some of the factors that affect the angular torque in turbine blades are as follows: H. Blades shape: Turbine blade manufacturers use a variety of techniques to improve angular torque in turbine blades. These technologies include the use of high-strength materials: Using

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Improved Designs: Improved blade design can improve the way gas interacts with the blades, which in turn increases angular torque. Improvements in turbine blade angular torque led to increased efficiency in a variety of applications [4]. Here are some specific examples of how angular torque is used in turbine blades: Wind Turbines: Wind turbines depend on the power of the wind to operate.

When air passes through turbine blades, it exerts a force on the blades, causing them to rotate. The angular torque generated by the turbine blades produces electricity. Higher-strength materials allow for the creation of stronger blades, resulting in greater angular torque [5]. As mentioned previously, turbine blades consist of thin, curved metal sheets. These blades are exposed to enormous forces during operation, including bending, compression, and tension forces [6]. Therefore, turbine blades must have excellent mechanical properties, especially flexibility, durability, and strength. Turbine blades must withstand force, whereas turbine blades must be strong enough to withstand bending, compressive, and tensile forces. Hardness, where turbine blades must be hard enough to resist deformations. Hardness. Turbine blades must be hard enough to resist wear. The mechanical properties of turbine blades play an important role in determining their angular stability [7]. The angular stability of turbine blades is defined as their ability to maintain their rotation without vibration or deflection [8, 9].The heavier the turbine blades, the more difficult it is to initiate and stabilize their rotation, and the greater their bending rigidity. It is difficult to bend the blades, as excessive bending can lead to a loss of angular stability. The center of gravity of the turbine blades should be as close to the axis of rotation as possible to improve their stability, turbine blades must have excellent mechanical properties to ensure their angular stability [10].To ensure this stability, the mechanical properties of turbine blades must be improved through the use of materials that improve those properties. For, example, composite materials, such as carbon fiber, can be used to manufacture strong and rigid turbine blades. And resistance to corrosion, or through the

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mechanical properties of turbine blades can also be improved through engineering design, and what is meant by angular stability is the ability of the body to maintain its rotation without vibration or deflection, or it can be defined as rotational stability or rotational stability.

Turbine blades are typically made of strong, durable, and corrosion-resistant materials, such as steel. Steel is one of the most common materials for manufacturing turbine blades. It is strong, durable, and resistant to corrosion, but can be heavy. The blades can also be made from aluminium alloys which are lighter than steel, allowing lighter turbine blades to be manufactured [11, 12, 13]. However, they are less strong than steel and can be more susceptible to corrosion. From Composite Materials: Composite materials, such as carbon fiber or glass fiber, can be used to manufacture strong, durable, and lightweight turbine blades. However, composite materials can be more expensive than metals. There are many methods for manufacturing blades, including traditional manufacturing methods, where turbine blades can be made using a variety of traditional methods, such as casting, forming, or cutting, or advanced manufacturing methods, where advanced manufacturing methods, such as 3D printing, can also be used to make turbine blades, and it depends The choice of material and method for making turbine blades depends on a variety of factors, including the application in which they will be used, the cost of production and manufacture, and the availability of manufacturing materials.

The importance of studying angular torque and its relationship to the mechanical properties of turbine blades is that it helps to develop sustainability. strategies From that an achieve economic standpoint, wind, gas, and aircraft turbines play an important role in the global economy. Improvements in the performance of these machines can save energy and reduce costs [12]. From an environmental standpoint, improvements in the performance of wind, gas turbines, and aircraft can help reduce carbon emissions [13]. From a scientific standpoint, studying angular torque and its relationship to the mechanical properties of turbine blades can provide a better

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understanding of how the work of these machines. This could lead to new technologies for manufacturing and operating more efficient turbines [13]. The study aims to understand the relationship between angular torque and the mechanical properties of turbine blades, in which the mechanical properties of turbine blades play an important role in determining their angular stability and efficiency. By understanding this relationship, researchers can develop techniques to improve the properties of turbine blades, leading to more efficient and stable turbines. Improvements in turbine blade manufacturing can produce lighter, stronger, and more corrosion-resistant blades. This could lead to more efficient and economical turbines [14]. The methodology used here is descriptive, simulation, and analysis, where a mathematical model will be created to calculate the angular torque generated by the turbine blades. The model was used to study the effect of various factors on the angular torque, including the gas flow velocity, the shape of the blades, and their mechanical properties. Then, a simulation was performed using ANSYS software to determine the relationship between the angular torque and the mechanical properties of the turbine blades. The results indicated significant deflection of the flexible blades and unstable rotation of the rotor blade systems [15]. Due to the effect of rotation and vibration coupling, where the mechanical properties of mass/inertia, damping, and stiffness distributions are related to changes in rotational speed and local deformation in rotor blade systems, harmonic equilibrium should occur and the mechanical properties of the blades improve [16].

2. Overview of the literature review and analysis

Research literature indicates that there is a close relationship between the mechanical properties of turbine blades and their angular torque. In general, increasing the mechanical properties of turbine blades leads to increased angular torque [17]. The factors that affect the relationship between mechanical properties and angular torque are the type of material, as some materials have better mechanical properties than others [18]. For example, composite materials, such as carbon fiber, have better mechanical properties

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than traditional metals, such as steel. Blade Design Blade design can also affect mechanical properties and angular torque. For example, blades with greater curvature can result in increased hardness and hardness, resulting in increased angular torque. Operating Conditions Operating conditions can also affect the relationship between mechanical properties and angular torque [19].In this section, we will explain through presentation and analysis the previous studies that dealt with the topic, and present the most important results they reached.

In a study by [20] they pointed out that their study is to realize that in 2033, 200 thousand tons of wind turbine blades will have to be disposed of worldwide. The aim is to compare the sustainability of different methods of dealing with this waste: landfilling, incineration with heat recovery; and joint processing in cement kilns; The method is to use the United Nations Sustainable Development Goals (SDGs) as a rationale; To achieve this development, turbine blades must be developed in terms of mechanical properties to improve the relationship between angular torque and turbine fins. This has been confirmed by many studies, including a study (by the National Academies of Sciences). in which he pointed out the necessity of using modern technology to improve the mechanical properties of turbine blades to improve angular rotation, In their study [21] on angular rotation optimization, to facilitate accurate estimation of the current angle required to achieve maximum efficiency of an internal permanent magnet synchronous motor (IPMSM), they proposed improved mathematical models for torque and system efficiency. First, an improved torque and efficiency calculation process was developed that incorporates the effects of parameter variations, such as inductance, stator resistance, simultaneous PM flux coupling, and inverter and motor losses, using a combination of specific analytical models and practical experiments, and the results indicate an improvement in angular rotation despite The models were modern, as they were able to determine the relationship between the

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temperatures of the stator and the rotor and their relationship to the properties of the turbine blades.

In a study [22] on the factors affecting the relationship between angular torque, they pointed out that after the rapid development occurred in turbine technology, especially after World War II and the oil crisis in 1973. Development continued during the twentieth century, which led to the emergence of turbines of a larger size and technology. More advanced. Today, electricity generation, energy problems, and the development of the energy field have become linked to improving and developing the relationship between angular torque, and by knowing the factors affecting the relationship, it can be developed. Among these factors are the cost of manufacturing, raw materials, improving the properties of those materials, and engineering design methods. This is the case. Many other studies have confirmed this, such as the study [23]. which included The effect of fire engine concentration on the mechanical properties of turbine blades has a direct effect on angular torque.

in a study by [24] To accurately predict and optimize the behavior of wind turbine blades, three aspects related to the reliability and strength of the rotor blades were studied. : (1) establishment methods for experimental determination of reliable material properties employed in designing wind turbine blade verifying the blades, design experimentally models. (2) Developing prediction models for life expectancy blades, residual strength, and failure probabilities and (3) analyzing the influence of microstructure on its strength using Organics developed computer Systems, programs strengthening materials through optimization to microstructure effects. The effect of test parameters on the bearing Literary Requirements Interface properties, as well as other factors related to the strength and lifespan of wind turbine blade materials, has been studied and analyzed to improve the performance and durability of these critical components in wind energy systems.

3. The method and methodology

We will use scientific, analytical, and simulation methodology to obtain the results of the effect of angular torque on the mechanical properties of turbine shafts and the relationship between improving mechanical properties and improving angular torque. The methodology here is descriptive, involving mathematical modeling and simulation. The methodology and method were carried out according to a set of basic steps described in the practical framework shown in figure (1).

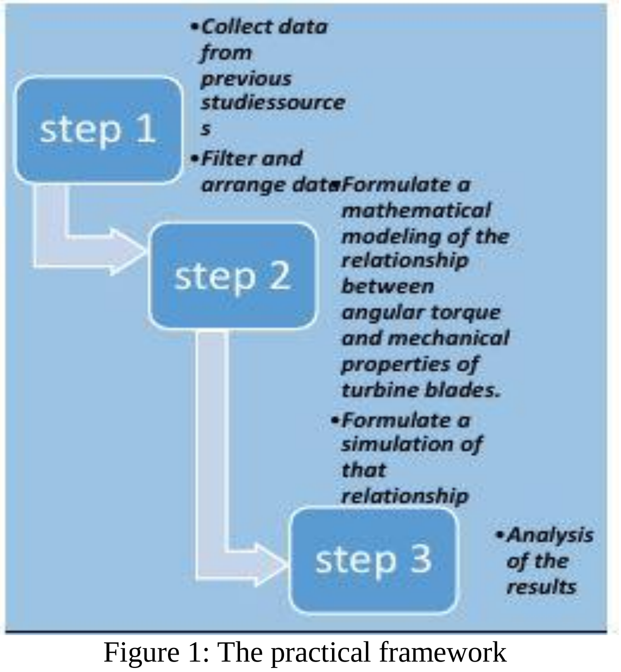

Figure 1: The practical framework
Source: research results

3.1. Procedures and method

Studied using micro-mechanical finite element simulations. A practical and simplified analysis of all the presented studies highlights the crucial importance of the relationship between angular torque and the mechanical properties of turbine blades, making it one of the key factors in improving angular rotation and stability.

The goal is to create a reliable database and establish solid parameters based on previous research and studies, and develop a modeling formulation**.**

The relationship between angular torque and mechanical properties of turbine blades can be formulated by the following general formula:

$$\boldsymbol{T} = \boldsymbol{f}(\boldsymbol{K}, \boldsymbol{S}, \boldsymbol{E})$$

Where:

T: angular torque

K: stiffness (instead of "hardness") : Hardness generally refers to resistance to indentation, while stiffness is a better term for describing the material's ability to resist deformation under load.

S: strength (instead of "durability") : Durability refers to the lifespan of a material, whereas strength describes its ability to withstand applied forces without failure.

E: elasticity (instead of "flexibility") : Flexibility can be somewhat synonymous with elasticity, but elasticity is a more precise term in mechanics that refers to the ability of a material to return to its original shape after deformation.

The relationship between angular torque (T) and the stiffness (K) of turbine blades, considering the blade radius (r) and angular velocity (Ω), can be expressed as:

$$\boldsymbol{T} = \boldsymbol{K} * \boldsymbol{r} * \boldsymbol{\Omega}^2$$

Where:

T: Angular torque

K: Stiffness of the turbine blade

r: blade radius

Ω: angular velocity

This equation illustrates how angular torque is influenced by the stiffness of the blade, its radius, and the square of the angular velocity. As either r or Ω increases, the angular torque T will increase, assuming K remains constant.

In general, the relationship between angular torque and mechanical properties of turbine blades can be expressed as follows:

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$$T = f(K,S,E) = K * f(r,\Omega) * f(S,E)$$

Where:

f(r,Ω): A function that depends on the blade radius and angular velocity.

f(S,E): A function that depends on strength and elasticity modulus.

General formula: ***f(S,E)*** represents the combined influence of strength and elasticity modulus.

The function ***f(S,E)*** can be formulated as follows:

$$f(S,E) = a * S^b * E^c$$

Where:

a : constant of proportionality

b : impact factor of strength (or toughness)

c : impact coefficient of elasticity

The coefficients can be obtained from laboratory results or previous research to formulate the second-degree relationship, use numerical approximation methods, and formulate them in the Python language.

The function f(r, Ω) can be formulated as follows:

$$f(r,\Omega) = a * r^b * \Omega^c$$

Where:

a: constant of proportionality

b: impact coefficient of blade radius

c: Impact coefficient for angular velocity

Conduct a Simulation

Computer modeling software can be used to create a 3D model of the turbine blade. This model can then be used to calculate the expected angular moments, taking into account the material properties and operating conditions.

4. Results and discussion

According to Figure (2), the relationship between angular torque stress and stiffness is clear through the simulation: the more rigid the turbine blade, the greater its ability to withstand angular torque

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stress. The angular moment stress is the force applied to the turbine blade that bends it, resulting from the stream of hot gases. Furthermore, according to Figure (2), it is evident that the relationship between angular moment stress and deformation in the turbine blades is a direct one. The greater the angular moment stress, the greater the deformation in the turbine blade [25, 26].

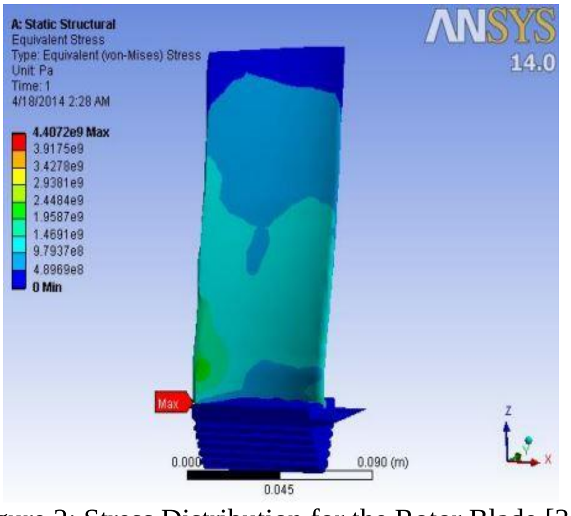

Figure 2: Stress Distribution for the Rotor Blade [31]

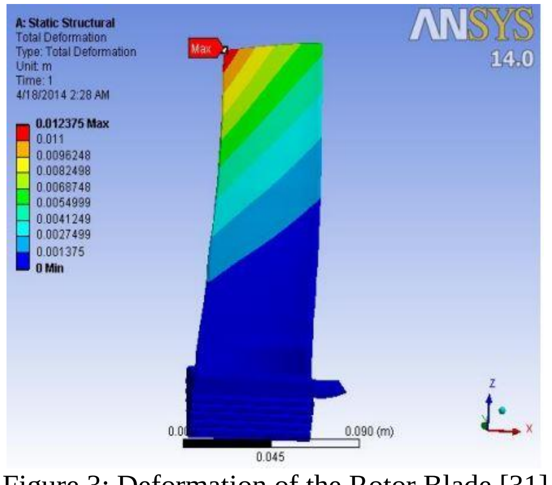

Figure 3: Deformation of the Rotor Blade [31]

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To provide you with an equation for the relationship between angular moment stress and deformation in turbine blades, it typically depends on the material properties and the geometry of the blade (Figure (3)). A common formulation in mechanics is the following:

$$\boldsymbol{\sigma} = \frac{\boldsymbol{M}}{\boldsymbol{I}} * \boldsymbol{r}$$

Where:

$\boldsymbol{\sigma}$: is the stress (angular moment stress) in the turbine blade,

M : is the applied moment (torque),

I : is the moment of inertia of the blade's cross-section,

r : is the distance from the center of rotation to the point where the stress is being calculated.

Alternatively, if you are looking for an expression relating stress and deformation (strain) based on Hooke's Law, it can be expressed as:

$$\boldsymbol{\sigma} = \boldsymbol{E} * \boldsymbol{\epsilon}$$

Where:
E : is the modulus of elasticity,
ε : is the strain (deformation per unit length).
The flexibility in the turbine blades also helps stabilize the angular rotation and thus prevents the blades from deforming [27]. According to Figure (4), as the speed increases, the force applied to the body is directly proportional to the angular velocity. This means that the torque will also be directly proportional to the angular velocity, and thus the torque stress is directly proportional to the speed. We notice an increase in the stress when the number of turns

of the blade increases from 10,000 revolutions to 100,000 revolutions. The stress increases by 20%.

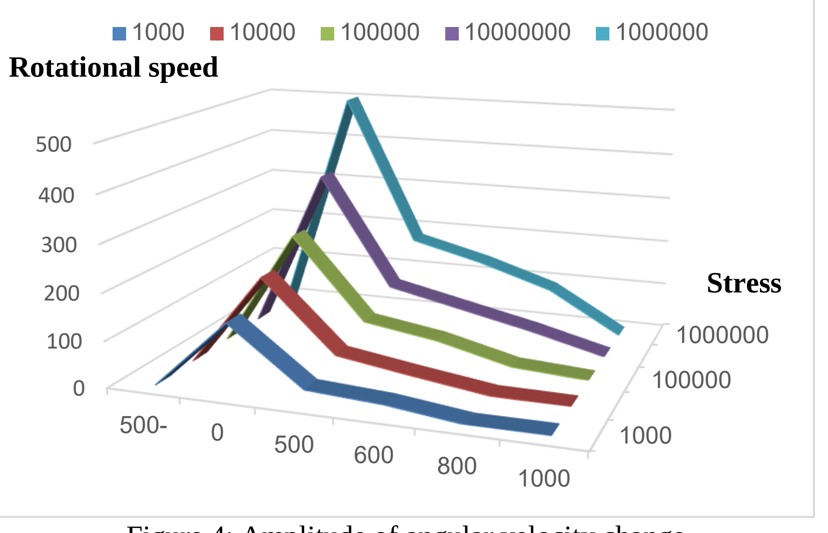

Figure 4: Amplitude of angular velocity change

Source: research results

Young's modulus is a property of the material that determines its hardness, as it indicates the amount of force that can cause the material to bend or deform. There are two types of deformation: elastic deformation, which is a change in the shape of the material that can be reversed. When the stress ends, elastic deformation returns to its original shape, or permanent deformation, which means a change in the shape of the matter that cannot be reversed. When the stress is over, permanent deformation remains in the material. In the case of turbine blades, deformation is a change in the shape of the turbine blade as a result of the application of angular moment stress. Deformation can cause the turbine blade to bend or even break [28]. According to Table (1) and Figure (6), it indicates that as the rotational speed increases, the angular torque increases when the diameter of the blade and its hardness factor remain constant. Therefore, stiffness must be increased and improved so

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that we can enhance the power resulting from the angular torque, as the relationship between angular velocity and constant torque is a direct relationship. The greater the angular velocity, the greater the torque.

The relationship between angular velocity and torque can be expressed by the following equation:

$$T = I * \omega$$

Table 1: The relationship between stiffness and angular moment

Angular moment n*m	Angular velocity r p m
20000000000	1000
5E+11	5000
2E+12	10000
4.5E+12	15000
8E+12	20000
1.8E+13	30000

Source: research results

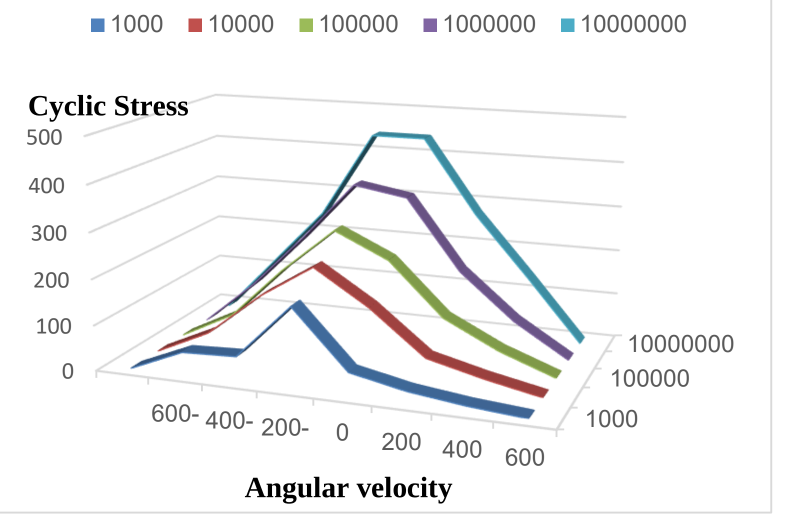

Figure 5 : Cyclic stress with change in angular velocity
Source: research results

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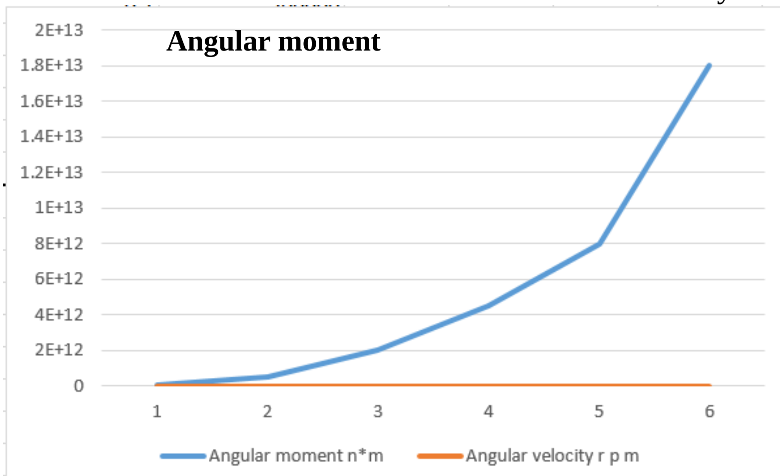
According to Figure (5), as the speed increases, the force applied to the body is directly proportional to the angular velocity. The cyclic stress on the turbine blade increases. The stress increases by 25%.



Angular velocity

Figure 1: The relationship between stiffness and angular moment

Source: research results

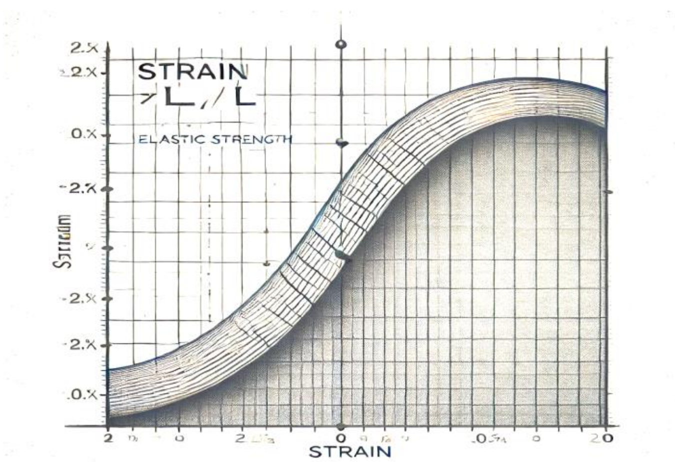


Figure 7: The relationship between stress and strain in metals

Source: research results

According to Figure (7), it is clear that flexibility and rigidity are closely related, but they are not synonymous. A material can be flexible but not rigid, and it can be rigid but not flexible. In general, more flexible materials tend to be less rigid. For example, rubber is very flexible but not very rigid, as stiffer materials tend to be less flexible. For example, steel is very hard but not very flexible.

5. Conclusions

To achieve sustainability in the field of energy, especially related to turbines, it is necessary to improve the relationship between the angular torque and the mechanical properties of the turbine blades Improvement processes should not be limited to mechanical properties only, but rather include improving physical properties as well. It becomes clear the importance of the relationship between angular torque and the mechanical properties of turbine blades, and that it is one of the most important factors related to improving angular rotation and stability. Hardness is the resistance of a material to deformation. Stiffness determines the amount of force that can cause a turbine blade to bend. In general, the stiffer a turbine blade is, the greater its ability to withstand angular moment stress without collapsing. This is necessary to ensure that the turbine blades remain intact during operation [29].

Deformation can cause the turbine blade to bend or even break. Therefore, the stiffness of the turbine blades must be improved to avoid any deformation that ultimately leads to the blades breaking [27]. the rotational speed increases, the angular torque increases when the diameter of the blade and its hardness factor remain constant. Therefore, the hardness must be increased and improved so that we can increase the power resulting from the angular torque, and the flexibility in the blades increases. The turbines help stabilize the angular rotation and thus prevent the blades from deforming [28].

The relationship between elasticity and hardness depends on the properties of the material, such as the type of material, its composition, and temperature [30].

Declaration of competing interest

I declare that there is no competing interest with any other authors and that there is no interest or benefit that influenced the results of the research.

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