The Effect of Pulse Magnetic Field (PMF) on Life Service of Fe-34Mn-10Al-0.76C Alloy.

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Abstract: We develop a distributed tree based data dissemination protocol called TEDD has been proposed. The proposed protocol can efficiently manage the sink mobility. The simulation is performed with the random way point mobility model. The results are compared with the existing protocols such as SUPPLE, SN-MPR and ART. It has been observed that the TEDD outperformed the above protocols, because of its unique method to handle the sink mobility.

Abstract: This paper introduces a mathematical model of fatigue life of a tidal turbine that is affected by floating thrust forces using Rainflow algorithm. The decision taken to assume that, the blade is made of Fe-34Mn-10Al-0.76C and treated using (PMF) with a voltage of 100 v. Obtained results showed that, increasing blade thickness resulted in increasing the fatigue lifetime. Both of the fixation depth of the tidal turbine hub and its operating hours had been studied as well, as three different depths (5, 10 and 15 m) and three different periods (8, 16 and 24 hrs) had been studied to investigate their effect on the fatigue service lifetime of the studied turbine. Obtained results showed that, deepening the fixation point of the tidal turbine or increasing its operating period would result in a significant reduction in the fatigue lifetime of the turbine. Hence, the blade thickness ought to be optimized according to the desired service lifetime, load to be supplied and the environmental and operating conditions of the turbine.

Keywords: Fatigue failure, Equivalent damage load, Rain flow algorithm, MATLAB, Pulse magnetic field (PMF).

1. INTRODUCTION

One of the essential merits of tidal energy is its availability. This feature has encouraged energy engineers to increase tidal power harnessing and storage such that it can entirely relied upon as one of ultimate source of electrical power. However, this can only to be achieved when its generation is cost effective. With reference to information offered by IRENA, tidal power has the capacity of providing potential sustainability level because of its high promising ability. The figure below illustrates the tidal energy distribution in the world, it is evident that; there exists a great potential of power that would contribute to a great proportion of electricity demanded by the universe if tidal energy is harnessed with a high-energy transformation ratio [1].

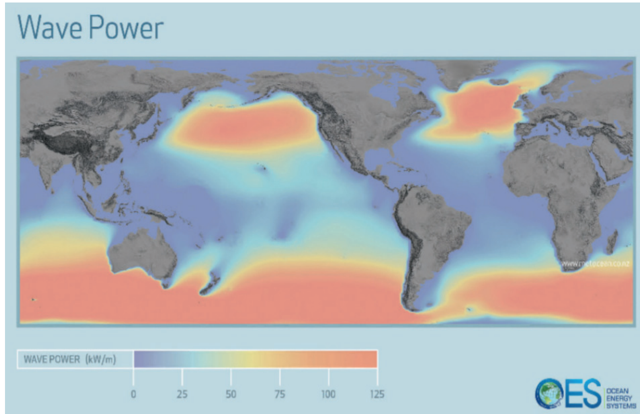

Figure 1. Tidal power distribution around the world [1].

Tidal turbines are mainly such technology that tend to generate electrical power from tides. A subsequent higher amount of tidal energy harnessed, if the displacement height of tidal wave is higher or if the speed of the tidal wave is higher. Changing climatic patterns of the tidal waves creates an unending dissipation of mechanical energy for the earth–moon relationships since it pushes water through the existing natural margins near the coastlines as well as viscous dissipation in the deep seabed when the flow is turbulent. The figure below shows a clear image of the changing climatic patterns of the wave tides and their resultant impact on the resultant tidal power. In fact, this change in the wave head is highly desirable to generate electricity, but it resulted in effecting by a cyclic loading on the turbine that considered as being the main source of fatigue [2].

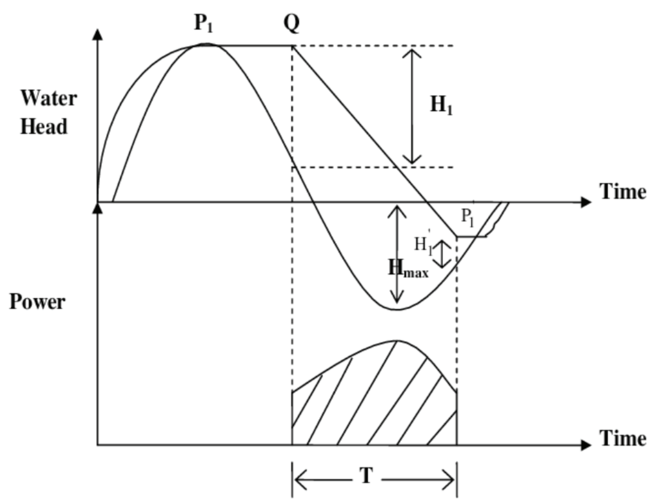

Figure 2. Effect of the water head on the tidal power [2].

Turbine blades designed such that they are able to work under extreme adverse conditions. In addition to various forces such as hydrodynamic forces that are different in terms of magnitude and direction because; they expected to affect this. Actually, knowledge on the operational conditions are necessary and ought to be put into consideration to avoid chances of mechanical failure. Varying the magnitude & direction of force executes a fatigue loading on the turbine blades fabric that causes a specific type of failure after a countable number of cycles. The number of cycles that cause failure greatly relies on the nature of material, configurational parameters, the operating conditions and the mechanical properties of the turbine [3].

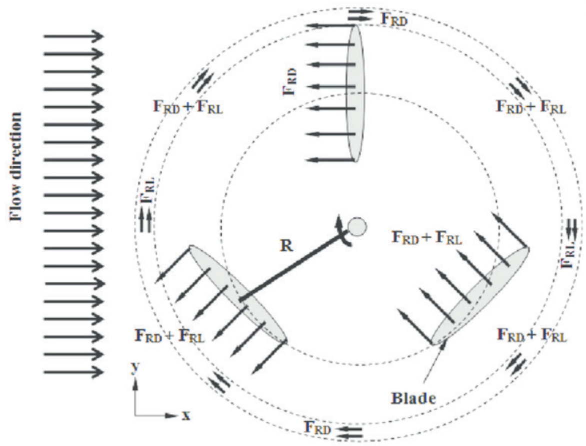

Figure 3. Hydrodynamic forces executed on a blade [3].

The conversion of kinetic energy in tidal waves to mechanical energy can be used to produce electricity using an electric generator. A tidal turbine specifically designed to operate similar to the operation of wind turbines but they are mechanically stronger to resist the great mechanical loadings that they are subjected to. The increased mechanical loadings that subjected to the relatively higher density of seawater as compared to air density. The high density of sea water increases the magnitudes of lift and drag forces as well. In addition, constructing a tidal turbine in the seabed that assumed to be affected by hostile environmental conditions that can cause failure of the blades. Scientists have directed many efforts on tidal power; this has led to invention of different types and mechanisms that enhance harnessing of tidal power at different locations and at varying depths below the seabed. The figure bellow illustrates the five major types of tidal turbines that employed to generate electrical power. Their differences are bases on their arrangements and their blade designs to fit different geographical locations [4].

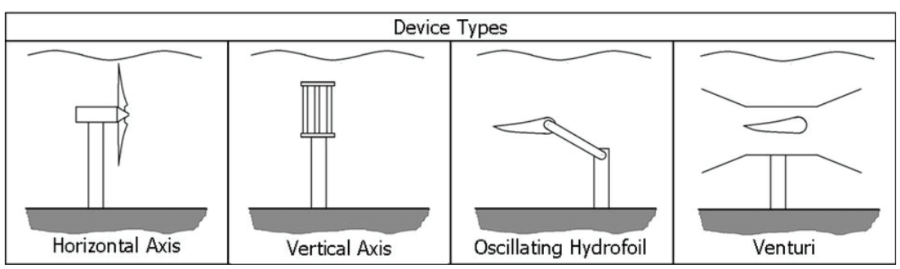

Figure 4. The four major types of tidal turbines [4].

2. LITERATURE REVIEW

The operation of a tidal turbine.

Tidal power has gained a lot of interest in the past decades; hence it is predicted to greatly contribute to the electrical power consumed globally when harnessed efficiently. The energy transformation efficiency of a tidal turbine which greatly dominated by various parameters that are so difficult to be looked into in a single research. A tidal turbine specifically constructed to transform tidal current to produce mechanical energy, which is later converter to electrical energy by employing an electric generator. Figure 5 shows a schematic representation of a tidal turbine when it operates [5].

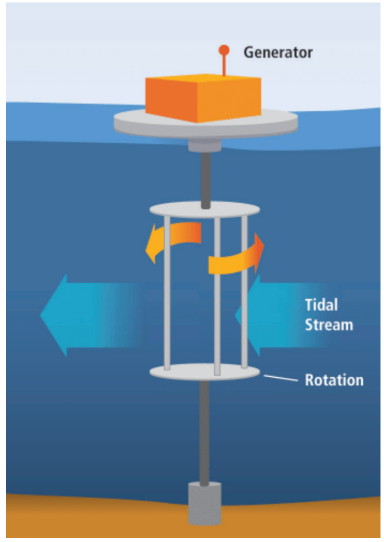

Figure 5. A schematic diagram on how a tidal turbine operates [5].

When seawater flows through the designed blade, the kinetic, pressure and potential energies possess by the water is partially converted into two major forces i.e. the drag & lift forces. For tidal turbines the lift force is prioritized and optimized since it is the major source of mechanical energy. The drag force is minimized because it is the major cause of power loss. The figure below illustrates the behaviour of a tidal blade when subjected to hydrodynamic forces [6].

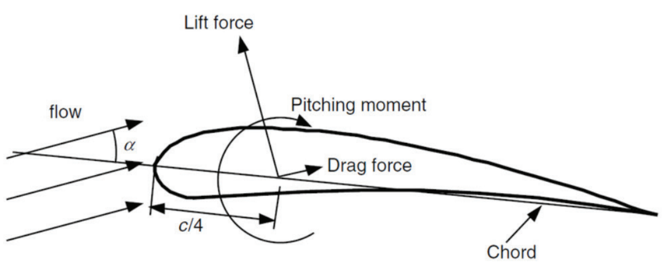

Figure 6. 2D schematic illustration of drag and lift forces executed on a tidal blade [6].

A. Fatigue failure

Fatigue causes failure in the tidal turbines; it generated because of the oscillating nature of hydrodynamic forces acting on the blades. Generally, fatigue is predicted to degrade the efficiency of energy transformation on a tidal blade, increasing cost of maintenance as well as causing fractures or damage at extreme circumstances. In addition, crevices formed on the blade surface tend to result of fatigue end up lowering the reliability of the tidal turbine together with its mechanical safety [7].

Turbine failure caused by fatigue is very common, it causes a reduction in the electrical power generated thus reducing its reliability and its economic advantages. Fatigue loading is produced because of the oscillating forces subjected as illustrated in the figure below. Such oscillating forces can be entirely reversed (a) the average stress not zero (b) or zero tensional loading (c) or zero fatigue loading. Executing any of these rotational forces is estimated to result in subjecting a fatigue loading on the blade causing a mechanical fracture to happen after a specific number of stress cycles. The set number of stress cycles greatly relies on the material features as well as several other parameters such as the highest and lowest values of executed force, the configuration of the construction, corrosion, etc. [8]

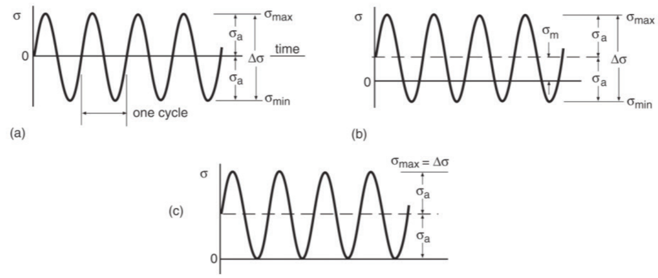

Figure 7. The major sources of fatigue loading [8].

Fatigue loading describes the ability of a fabric to resist oscillating loads for a given number of stress cycles. Fatigue loading is the major mechanical feature that should been considered in material selection. The figure below illustrates the commonly known stages of fatigue failure [9]. According to the objective of a proposed research, it is evident that; the working of a tidal turbine is estimated to have a relation to the fatigue phase. This means that, at the second phase of fatigue failure a small crack had generated. Therefore, the surface becomes rough due to presence of a cracks resulting to a weakening the structure itself (the blade) being formed downstream, this has a great influence in reducing the energy conversion ratio of the tidal turbine as well as its safe operation. Fatigue failure can be more hazardous and its impacts so harmful to the tidal turbine especially when the surface crevices grow larger to an extent of causing a mechanical fracture leading to operational and financial disastrous implications [7] and [10].

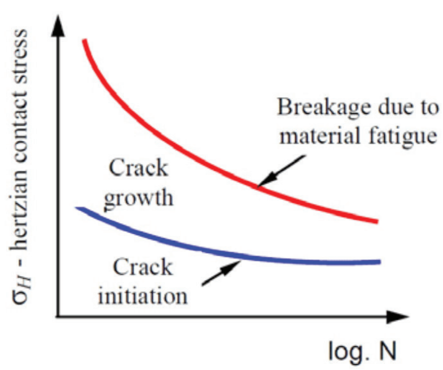

Figure 8. Phases of fatigue failure [9].

3. STEEL ALLOYS

Tidal turbines are predicted to be influenced by various parameters that should be taken into consideration at the initial stages of design so as to maximize turbine performance. For instance, the turbulence intensity of tidal waves differs as per the geographical positions of the turbine, the geographical location of the turbine should been settled on while studying the turbine ability to withstand these seasonal fluctuations. Such decisions aid design engineers in choosing a highly working blade pattern (profile) and efficient material that can offer the required level of safety. In addition, the speed of sea water greatly affects the level of drag and lift forces executed on the blade that are assumed as being the major reason of fatigue loading. Tidal turbines constructed such that they have the capacity of operating in extremely adverse conditions sustainably for a prolonged period-of-time since they are quite expensive with a long payback period. However, the main challenge of attaining the aforementioned objective is entitled to the material chosen to fulfil these conditions [11].

Material selection process should be based on operational conditions and environmental factors as well as its mechanical safety. Since the chosen material must characterised by lower density in order to lower energy losses incurred in the energy conversion process. The fabric should merited by high abundance, ease of being manufactured due to the high complexity of the profile of the blade as well as high level of reliability. Such beneficial characteristics greatly help in lowering production costs; high reliability would improve its dependency. The chosen material should be environmental friendly to avoid reduction in water quality as well as not causing death to marine creatures [12].

Many materials have shown potential performance to meet the optimum performance of tidal blades. The essential enhancement had been attained in applied metallurgical science has enabled using such alloys to be formed in complex profiles which are characterised by uncommon mechanical, physical and thermal features. Metals such as iron that has high mechanical properties had been invented greatly in the past decades, their unique operations has encouraged scientists to maximize its carbon composition to achieve the wanted mechanical performance. Many composites had tested by varying the levels of carbon contents, which enables optimizing its content according to its needed by the application. Every alloy been examined to offer a unique performance in such execution. The table below illustrates the common composites of monolithic low density [13]. Fe-34Mn-10Al-0.76C (a steel alloy), is predicted to offer a high resistance to corrosion and oxidation, this makes it the most suitable material to manufacture tidal turbines that can operate in extremely harsh environmental conditions. its unique properties brings the ability of resisting high levels of corrosion under seabed, unexpected impacts, relatively low initial cost, high energy conversion efficiency of the turbine and extended service lifetime.

Table 1. Illustration of the commonly used alloys monolithic low density steel [13].

Alloys	Targeted properties	Developers	Aimed applications	Year
Fe-13Mn-1.2C	High toughness and excellent wear resistance	Hadfield	The mining industry, cement mixers, railway switches	1882
Fe-(20–50)Mn-(3–12)Al	Good ductility and corrosion resistance	Dean and Anderson	Electrical heating elements	1943
Fe-34Mn-10Al-0.76C	Good corrosion and oxidation resistance	Ham and Cairns	Replacement of Cr-Ni stainless steels	1958
Fe-(25–30)Mn-(8–10)Al-1C	Precipitation hardening and good oxidation resistance	Kayak	Springs, gears, landing gears	1969
Fe-30Mn-5Al-0.3C-Nb	High strength and elongation at lower temperatures	Kim et al.	Cryogenic structures	1985
Fe–(18–28)Mn–(9–12)Al–(0.7–1.2)C	Low weight, high crash worthiness	Frommeyer and Brüx	Automotive body frames	2000

With regards to the steel alloy, the presence of iron guarantees great mechanical properties that fit with the targeted application (tidal turbine), the presence of magnesium aids in improving the stated mechanical properties, aluminium in this alloy helps in lowering the density of the blades thus lowering the designed engineering structure's weight that results in reducing the me. Carbon usually added to improve the blades toughness causing an increased resistance against effects of unpredicted collisions [14].

4. PULSE MAGNETIC FIELD (PMF)

Purification of the material is an essential process that dictate the mechanical properties of metals. The PMF shows a means for grains purification meant to enhance the solidified microstructure of the metal. PMF taken as an important parameter in material manufacturing or processing because of its wide usage in achieving metal solidification. This method is different from other ancient methods of solidification since it preserves the molten matter from contamination. Usually, a PMF having a direct current can greatly lower the convection process via solidification, while fluctuating the flux can be helped in regulating and adjusting the solidification and thereafter the microstructure [15] and [16].

The solidification procedures of Mg-Al-Zinc composite had examined while subjected to PMF. This research aimed at examining the effect of low voltage PMF (LVPMF) on various mechanical properties like the ultimate tensile strength, microstructure creation and the yield strength.it was shown that [17];

- Executing LVPMF in the solidification process leads to better purification of the microstructure.
- LVPMF highly increased the yield strength of the composite in both semi-casting and normal casting.
- A drop in the ultimate tensile strength (UTS) observed when casting under normal conditions. This can be explained by the shrinkage happening at the PMF that lowers the UTS. This drop can be avoided by utilizing the semi continuous casting, which resulted to a rise in the UTS value.

The impact of PMF on the Mg-Zn-Y alloy solidification procedures have been researched on. Together with the effect of vibrational energy on the minor structure and mechanical features of the composite. Therefore, it was concluded that [18]:

- Because of increased vibrational energy, the Mg93Zn6Y alloy microstructure became more and more purified. Furthermore, the phase of icosahedral that adjusted from constant thick structure to form a discontinuous shape that is particle like.
- The proportion of escalating the icosahedral phase which seen to reduce over the sample, when the zinc and Yttrium components were increased due to the PMF. The icosahedral phase was the reason for greater concentration of load, consequently offering a chance for the formation of micro-crack.
- The Mg93Zn6Y alloy exhibited improved mechanical features that were unique and better than the composite that not subjected to PMF. An electric power of around 350W had used for the treatment. The unique properties that contrasted were the ultimate tensile strength yield strength and the alloy; the results were 221 MPa, 162 MPa and 1.99% respectively. For an alloy that not subjected to PMF, the values showed a significant rise by proportions of 66%, 65% and 124% respectively as an effect of PMF.

The impact of low voltage PMF on aluminium-cooper alloy internal structure was examined. The cooling cycle was analysed to visualize its impact on the technique of grain improvement by pulsed magnetic frequency. it was established that, the PMF had a significant impact while in use via nucleation stage, since it generates smaller structures of grain. In addition, when LVMPF had used by the fluid phase, it had no significant effect on the solidified microstructure. A similar behaviour was observe at the crystal growth [19] and [20].

5. RAINFLOW ALGORITHM

Fatigue is an extremely complex mechanism to be mathematically expressed especially when handling large quantities of data like recorded thrust cyclic loadings resulted from seasonal fluctuations of turbulence intensities and tide highest in such a location for a whole year. However, this can be solved by transforming this complex and unarranged life cycle stress to form separate loads. This can enable estimation of the fatigue life span of the material under research with a better accuracy level. Predicting the performances of tidal turbines is difficult, various methods had been suggested with the objective of satisfying this parameter. Fatigue load is estimated to be generated because of the high cyclic stresses that keep changing over the year, this further escalates the complexity level of this research [21].

Rainflow algorithm has been assumed as being one of the most efficient, accurate and simplest techniques to express a fatigue mechanism mathematically, which results evaluating the fatigue life of a tidal turbine affected by applied drag and lift forces. Actually, scientists that can help in counting the load cycles have invented many techniques. The said methods are complicated and need sequencing and configuration of large amount of information. Rainflow counting technique is simple to use and had be used with large amount of information. It majorly relies on the reaction of the stress-strain features of the material upon application of an external force. The Rainflow counting technique is capable of transforming the extremely difficult cyclic stress load especially because of the variable changes on lift and drag forces executed on the blade into maximal and minimal cycles. For a deeper recognition, assume an external force is executed on an engineering allocation and is needed to estimate its impact on the device safety. The executed force is estimated to change against time; this suggests a high chance of fatigue stress to happen. For large quantities of data, using Rainflow technique would be so difficult and take a lot of useful time. The most recent software packages enable coding as illustrated or feeding it in is MATLAB software. MATLAB has an inbuilt function of the rainflow enumeration technique that needs only identifying the cyclic stress to initiate their counting [22].

6. METHODOLOGY

This paper deals with a characterized tidal turbine aiming to be able of predicting its fatigue service lifetime mathematically using MATLAB code. The study is established based on such assumptions and scientific approaches that had been discussed in details in this section. These approaches are separated into sequenced steps, which are mentioned as follow;

1. The studied tidal turbine constructed from three identical blades as seen in the 3D model represented in figure 9.

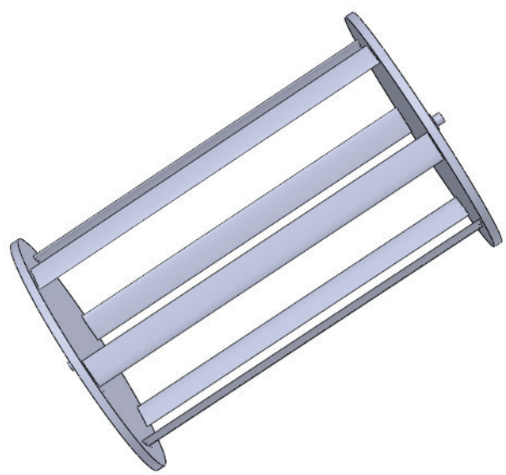

Figure 9. 3D representation of the tidal turbine.

2. This tidal turbine has a turbine diameter of 1000 mm, hub diameter of 1788.46 mm, blade pitch of 6 degrees, stanchion centre to turbine blade centre distance of 2500 mm and stanchion diameter of 1500 mm. The 3-bladed horizontal tidal turbine has a length of 150 m, width of 50 m and height of 50 m. Its tip speed ratio is 3.61 and rotational velocity of 2.22 rad/s.
3. Each blade installed in the studied horizontal turbine is made of Fe-34Mn-10Al-0.76C alloy, which assures a high performance of the turbine, high lifespan and high fatigue and mechanical stresses resistance.
4. Each blade had decided to be treated using pulsed magnetic field with a voltage of 100v.
5. The PMF treated Fe-34Mn-10Al-0.76C alloy been scanned using SEM and its microstructure represented in figure 10.

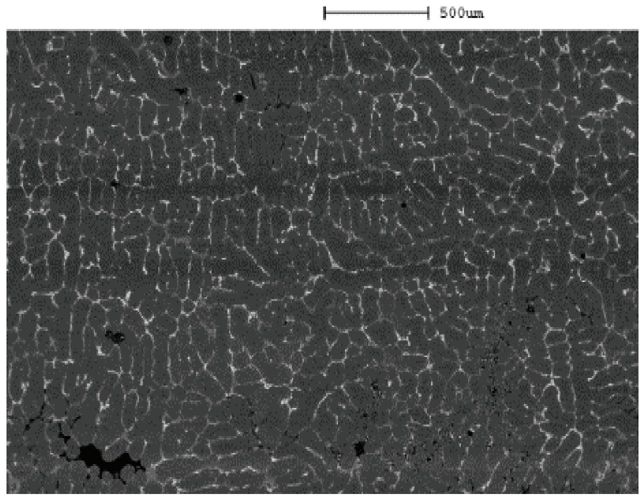

Figure 10. PMF treated *Fe-34Mn-10Al-0.76C alloy specimen microstructure using SEM (x40).*

6. Fatigue strength of the PMF treated Fe-34Mn-10Al-0.76C alloy specimen decided to be investigated experimentally using fatigue strength test machine. The machine recommends using a standardized specimen that described geometrically in figure 11, while figure 12 shows the experimentally tested specimen.

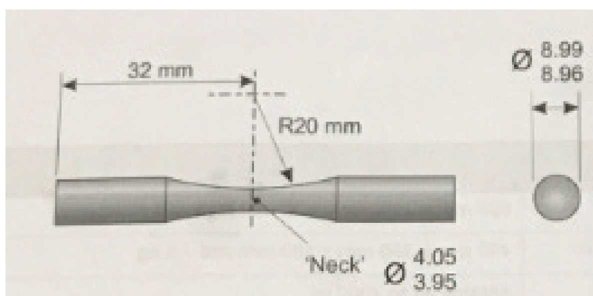

Figure 11. Geometry of the specimen to be tested using the machine

Figure 12. PMF treated *Fe-34Mn-10Al-0.76C alloy specimen to be tested.*

7. The fatigue strength test had established based on varying the cyclic loading applied on the specimen and counting the cycles before mechanical breakage takes place. This had applied several time in order

to get different fracture points for different cyclic loadings. The experimental results had expressed graphically to plot S-N curve of the material to be able of calculating m value, which is very important to indicate for fatigue lifetime mathematical model that decided to be constructed.

8. As soon as S-N curve of the material had plotted, m value indicated and it predicted to be 4.86, which is lower than the Fe-34Mn-10Al-0.76C alloy that is not treated using PMF. As the untreated Fe-34Mn-10Al-0.76C alloy, m value investigated experimentally and it was 5.03. Hence, PMF is decided to have a positive effect on the studied alloy's fatigue lifetime due to the microstructure refining had been attained by applying the pulsed magnetic field on the material.
9. Fatigue mechanism mathematical expression is not simple and require following such procedures that allows reducing error percentage of the mathematical model. The main source of complexity that subjected to the fluctuating turbulence intensity and tide highest over the year, which results in varying the thrust forces applied on each blade of the studied tidal turbine. A high attention paid to these fluctuations and they had been recorded respect to time and angle of rotation of the blade itself. These fluctuating thrust forces estimated as being the main source of fatigue that had paid the highest attention in the proposed paper. These cyclic loadings can studied individually or by taking the average value of them. Referring to the recorded data had been plotted graphically in figure 13, the thrust forces applied on blades 1, 2 and 3 highly fluctuate over time. The thrust forces differ as during 27 seconds, due to changing the turbulence intensity and tide heights.

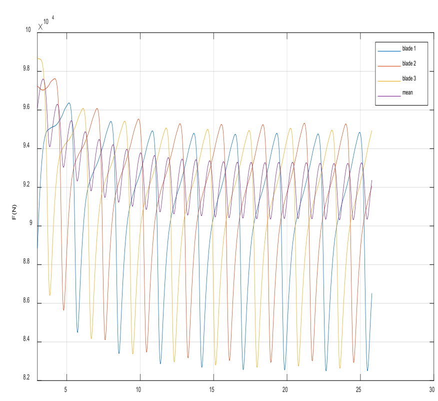

Figure 13. Cyclic loadings applied on the three blades respect to time.

On the other side, these thrust forces are estimated to be differed respect to the rotating angle of the blade. Figure 14 shows the thrust forces applied on each blade as well as the mean thrust force for different rotating angles.

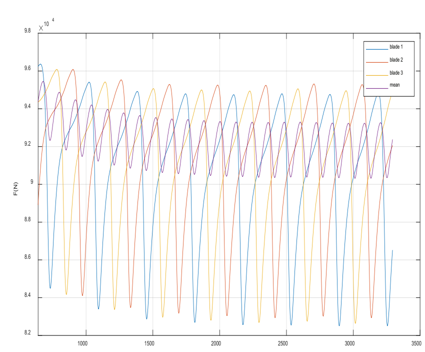

Figure 14. Cyclic loadings applied on the three blades respect to angle of rotation of the blade.

10. Hence, a key issue of reducing the high complexity level of the fatigue mathematical mechanism subjected to refining and rearranging these fluctuating thrust forces. This can been achieved using Rainflow algorithm. The mean thrust forces values can be rearranged using Rainflow algorithm function exists in MATLAB. It allows recognizing the frequency of each cyclic load, which allows taking into consideration the dominant values. Figure 15 shows the cyclic loading range and its frequency.

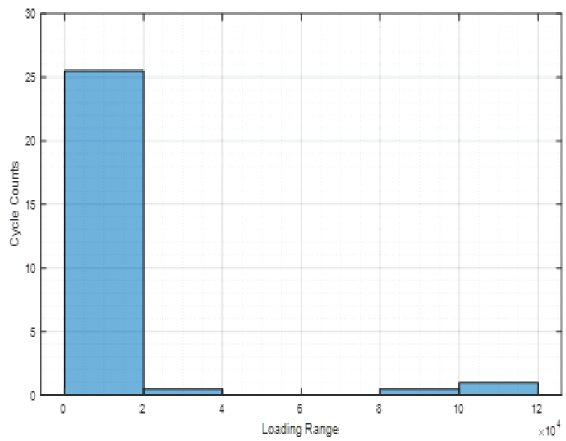

Figure 15. Cyclic loading ranges and their frequencies using Rain flow algorithm.

11. As soon as the frequency of each cyclic loading range had been determined, the damage equivalent load (DEL) can calculated as it represented in the following mathematical correlation [23].

$$DEL = \left(\frac{\sum_i (l_i^m * n_i)}{t}\right)^{m^{-1}}$$

This mathematical correlation can used in describing the damage equivalent load to been used in determining the fatigue service lifetime of the studied tidal turbine. Where (*t*) is, the thickness of the blade made of PMF treated steel alloy, (*li*) refers to the time history and (*m*) is the negative inverses slope of the S-N curve been indicated of the material. Also, (refers to the number of cycles for each cyclic loading range (*i*). It is worthy to mention that, changing the voltage of the PMF would result in altering the S-N curve of the material leading to varying (*m*) value. Hence, this study is applicable only for the blade made of Fe-34Mn-10Al-0.76C and treated using PMF with a voltage of 100 v.

12. DEL values for each cyclic loading range (*i*) had used in determining the fatigue lifetime of the tidal turbine using the following two mathematical correlations [24].

$$\mathrm{S.E.L_i} = \frac{\mathrm{D.E.L}}{A}$$

$$\mathrm{lifetim\ e_i} = \left(\frac{\mathrm{S.E.L_i}}{\mathrm{S_f}}\right)^{-\mathrm{m}}$$

Where, S_f is the fatigue strength, which is one of the most important characteristics of the material.

13. The study decided to consider a couple of parameters that been estimated as being highly influencing in the fatigue service lifetime of the studied tidal turbine. These parameters are the fixation depth of the tidal turbine hub under sea level and the number of hours of the turbine operation. In fact, deepening the fixation of the tidal turbine hub results in raising the pressure head on it, increasing turbulence

intensity and increasing the applied thrust forces. Hence, the fixation depth predicted to be a highly influencing parameter. On the other side, the operating hours of the tidal turbine highly effects on its life and output. Both of the aforementioned parameters should been optimized to assure satisfying the electrical load required to be supplied as well as assuring achieving a long time of operation of the designed tidal turbine.

RESULTS ANALYSIS

According to the discussed methodological approaches, the decision is taken to plot the S-N curve of the turbine had been decided to be studied. The research been executed on the standardized samples composed of the researched Fe-34Mn-10Al-0.76C alloy that has been subjected to a pulsed magnetic field taken in to estimate the fatigue stress at a cyclic loading after a specified number of cycles. Attained outcomes illustrated in the figure below and it is evident that, escalating fatigue stress leads to an observable decline in cycle numbers. It is worthy to mention that, the experimentally tested Fe-34Mn-10Al-0.76C alloy specimen was treated using PMF at a voltage of 100 V. Numerical data had been fed into the MATLAB software and scaled to form a curve as clearly illustrated in the figure below. Actually, marking the S-N curve of the material is important to determine the fatigue lifespan of the tidal turbine. As it is vital to know the material's (m) factor had used in expressing the fatigue mechanism mathematically. m is considered as an important factor, and it is the inverse slope of the S-N curve has been shown as per the figure illustrated below.

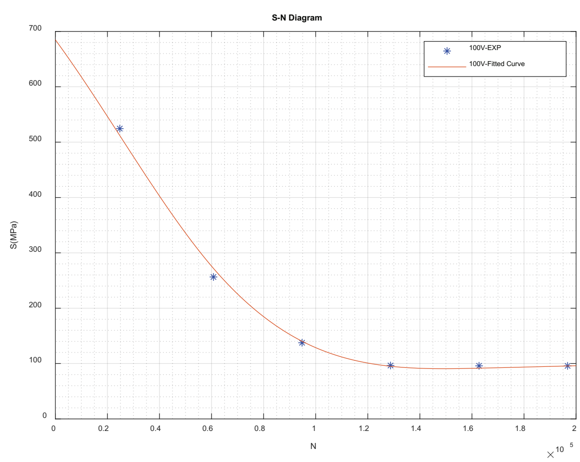

Figure 16. Experimental fatigue stresses for the tested specimens made of Fe-34Mn-10Al-0.76C and treated using PMF with a voltage of 100 v.

According to the procedures that had explained extensively in the methodology section, the fatigue life span in years can been identified for varying thicknesses of the blade. It was evidently examined that, raising the thickness of the fabric would lead to a rise in the operational life span of the blade. However, raising the tidal blade thickness is not conducive because of the observable rise in tidal blade weight leading to a reduction in its performance as well as escalating its original cost. The outcomes illustrated in figure 18, when the researched tidal blade is fixed below the seabed approximately 5 metres and is presumed to be working for only eight hours.

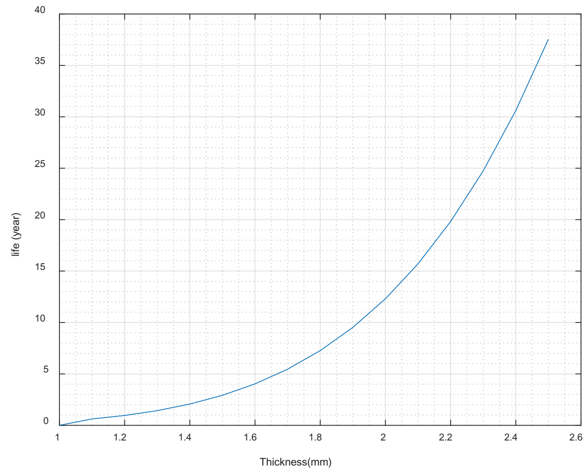

Figure 17. Predicted relationship between fatigue lifetime and blade thickness made of Fe-34Mn-10Al-0.76C and treated using PMF with a voltage of 100 v.

With the objective of scaling up the researcher's details related to the parameters that affect the fatigue resistance of a tidal blade, three tidal turbine depths had taken into account in the proposed paper. Every tidal blade installation depth that evaluated using a similar scientific design to achieve a comprehensive comparison. Attained outcomes showed that, escalating the fixation depth of the researched tidal blade had a noticeable impact on the fatigue life span for all the four examined blade thicknesses. It was estimated that, the optimal service lifespan is attained upon fixing the tidal blade 5 metres under the sea level while the minimal service life span was attained upon fixing the tidal turbine 15 metres below the seabed. Achieved mathematical outcomes had illustrated in figure 19.

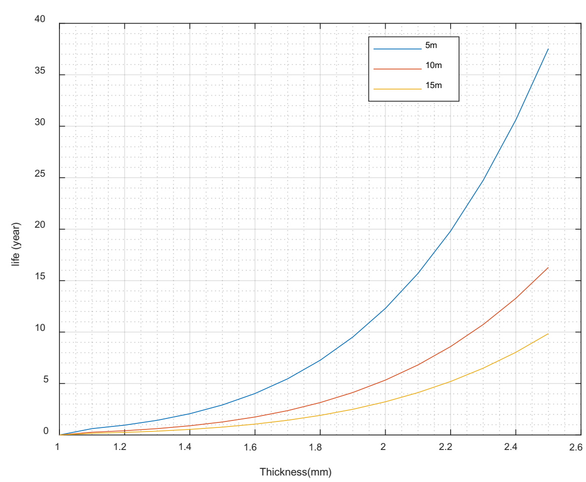

Figure 18. Impact of tidal blade installation depth on the fatigue lifespan at different thicknesses for the blade made of Fe-34Mn-10Al-0.76C and treated using PMF with a voltage of 100 v.

In addition, the working hours of the researched tidal blade that examined mathematically using the same MATLAB code to been greatly influenced by its fatigue lifespan that made it interesting to research its impact. Three different working periods been put into consideration in this research and the achieved outcomes were reasonable. Attained outcomes paved way for the estimation that, raising the number of working hours leads in an observable decline in the tidal blade service lifespan for every examined tidal blade thickness. Attained mathematical outcomes illustrated in figure 20. It had estimated that, the optimal service lifespan attained upon the tidal turbine working for only eight hours in a day while minimal service lifespan attained upon the tidal turbine working for 24 hours in a day.

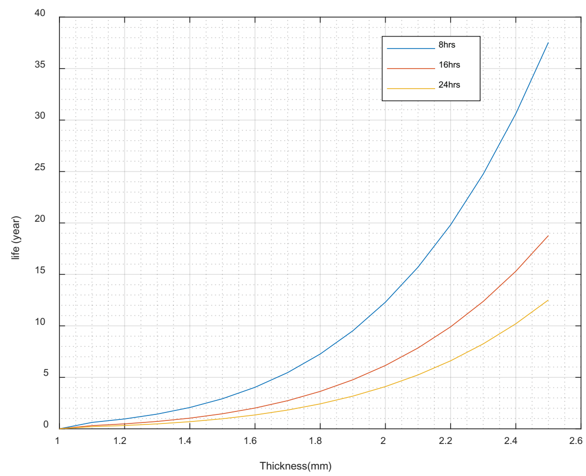

Figure 19. Impact of tidal blade operation time on the fatigue lifespan at different thicknesses for the blade made of Fe-34Mn-10Al-0.76C and treated using PMF with a voltage of 100 v.

DISCUSSIONS

Tidal power had gained a lot of interest in the past decades because of its potential performance and capacity of contributing large percentage to the universal power demand. This performance had attained based on maximising such factors that improved tidal blade efficiencies, lowered their initial capital as well as reduced the related maintenance costs. Designing, constructing, processing, installing and working of a tidal blade is not a simple process that need extensive recognition of the predicted working scenarios. Various parameters had examined to determine its effect on the performance and safety of tidal turbines. Fatigue failure is the major forms of mechanical breakage that should be examined precisely to estimate the service lifespan of the tidal turbine, this aid in achieving high economic and environmental benefits. Fatigue initialises as soon as minor crevices produced on the surface of the tidal turbine, this therefore leads to an increased surface roughness causing an observable decline in its energy transforming efficiency. Choosing the material to be used is taken as an important process since it greatly affects the efficiency and safety factors. Every material can be chosen in meeting such needs is predicted to offer a group of merits and limitations that suit such working and environmental conditions.

The material chosen for tidal blade is characterised by low density, which would lead in lowering its output. It must be merited by high mechanical efficiency to evade a rise in blade thickness or its initial and operating costs. Since increasing the blade thickness to achieve higher safety factor against the predicted terms is examined in various researches and it has shown a reduction in power factor of the tidal turbine leading to a decline in its output. Steel alloys known by their great mechanical performances, simple manufacturability and average density. Their alloy performance can improved by the most recent technologies like the PMF.

Fatigue life span for a working tidal turbine greatly influenced by its fabric features, blade thickness together with the environmental conditions that the tidal turbine is operating under to. Because of the high complexity, levels of fatigue mechanisms and its climatic fluctuations of the executed thrust stress on every blade, the rainflow algorithm employed in rearranging these loads. This paved way to examine the fatigue life span of the researched tidal turbine for varying thicknesses. Raising the blade thickness that examined to cause positive impacts on the lifespan of the tidal turbine; however, it predicted to cause negative impacts on its energy conversion ratio.

Actually, fatigue lifespan found to been influenced by various parameters. Such parameters that related to the working periods of the tidal turbine or the environmental parameters. Constructing a tidal turbine below the sea level is examined to greatly affect the fatigue lifespan of the tidal turbine because of the high thrust hydrodynamic loading executed on the tidal turbines. The mathematical prototype of fatigue had programed using MATLAB software, which enabled estimating the observable effect of the installation depth of tidal turbine on their service lifespan since increasing it led to a drastic decline its lifespan. In addition, intensifying the turbine duty by raising its working hours daily that established to have negative effects on the turbine lifespan. Therefore, it had suggested maximizing the construction depth and the working hours based on the needed electrical energy output and the predicted turbine service life span.

CONCLUSIONS

Tidal turbines are highly operating and efficient energy converters that influenced by a categorised harsh environmental and working condition. These condition keeps changing annually, this makes estimating their lifespan difficult. The fabric used in making tidal turbines is an important aspect to be considered for efficiency and safety purposes. Fe-34Mn-10Al-0.76C alloy offered potential performances related to satisfying the roles of a tidal blade effectively. The efficiency can improved by using PMF. In addition, the blade thickness affects the fatigue lifespan of a tidal turbine. It should be maximised to attain a wanted lifespan. depth of installation below the seal bed together with the quantity of working hours of the tidal turbine greatly affect the fatigue lifespan, this suggests that considering such factors at the initial design stages of tidal turbines is crucial. Such factors should be optimized based on the electrical demand and the payback period of the turbine so that to achieve the economic advantages. Increasing the installation depth as well as the operating hours of the studied tidal turbine would result in a significant increase in the electrical power output but it would increase the total cost of the turbine as well as reducing its expected lifespan, which suggests optimizing these parameters based on the electrical load required to produce.

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