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Failure Analysis and Optimization of Maintenance for the Main Shaft of 1500kw Wind Turbine

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ABSTRACT

Maintenance actions do not always return the system to "as good as new" condition. Modelling System Failures (MSF) is a unique quantitative maintenance Optimization technique which permits the evaluation of life-data samples and enables the design and simulation of the system's model to determine optimum maintenance activities. In this paper, the approach of MSF is used to assess the failure characteristics of a horizontal axis wind turbine. By collecting the field failure data the shape (β) and scale (η) parameters are estimated using the maximum likelihood estimation in Weibull distribution for the main shaft of the wind turbine. Weibull probability plots, reliability graphs, failure versus time plots, and probability density function graphs for the main shaft are presented.

Key Words: *Reliability, Failure rate, Shape parameter, Scale parameter.*

1. INTRODUCTION

Wind power is an effective form of clean, renewable energy which operate both on land and offshore. It does not consume fuel or emit carbon emissions during its operation and is predicted to be the most cost competitive electricity source on macro-economic level by 2025 [1]. The wind turbine converts wind energy to electrical energy. The state-of-the-art wind turbine is an upwind three bladed turbine. Three blades are mounted on a rotor shaft and the wind forces is converted into torque on the rotor shaft by acting on the blades. This torque can be controlled by pitching the blades or by controlling the generator torque through a power converter. In between the rotor axis and the electrical generator, normally a gearbox is mounted, converting the low speed high torque rotor side with the high speed low torque generator side [2]. The main or low-speed shaft of a wind turbine connects and transmits rotational force from the hub to the gearbox. Wind turbines' main shafts are usually of forged alloy steel[3].This paper will demonstrate the practical application of one the quantitative maintenance optimization approach known as the Modelling System Failures (MSF). This paper focuses on the analyses of field failure and maintenance data of horizontal axis wind turbines collected from wind farms. The characteristics of the collected data are discussed. The data are analyzed using Maximum Likelihood Estimation (MLE) to estimate the shape (β) and scale (η) parameters of the Weibull distribution for one of the critical Component (Main shaft) of a particular type of 1500 kW wind turbine. Weibull probability plots, reliability graphs, failure verses time plots, and probability density function graphs for the component is of the 34 x 1500 kW wind farm is presented in to demonstrate the practical application of the estimated β and η values to determine and optimize maintenance activities for the main shaft of the wind turbine.

2. DATA COLLECTION

In order to evaluate the wind farms in confidentiality, they were labelled alphabetically (A to Z; AB); WF-C in column 1 of Table 2.1 denotes Wind Farm C. The wind turbines were named according to their respective wind farms; WF-A-WT 27 (Table 2.1 column 2) denotes Wind Farm A-Wind Turbine number 27.

Table 2.1 Failure Data for the Main Shafts of 1500 kW Wind Turbine

Wind Farm (WF)	Wind Turbine (WT)	Fail time (days)	Main shaft	Causes of failure
WF-C	WF-C-WT-13	315	F	Other
WF-K	WF-K-WT-7	424	F	Poor design
WF-F	WF-F-WT-16	492	F	Unknown
WF-A	WF-A-WT-27	529	F	Fatigue
WF-L	WF-L-WT-3	698	F	Fatigue
WF-N	WF-N-WT-3	936	F	Fatigue
WF-M	WF-M-WT-3	1233	F	Fatigue

3. SHAPE AND SCALE PARAMETERS OF MAIN SHAFT OF 1500 kW WIND TURBINE

The shape and scale parameters for components and subsystems of the various types of wind turbines are estimated in this section. It was mentioned previously that the value of β describes the failure pattern of the equipment, that is, β<1 means a reducing failure pattern, β=1 signifies a constant failure pattern and β>1 indicates an increasing failure pattern. The scale parameter (η) denotes the characteristic life of the equipment; the time at which there is probability of approximately 0.632 that the equipment will have failed. The reducing failure pattern (β<1) usually known as the infant mortality denotes failures that occur at the early-life of equipment and the likelihood of occurrence reduces as the age of the equipment increases. The constant failure pattern (β=1) represents failures that are independent of equipment age, that is, the likelihood of occurrence is invariable through out the life-cycle of the equipment. Lastly, the increasing failure pattern (β>1) commonly referred to as wear-out symbolises failures that occur at the later life of equipment, that is, the likelihood of occurrence increases with the age of the equipment[4].

Table3.1. Weibull -2P data for main shaft

Sub-system	**Distribution**	**Analysis**	**Shape (β)**	**Scale (η)**	**Failed**	**Suspended**	**Mean Life (MTBF)**
Main shaft	Weibull-2P	MLE	1.43	6389	7	70	5807

4. GRAPHICAL RESULTS

4.1 The Main Shaft weibull plot:

The estimated values of β and η for the main shaft are 1.43 and 6389 respectively. The β value of 1.43 indicate a *wear out failure pattern* while the η value of 6389 implies that there is a probability of approximately 0.632 that all the main shafts in a wind farm of 1500 kW turbine would have failed within 6389 days or approximately 18 years, given the assessed failure behaviour of the main shafts and the current maintenance strategy employed. The Weibull plot (graphical data analysis) for the

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main shafts failure data is shown in figure:

Where

$$F(t)=1-\exp\wedge(-t/\eta)\wedge\beta$$

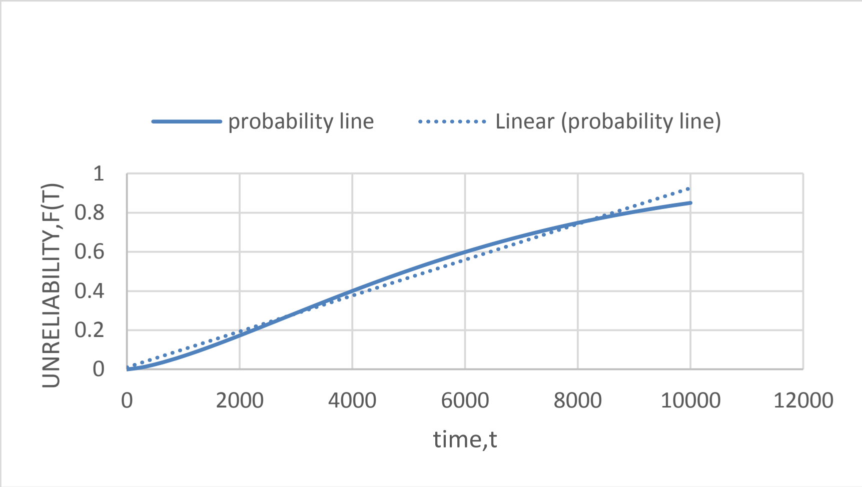

Fig.1 Main Shaft Weibull Plot

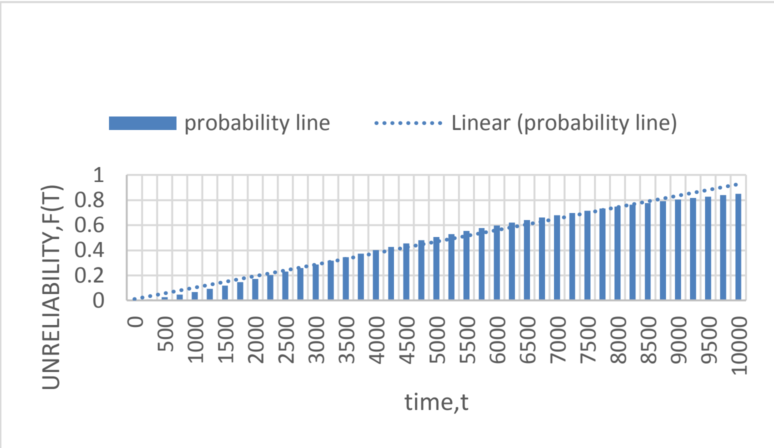

Fig.2 Main Shaft Weibull Plot

4.2 Main shaft pdf plot:

The probability density function (pdf) plot for the main shaft is presented in figure. The plot is skewed to the left showing that bulk of the failure modes occur between 0 and 4000 days even though the estimated MTBF is 5807 days.

Where

$$f(t)=\beta/\eta*((t/\eta)\wedge(\beta-1))*\exp(-t/\eta)\wedge\beta \;;t\geq 0,\beta>0,\eta>0$$

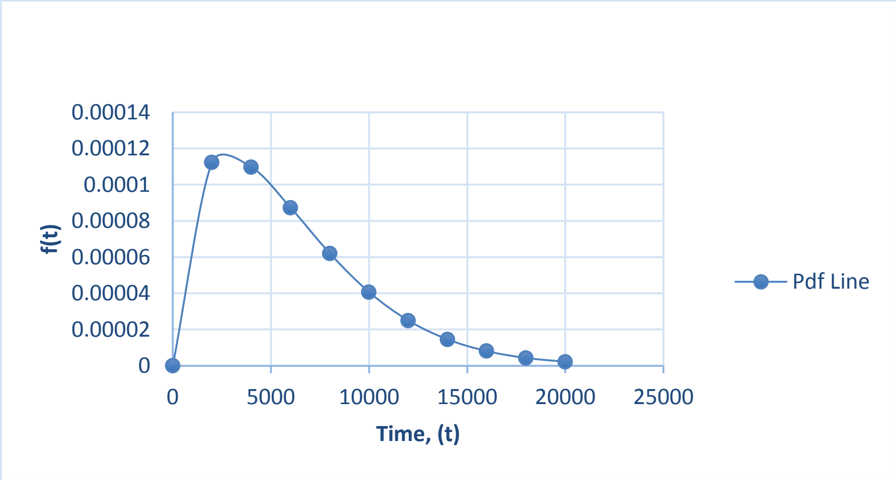

Fig.3 Main Shaft pdf plot

4.3 Main shaft failure rate function plot :

The main shaft failure rate plot is presented in figure. The plot shows a constantly increasing failure rate and not a clear wear out even though the value of β is greater 1. This demonstrates the significance of the plots to provide more information to support the calculated values.

Failure Rate function= f(t)/R(t)=(β/η)*(t/η)^(β-1)

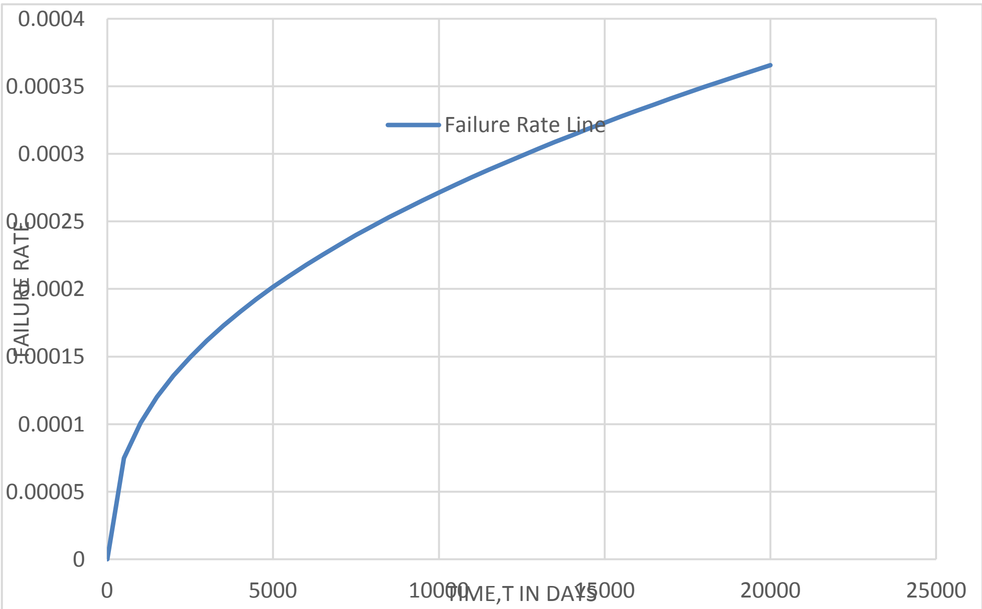

Fig.4 Main Shaft Failure Rate Plot

5. REFERENCES

[1] Daniel Chan, John Mo, "Life Cycle Reliability and Maintenance Analyses of Wind Turbines" Energy Procedia, Volume 110, March 2017, Pages 328-333.

[2] F.D. Bianchi, H. De Battista, and R.J. Mantz. "*Wind Turbine Control Systems*.Advances in Industrial Control' Springer Verlag, London, 2007.

[3] Burton, T., Sharpe, D., Jenkins, N. & Bossanyi, E. (2001),' Wind Energy Handbook, JohnWiley and Sons Ltd".

DOI : http://dx.doi.org/10.31695/IJERAT.2018.3264

[4] Cohen, A.C (1965) "*Maximum Likelihood estimation in the Weibull Distribution Based on Complete and on Censored Samples"*, Technometrics, 7(4), 579-588.

[5] P. Martin, "Consequential failures in mechanical systems",Reliability Engineering, Volume 3, Issue 1, January 1982, Pages 23-45.

[6] Yung-Chang Chang et.al, "Reliability Analysis of Wind Turbine Towers",Procedia Engineering, Volume 79, 2014, Pages 218-224.

[7] Fangfang Ding, Zhigang Tian, "Opportunistic maintenance for wind farms considering multi-level imperfect maintenance thresholds",Renewable Energy, Volume 45, September 2012, Pages 175-182.

[8] Karim Atashgar, Hadi Abdollahzadeh, "Reliability optimization of wind farms considering redundancy and opportunistic maintenance strategy",Energy Conversion and Management, Volume 112,15 March 2016, Pages 445-458.

[9] Kazem Alemzadeh, Ike Anyanwu-Ebo,et.al, "A Systems Approach Towards Reliability-Centred Maintenance (RCM) of Wind Turbines" , Procedia Computer Science, Volume 16, 2013, Pages 814-823.

[10] Yonggang Lin, Le Tu,et.al, "Fault analysis of wind turbines in China", Renewable and Sustainable Energy Reviews, Volume 55, March 2016, Pages 482-490.

[11] Joel Igba,et.al, "Through-life engineering services of wind turbines", CIRP Journal of Manufacturing Science and Technology, Volume 17, May 2017, Pages 60-70.

[12] C.J. Hockley, "Wind Turbine Maintenance and Topical Research Questions",Procedia CIRP, Volume 11, 2013, Pages 284-286.

[13] Himani, Ratna Dahiya, "Condition monitoring of wind turbine for rotor fault detection under non stationary conditions" ,Ain Shams Engineering Journal,2017.

[14] Andrawus, J.A., Watson, J. and Kishk, M. (2006a), "Asset Management processes in the Wind Energy Industry", Proceedings of the 2nd Joint International conference on Sustainable Energy and Environment, Bangkok, pp. 269-274.

[15] Andrawus, J.A., Watson, J., Kishk, M. and Adam, A. (2006b), *Determining an appropriate Condition-Based Maintenance strategy for wind turbines*, Proceedings of the 2nd Joint International Conference on "Sustainable Energy and Environment" Bangkok, 275-280.