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Nduka Udoye
Covenant University Ota Ogun State, Nigeria

Ojo Sunday Isaac Fayomi
Bells University of Technology

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REVIEW ON PERFORMANCE OF EXISTING COOLING TOWER FAN BLADE IN THE PRODUCTION INDUSTRY

Nduka Ekene Udoye
Department of Mechanical Engineering, College of Engineering, Covenant University Ota, Ogun State, Nigeria

Ojo Sunday Isaac Fayomi
Department of Mechanical Engineering, College of Engineering, Covenant University Ota, Ogun State, Nigeria
Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, Private Bag X680, Pretoria 0001, South Africa.

Anthony Omieraokholen Inegbenebor
Department of Mechanical Engineering, College of Engineering, Covenant University Ota, Ogun State, Nigeria

ABSTRACT

Cooling towers are the major industrial part for heat rejection in petrochemical industry, oil refineries, chemical plants, thermal power plants and HVAC systems for cooling structures. The fan is a mechanically forced-draft used to extract the heat accumulated in the flowing cooling water components and the fan blade is a very important part of the towers. Failure of fan blade leads to low productivity, high cost of replacement and maintenance of cooling tower fan blade in service. This paper presents a review on failure mode and material availability of cooling tower fan blade.

KEYWORDS: Cooling tower, Cooling tower fans, Vibration analysis, Failure mode.

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1. INTRODUCTION

The towers are the basic components of power stations which serve as a chilling system. They assist in the removal of heat absorbed in the system by ejecting the unwanted heat to the atmosphere by reducing the heated water to low temperature. They signify a moderate cheaper and dependable technique of eradicating heat from cooling system. The reservoir water is used to replenish water lost to vaporization and heated water from condenser is moved to the cooling base. The water that leaves the cooling tower is return to the boiler units for further processing [1]. The fan blade blow the coil during operation and heat from the coil will transfer from the shaft to the blade. One of the major challenges facing textile industry in recent time especially with spare part is the cost of replacement and maintenance of cooling tower fan blade in service. Cooling tower fan is automatically forced-draft used to extract the heat accumulated in the flowing cooling systems and the Fan blade is a very important part of the towers [2].

The natural and induced draft cooling towers are the two major kinds of cooling towers. The fan blades are faced with several vibration predicaments throughout their life span [3]. The energetic and forceful behaviour have negative impact on the fan blade structure that leads to break down of cooling tower. Moreover, it is better to study the blade structure in order to know the necessary design needed for normal operation. Glass fiber reinforced composites are utilized for the structural application to reduce the vibration of the fan blades. The structural material used is light in weight which offers more advantages than other materials available [4] [5].

The major cause of repeated failure of plastic fan blade is as a result of heating the fan blade above its melting temperature thereby causing repeated break down of the fan blade. Mechanical defect and stress induced due to the exposure of plastic fan blade to heat from the coil transferred through the shaft to the blade leads to poor structural and thermal properties [6]. Threat due to harsh condition such as high temperature is a limitation on the use of plastic in the textile industry. Their thermal stability depreciates in the presence of heat which initiates crack of the blade from the base.

2. FAILURE MODE OF COOLING TOWER FAN BLADE

The failure of a single blade affects other blades, drive shaft, coupling components which resulted to huge financial impact as well as fan availability. All these necessitate the interest towards researching the best option to improve on the fan blade performance. Forced draft fans are utilized in feeding combusted air into boiler in coal fired power plants and the failure of forced draft fans are caused by erosion and corrosion fatigue [7]. The axial and centrifugal flow fans are the two forms of forced draft fans [8]. The forced draft fans can also be caused by dilapidation machinery resulting from maintenance cost. The authors deduced that majority of the damage in power plant fans are caused by corrosion, erosion and vibration. Yan-qing *et al*., (2008) also reported that the catastrophe experienced in fan blade was as a result of machine vibration [9].

According to Gogula *et al*., (2016) "Glass fibre reinforced plastics (GFRP) are used to manufacture cooling tower blades to prevent pitting on the surfaces, scales formation and maintenance cost reduction". The authors successively replace the conventional aluminium material with GFRP and examined the mechanical properties and airflow of the rotor blade before installation. The result of GFRP fan blade and conventional aluminium blade shows that airflow rates of the conventional blade and GFRP blade are 9510 and 9622 m^3/hr respectively. The weights of conventional blade and GFRP blade showed that reducing the weight of GFRP blade will result to decrease in thrust and vibration on bearing while fan is rotating. Hence, GFRP fan performed better than the existing conventional blades and more economical. The results obtained revealed that the GFRP blade has lesser weight, low maintenance cost and low power consumption than the conventional blades [10].

Zhao *et al*., (2018) utilized static and dynamic analyses to investigate the foundational reason for the blade crack of a motor cooling fan in a high-speed reciprocating compressor platform. The authors established that the undue dynamic pressure at the base of the blades initiated by torsional reverberation was credited to the fatigue crack of the fan. The results obtained showed that blades enhancements were executed to avoid structural resonance which includes decreasing the altitude of the blades, additional increments on the number of blades and altering the weld sites [11].

According to Khandare *et al*., (2015) "Structural vibration problems causes a major hazard and design limitations for a very wide range of engineering products". The authors study vividly the natural frequencies of fiber reinforced plastic tower fan blades of dissimilar sizes of 24ft, 26ft and 30ft by performing model analysis in ANSYS. This is to ensure that designers avoid the natural frequencies that will not near the frequency of the main excitation forces in order to prevent resonance. The authors carried out experimental study on FRP composite blades and comparing them with ANSYS results to found the frequency range of interest. The authors asserted that the ANSYS results and experimental results are close and has been found in the frequency range of interest for FRP Composite blades. Hence, obtained natural frequencies can be considered while designing the FRP fan blades [4].

According to Kushwaha (2017) "The failure of one blade also damage other blades, drive shaft and other components and hence causes huge financial impact as well as fan availability". The author studied fatigue failure analysis of the fan blade used in a 500MW unit of a thermal power plant. The author developed a 3D modelling of the blade by using Pro-Engineer based on dimensions of the actual blade used at site and FEM analysis was carried out by Ansys software. Concurrence between FEM results and observations of failing pattern at site has been found. The result of the experiments shows that fan blade failure was due to excessive deflection caused by crack initiation at its root. The hitting of other deflected blade with other fan components such as drive shaft and failure of any one blade becomes primary reason of failure of other fan components. The analysis of failed blade by visual inspection and finite element analysis shown that the blade is failing repeatedly at mainly two point one at its shank/neck portion and second near 1/3 of the blade length from its tip side. Figure 1 shows the failed fan blade at the neck portion and figure 2 shows the failed fan blade at 1/3 of the blade length [12].

Figure 1: Failed fan blade at the neck portion [12]

Figure 2. Failed fan blade at 1/3 of the blade length [12]

Valyakala *et al*., (2013) studied the cause for the catastrophe of a forced draft fan based on a study carried out in a petrochemical industry. The main factor affecting failure of a forced draft fan was vibration and vibration in turn caused bearing failure. The causes of failure of fan blade are divided into four main parts: machine, material, equipment, and labour. Figure 3 shows the fish bone diagram that explains main section of fan blade failure.

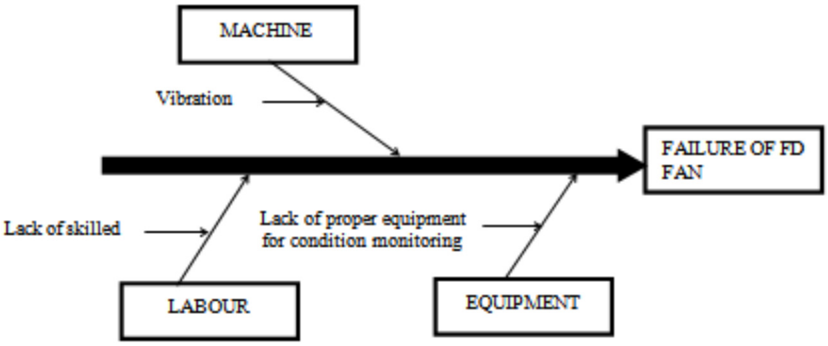

Figure 3: Fish bone diagram [13]

Figure 4 depicts plotted graph on a Pareto chart using maintenance log sheet. The result shows that 80% of the problem is due to machine errors.

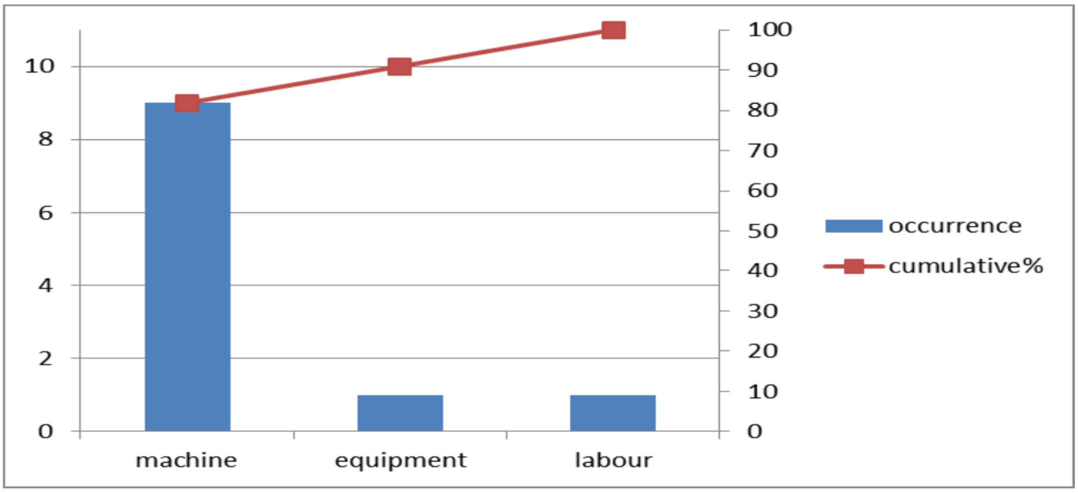

Figure 4: Pareto chart [13]

It can be shown from figure 4 that 80% of the vibration is due to unstable impeller and lopsided base and fastener failure. The authors affirmed that erosion on the blades is instigated by suspended particles in the air. Furthermore, erosion and corrosion cannot be measured as the industrial environment is polluted. Therefore, the authors concluded that forced draft fan catastrophe was caused by bearing damage and it can be avoided by eliminating disruption in the impeller and misalignment of base and fastener failure [13].

Nurbanasari *et al.,* (2017) examined the coal fired power plant of 300 MW capacities that is being hampered by devastating failure in a forced draft fan (FDF) blade. Cast Al-Si alloy (A356.0) was used for the FDF blade usage. The authors deduced that the blade spoilt mostly at the base of the blade and at the one- third of the blade altitude. The authors further attested that the catastrophe at the base blade was caused by fragmentation of the other damaged blades that entered in between casing (stator) and the blade (rotor) obstructing the blade spin [14].

Poursaeidi and Salavatian (2007) investigated the analytical damage of a generator rotor fan blade by machine-driven and metallurgical observation of rupture surface. The authors established that the failure analysis was caused by bending mode of resonance vibration which doubtless caused by aero dynamic disorders. Fracture occurs at the airfoil base and surface observation depicts blade cracking utilizing high cyclic fatigue device. The authors suggested a power-driven process that can predict stress and dynamic distinctive of turbine blades required to lower blade failures. However, material defect was not considered in the study [15].

Torshizi *et al.,* (2009) studied failure analysis and method of preventing fracture in generator's fan blade. Microstructure dilapidation has not been detected in the metallurgical and structural analyses. Report has affirmed that fracture occurred as a result of high cycle fatigue using scanning electron microscope. The authors concluded that the blade crack was due to fatigue situations in resonance state and growth of existence small feasible cracks [16].

Aher *et al*., (2016) investigated the natural frequency of fiber reinforced plastic fan blades of various materials and sizes. The author has revealed that using Matlab and Ansys results in comparison with computed and the experimental results yielded favourable results. The Matlab program can envisage the natural frequency of fiber reinforced plastic blades. The authors observed that MATLAB and ANSYS can be used to compute the natural frequencies of fiber reinforced plastic composite blades and other similar types of blades [17]. Basavaraj *et al*., (2017) studied the resonance of cooling tower fan blade using vibration analysis. The authors reduce the catastrophes of the cooling tower fan blades, truncate the repair sequence, maintain smooth production process and increase the cost-effectiveness competence [18].

3. CONCLUSION

The above review for the performance of existing cooling tower fan blades leads to the following conclusions:

- Vibration frequencies at the cooling tower fan blade was caused by fan unbalance, rubbing of one fan blade on shroud, blade pitch problems and blade cracking near hub.
- The authors concluded that mostly severe damage that happened in power plant fans are corrosion, erosion and vibration
- The analysis of failed blade by visual inspection and finite element analysis shows that the blade is failing repeatedly at mainly two point one at its shank/neck portion and second near 1/3 of the blade length from its tip side.
- The results obtained showed that design perfections were employed to avoid the structural resonance which includes minimizing the blades height, multiply the number of blades and altering the weld positions.

- The authors suggested a mechanical process that is capable of forecasting stress and dynamic distinctive of turbine blades required to minimize blade failures. However, material defect was not considered in the study.

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