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Damage analysis of the forced draft fan blade in coal fired power plant

M. Nurbanasari*, T. Kristyadi, T.S. Purwanto, A. Maulana, R.R. Fadilah

Department of Mechanical Engineering, Institut Teknologi Nasional, Jl. PHH. Mustapha 23, Bandung 40124, Indonesia

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ABSTRACT

The Forced Draft Fan (FDF) blade in a 300 MW coal fired power plant that experienced catastrophic failure has been investigated. There were two main locations of the blade damage, namely damage at the root of the blade and the other one is at the third of the blade height. The FDF blade has been run for 5 years and before its failure, the FDF experienced high vibration (14 mm/s). The forced draft fan is an axial flow fan horizontally in front of the boiler and the fan is single stage. Visual inspection, metallographic analysis, chemical composition and hardness test were carried out to find the cause of the failure. It is concluded that the material of the blade is cast Al-Si alloy (A356.0) that fits the requirements for FDF blade application, the failure of the third of the blade height is owing to the external particles collide to the leading edge of the blades causing erosion and notch. That notch acted as initial crack. The failure at the root blade was caused by broken fragments of the others damaged blades entered in between casing (stator) and the blade (rotor) so they obstructed the blade rotation.

1. Introduction

In coal fired power plants, forced draft fans (FDF) are usually used to supply combustion air into boiler [1]. The FDF has an important role to provide the effective combustion in various conditions and produce better heat transfer by circulating gases. In boiler, the combustion air flow consumption depends on the boiler load and is controlled by an oil-hydraulic impeller blade adjustment system. There are two types of FDF blade, e.g.; axial flow and centrifugal flow fan [2]. The FDF components can be damaged due to some degradation mechanism and cause to high cost maintenance activities. It has been reported that most common serious damage occurred in power plant fans are corrosion, erosion, vibration. Valyakal et al. [3] and Yan-qing et al. [4] found that the failure of a fan blade was due to vibration in the machine. Kazempour-Liacy, et al. [1] reported that the erosion and corrosion fatigue caused the failure of the FDF blade. This current study investigated a forced draft fan (FDF) blades, which experienced catastrophic failure in a 300 MW coal fired power plant resulting the whole system was shut down. The FDF has been operated for 5 years and before its failure, the FDF experienced high vibration (14 mm/s) whereas the maximum allowable vibration when the engine is operated at 7 mm/s. The forced draft fan is an axial flow type, installed horizontally in front of the boiler and consists of 14 blades. The fan is single stage and has a casting structure. The blades are adjusted during operation by the hydraulic impeller blade adjustment system and kept in position. The blades were installed to a centre spindle using screw and the direction of rotation of the fan is clockwise viewed upstream. The premature failure of these blades was unusual and need an exact failure analysis.

* Corresponding author.
E-mail addresses: meilinda@itenas.ac.id (M. Nurbanasari), kristyadi@gmail.com (T. Kristyadi), trisigitp@itenas.ac.id (T.S. Purwanto), andriemaulanamocca@gmail.com (A. Maulana), tahefadilah94@gmail.com (R.R. Fadilah).

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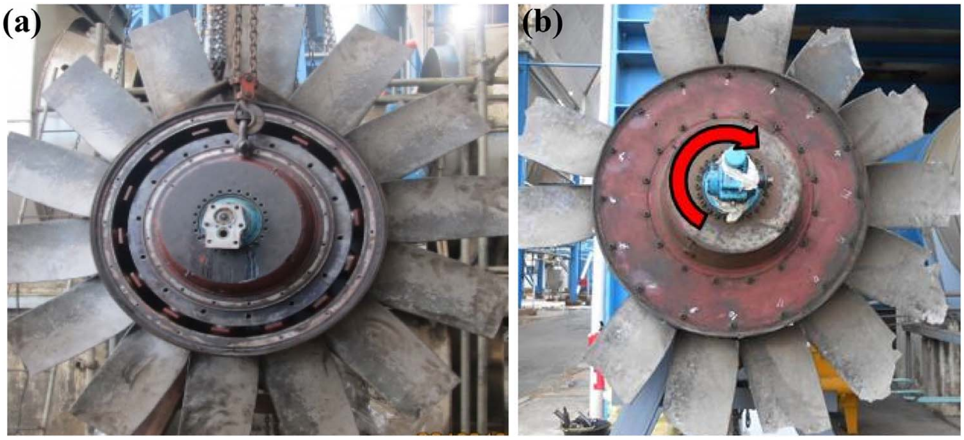

Fig. 1. Investigated FDF blades: (a) before failure and (b) after failure (red arrow indicates direction of rotation).

2. Methodology

To define the cause of the damage, some methods consist of non-destructive and destructive examinations were carried out. Fig. 1 shows the FDF blades before and after failure.

Visual inspection found that the coating of leading edge of the the blade had serious erosion damage, as can be seen in Fig. 2a and lots of debris had been collected behind the fan, including the heavily damaged blade itself. The debris of fractured blades was accumulated to support the analysis (see Fig. 2b). Fig. 2c shows the fractographs of damaged coating near to the leading edge of the blade. The coating of the blade has already lost and the base metal is clearly seen. Visual observation also found that there were two locations of damaged blade e.g., damage at the root of the blade and the other one is at the third of the blade height, as shown in Fig. 3.

Based on the visual inspection findings, the following methods were chosen to determine the cause of damage namely, metallographic analysis, chemical composition test and hardness test. Atomic absorption spectrometer was used to chemical composition analysis of the blade's material and the debris. Average hardness data was taken from 6 times measurement on the blade surface and was performed on Vickers Hardness Tester with load 200 grams and dwelling time 15 s. Scanning electron microscope (SEM) was used on JEOL 610-LA operated at 20 kV to find the fracture morphology and the EDS (Energy Dispersive Spectroscopy) was performed for local chemical analysis to study the deposit of the surface fractured blade. The coating of the blade was also studied using SEM-EDS. Microstructure sample was prepared using metallography standard and Keller's etchant was applied to reveal the microstructure. Fig. 4a and b show the locations of sample taken from the two investigated blades for metalographic analysis, chemical composition test and hardness test. The samples were cut using electro discharge machine.

3. Results and discussion

3.1. Material verification of the damaged blade

Chemical composition analysis of the investigated blade confirmed that the blade was made of aluminum alloy, which consists of 6.5% Si, 0.16% Fe, 0.8% Cu, 0.2% Mn, 0.3% Mg, 1.2% Zn (in %wt) and Al is balance. The chemical composition analysis of the debris was also in a good agreement with the materials of the damaged blade. The average hardness of the blade is 123.7 HV and the microstructure of damaged blade is shown in Fig. 5.

Fig. 5 shows the coarse microstructure consists of dendritic structure α-Al phase and associated segregation. The dendritic structures are surrounded by eutectic silicon and this is strong evidence that the blade was made by casting process. The cast alloys need to be well observed due to the defects formation during solidification process and the chemical composition of the alloys affect the mechanical properties [5]. There are some requirements for material to be used as FDF blade, e.g.: light weight, good wear resistance in high flow rate, good corrosion resistance and low maintenance. The application of aluminum cast alloy for the FDF blade is widely used in industry by considering that the characteristic of the aluminum alloys fulfill the requirements for the FDF [6]. Therefore, the use of Al-Si alloy for FDF blade in this coal fired plant met with the requirements. Refering to the results of the chemical composition, hardness and miscrostructure analysis of the blade, it can be concluded that the blade material is within the standardized cast Al-Si alloys (A356.0) and there was no indication of manufacturing defect, which contributed to the failure of the blade.

3.2. Coating material

Fig. 6a shows a back scattered SEM image taken from undamaged area of the primary and intermediate of the blade coating. The