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The H_2S Corrosion Effect On The Stationary Turbine Blade

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ABSTRACT

The Geothermal fluids were disturbed by volcanic gas sulfide deposit reactions which form by reaction of metal(s) with H2S. this sulfate acid is one of the most corrosive compounds in the steam which lead the pitting, stress corrosion cracking and other corrosion mechanisms. An optical microscope, XRF dan X-ray diffraction is used to observe the sediment samples that came from stationary blades. The results show that it mainly consists of 89.7%wt iron sulfide (FeS) and 10.3%wt arsenic trisulfide (As2S3). This phase is toxic by inhalation and ingestion. Downstream steam pipeline treatment is required to reduce sulfide carried away into steam turbines such as scrubbing or washing steam. For this reason, special handling is needed for the toxic waste resulting from washing.

Keywords: *Geothermal, Steam turbine, sulfide, pitting corrosion*

1. INTRODUCTION

Darajat is one of the largest vapor-dominated geothermal fields globally, with a current total capacity of 271 MWe, accommodated by three power plants [1,2]. This power plan is located in West Java, Indonesia the location is 150 km from Jakarta and is at an altitude of 1750 m above sea level.

This geothermal energy is relatively environmentally friendly. the heat it generates converts the water that enters the earth into pressurized steam which can be used to drive power generation turbines. The cost required to build geothermal power plants is more expensive than building power plants that use fossil fuels. However, after starting operations, the cost of producing electricity is cheaper than the cost of producing electricity from fossil fuel power plants.

The steam generated by geothermal descends bringing other particles from within the earth. This is caused by the interaction between the water that goes into the bowels of the earth with rocks and magma. The content is divided into rock-forming constituents, e.g., Si, Al, Na, K, Ca, Mg, Fe, Mn, and incompatible constituents, e.g., Cl, B, Br [3].

The original composition of the rock as the geothermal alteration controlled the temperature, pressure, the chemical composition of the fluid(e.g., CO2, H2S), reaction time, rate of water and steam flow, permeability, and type of permeability, and these products [4].

On the other hand, the fluid generated by geothermal wells can be disturbed by the presence of volcanic sulfide deposits. On the other hand, the fluid generated by geothermal wells can be disturbed by volcanic sulfide deposits. This gas occurs due to the reaction between metal elements and H2s gas. The sulfate ion is very detrimental because it is very corrosive when dissolved in the fluid. These ions cause corrosion in the power plant turbine system; through pitting, stress corrosion cracking, and other corrosion mechanisms. This causes damage to expensive power plant components; like turbines and rotary blades can lead to unplanned shutdowns and extensive maintenance cost [5].

Table 1. Steam purity

No	Date	Iron Fe (ppm)	Silica SiO2 (ppm)	Chloride Cl (ppm)	TDS (ppm)	TSS (ppm)
1	1/29/2019	0.117	0.061	<0.01	<0.30	<0.3
2	2/28/2019	0.021	<0.05	0.011	<0.13	0.39
3	3/28/2019	0.015	<0.05	0.017	<0.12	<0.3
4	4/30/2019	0.058	0.084	<0.01	<0.18	<0.3
5	5/22/2019	0.121	<0.05	<0.01	<0.21	<0.3
6	7/4/2019	0.029	0.050	<0.01	<0.18	<0.3
7	8/8/2019	0.071	0.062	<0.01	<0.18	<0.3
8	9/11/2019	0.018	<0.05	0.011	<0.13	<0.3
9	9/16/2019	0.009	<0.05	0.012	<0.12	<0.3
10	12/17/2019	0.109	<0.05	0.011	<0.20	<0.3
11	2/27/2020	0.010	0.062	0.012	<0.12	<0.3
12	3/11/2020	0.070	<0.05	<0.01	<0.16	<0.3
13	5/6/2020	0.005	0.054	0.015	<0.11	<0.3

In vapor-dominated geothermal fields, routine steam properties, steam purity are monitored to ensure steam turbine including auxiliary's equipment reliability and predicted equipment degradation due to erosion and corrosion issues as described in Table 1.

Another monitored properties of non-condensable gas consisting of one of the most corrosive ions can lead to pitting, stress corrosion cracking, and corrosion mechanisms, as described in Table 2.

Table 2. Non-Condensable gas properties

No	Date	NCG	CO_2	H_2S	NH_3	Ar	N_2	CH_4	H_2
		wt %	mol%						
1	3/27/2019	0.67	94.25	3.80	0.048	0.0022	0.527	0.033	1.34
2	8/2/2019	0.66	94.00	3.96	0.057	0.0021	0.497	0.047	1.44

Steam turbine last stationary blade residual deposit sampling and analysis during overhaul purposes to evaluate potential steam impurities impact the rotary and stationary parts of the steam turbine. Deposit analysis combining with surface equipment will lead to initiate failure mode root cause analysis while required.

2. METHODOLOGY

A deposit sample was taken out from the steam turbine's last stationary blade parts during the shutdown period. The last stationary blades are based on the thermodynamic process showing last stationary blades operate in the lowest pressure nearby dual-phase and accumulate much more than high-pressure stationary blades.

Deposit sample contamination avoidance is requiring during carrying out from stationary blades, as shown in Figure 1. Gentle handling of the Deposit sample preliminary analysis required a sealed or vacuum chamber to minimize excessive vaporized gas in deposits, as shown in Figure 2.

Sample identification is carried out in three types of testing. The first test is the identification of macrostructures as initial observations to estimate the phases formed in the deposited sample.

Figure 1. Gathering process of the sample.

The second test is the identification of various elements contained in the deposit using X-Ray Fluorescence (XRF). These elements show the characteristics of the rocks contained in geothermal sources.

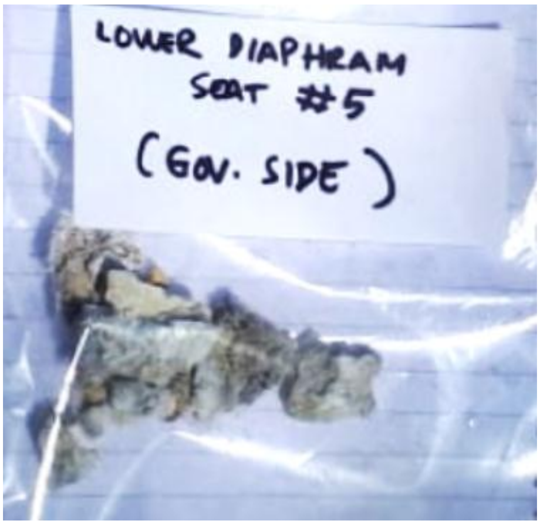

Figure 2. Sealed sample to minimize excessive vaporized gas contains.

The third identification is the identification of the crystal structure formed in the deposited sample. X-Ray Diffraction (XRD) Philips Analytical PW 3050/60 X'Pert PRO instruments were carried out to identify the presence of crystalline structures in the deposited sample. The deposit sample was scanned within the 2θ range of 5–90 with step size 0.0170 using Cu radiation source

(λ=1.54060Å) combine with a monochromator on the secondary optics.

3. RESULTS AND DISCUSSION

Laboratory tests for the deposit samples were carried out with several results; macrostructural features, chemical composition, and phase crystalline structure.

The identification of the macrostructure of the surface sediment sample carried out by an optical microscope is shown in figure 3. On the surface of the deposited sample, it can be seen that the sediment forms lumpy grains that originate from the gas flow nucleation process when attached to the turbine blades. the difference in the color of the crystals indicates a phase difference between the crystal grains. Among these grains, there is a yellow grain which indicates the presence of arsenic compounds [6,7].

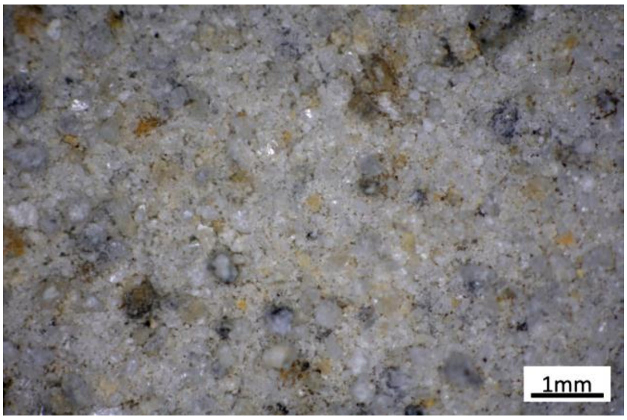

Figure 3. Macrostructure of the deposited sample.

The result of X-Ray Fluorescence (XRF) spectroscopy for the deposited sample had shown in figure 4. The chemical diagram was shown that the compound dominated with the Fe, Sulphur, and arsenic element. Most of the minerals Fe originate from the elements that form volcanic rocks. These minerals form a scale in the pipeline from the wellhead to the turbine inlet [8]. Likewise, elements of sulfur and arsenic are sourced from geothermal alteration rocks [9]. This informs that geothermal energy produced by these wells comes from volcanic activity.

Analysis composition of the deposit element is shown in Table 3. The table shows the presence of sulfur content of 10% wt in the sample deposit. The presence of sulfur triggers ionic corrosion on the surface of the stationary blade. The accumulation of sulfur content indicates the occurrence of pitting corrosion on the stationary blade's surface [10,11].

The Fe content in the deposit samples is thought to have come from corrosion that occurs on the stationary blades due to its reaction with sulfur. This allegation needs to be proven by comparing the results of damage due to corrosion on the stationary blade.

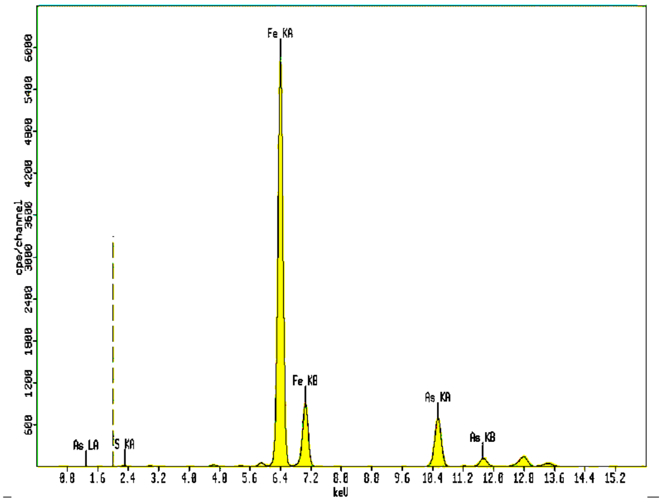

Figure 4. Sample Chemical element.

Table 3. The element of the sample.

Element	Description	%wt
S	Sulphur	10.8
Fe	Ferro	83.85
As	Arsenic	5.35
Total		100

XRD examination results are shown in Figure 4. The peak diagram shows that there has been a crystallization process on the surface of the stationary blade. These crystalline structures consist of two-phase which are 89.7%wt Iron sulfide phase (FeS) and 10.3%wt Arsenic Tri sulfide phase [12–15]. The structure of the FeS phase has a hexagonal form. Naturally, the FeS phase compounds are generally found in the Earth's core layer or in meteorite rocks that fell to Earth [16,17].

However, the presence of FeS content coexists with the presence of sulfur in the deposits on the surface of the stationary blades, indicating that the FeS is also derived from sulfur corrosion against the steel of the stationary blade. the chemical reaction takes place as follows:

$$H_2S + Fe \rightarrow FeS + 2H \quad (1)$$

In addition, the presence of the Arsenic tri-sulfide compound phase obtained by XRD was in line with the results of the visual identification of the macrostructures using optical microscopy. This arsenic tri-sulfide forms a monoclinic structure. Generally, this phase is yellow or red, solid or crystalline powder, flammable, insoluble in water, toxic by inhalation and if swallowed [6,7,18–20].

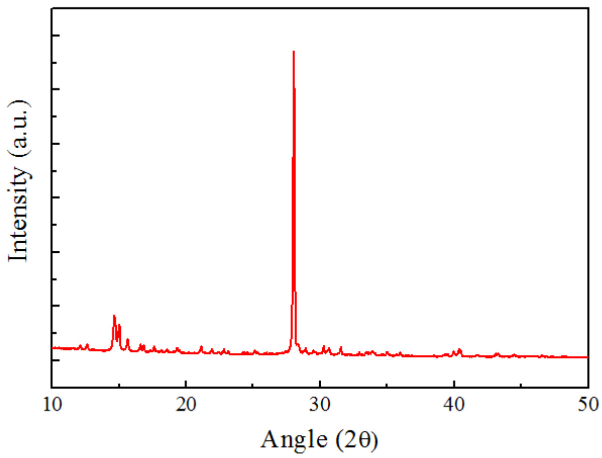

Figure 5. Sample XRD Pattern.

This indicates that the deposited sample contains toxins that can harm health. So that special handling is needed when carrying out the cleaning process of the deposits formed against the deposited waste. In addition, the presence of arsenic tri-sulfide compounds in the deposits will increase the corrosion process on the blade surface. This compound will trigger oxidation on the surface of the stationary blade [21].

To reduce those deposits and inhibit corrosion on the blades, downstream steam pipe maintenance is required. These treatments include scrubbing or steam washing. For this reason, special handling is needed considering that the deposit contains toxic compounds which can cause casualties and pollutes the environment.

4. CONCLUSION

Laboratory test results on deposit samples show the presence of sulfur compounds. The presence of this compound in the last stationary blades indicates that corrosion has occurred. Along with it, was also found the presence of arsenic tri-sulfide which is poisonous.

Downstream steam pipeline treatment is required to reduce sulfide carried away into steam turbines such as scrubbing or washing steam. however, special handling is needed for arsenic tri-sulfide compounds that also formed in the deposited sample.

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