Health Monitoring of Induced Draft Fan in an Aluminium Smelter

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Abstract. Maintenance is highly essential as to support the machine availability, product quality and plant safety. The timely repair at minimum cost is the basic criteria for good maintenance. Appropriate maintenance can sustain continuous and reliable operation with reduction in down time, high productivity, number of secondary failures, low inventory level and accident of the plant. In spite of high initial investment, most of the industries adopt condition based maintenance (CBM) to avoid sudden disruption in production. CBM is an important tool which includes observing, monitoring, diagnosis and prognosis for running a plant seamlessly, as this maintenance planning and actions have become an integral part of engineering investigation. In this paper, condition monitoring of Induced Draft (ID) fan in an Aluminium smelter has been done while it was in operation. The vibration of ID fan was measured and analyzed to detect the defect of its impeller and corrected subsequently.

Keywords: ID fan, Aluminium smelter, condition monitoring, vibration analysis.

1. Introduction

Aluminium is the most useful engineering material, next to ferrous metal. Aluminium is a good conductor of heat and electricity. It is lighter than other engineering material. The main areas of application in which aluminium is used are; electrical conductors, air craft, packaging, transportation and building materials. It is also extensively used in cooking utensils, electrical cables and telephone wires.

Aluminium is produced in mainly through two stages; mining and refining, smelting and casting. Aluminium refining is done by separating of aluminium oxide (or alumina) from the bauxite. Aluminium smelting is carried out through the electrolysis process [1]. The electrolysis is done in an iron vat, which serves as the cathode and carbon anodes are immersed for the electrolysis. Upon passage of electrical current through the anodes and electrolyte, the molten aluminium metal is deposited at the bottom of the vat/pot. The tapped metal is transferred to cast house. The molten metal is maintained at the suitable temperature of 750 °C (approx) in the furnace and cast as ingots, billets, slabs etc. in the cast house.

Besides availability of Raw materials like Alumina, Power & Carbon anodes, Continuous production of Aluminium from a Smelter also depends on the availability of its machine and machinery systems of the plant. To get maximum availability, it is essential to keep the machines and equipment in good operational condition. To achieve this, proper maintenance strategies and planning are required [2, 3, 4, 5 & 6]. The different types of maintenance strategies are as follows;

i Breakdown maintenance
ii Routine Maintenance:
iii Precautionary Maintenance
iv Condition Based Maintenance (CBM) through condition monitoring.

In spite of high initial investment, many industries adopt CBM to reduce unexpected shut down and accidents. It measure and monitors the condition of the machines using diagnostic tools and techniques, while it is in operation and the maintenance is done only when it is really necessary.

1.1 Condition Monitoring

Condition monitoring (or CM) determines the health and condition of machines and machinery systems by observing, checking, measuring, interpreting and monitoring certain parameters. CM provides information of the machine condition before it is going to fail. It helps in improving the reliability of the machines. It is used to check the machine while it is in operation and it gives indication (in advance) of deterioration before the breakdown occurs. There are different methods and techniques of CM, described as follows;

i. Performance monitoring

ii. Visual, optical, tactile and aural monitoring

iii. Temperature monitoring: If there is unusual heat generation in any running equipment, then that indicates presence of a probable defect (or abnormalities) in it [7].

iv. Vibration monitoring: Vibration analysis can be employed for the diagnosis of all types of defects in rotating element of the machine [8].

v. Lubricant Monitoring & Wear debris analysis: Lubricant Monitoring necessitates the lubricant condition in a bearing or gearbox to find out degradation in lubricant chemistry, water contamination and wear quantum. The debris, or particles, present in lubrication oil that could indicate type, size and texture of wear particles [9].

vi. Noise monitoring: The measurement of a machine’s sound can also be employed for detecting the defects, present in the running machines. The accuracy of this method depends on the differential sound pressure level [10].

vii. Motor Current Signature Analysis (MCSA): It is the technique used to diagnose problems in induction motors or motor driven rotating machines [11].

viii. Ultrasound/ultrasonic monitoring

ix. Leakage Monitoring

Since, the CBM’s initial investment is high; prior assessment is required before the implementation of CBM. Generally, Failure Mode, Effect and Criticality Analysis (FMECA) is done to classify the critical machines before going to execution of CBM of an industry.

1.2 FMECA through RPN

FMECA [10] analyze the probable component’s failure modes, assess the risk associated with these failure modes and find out the resultant effects on system. The main steps are:

a) Identifying the machines to be analyzed.

b) Identifying the function(s), failure(s), effect(s).

c) Evaluating the risk associated.

d) Prioritizing and assigning corrective actions.

There is a tool, used to determine the criticality of the machines. i.e. Risk Priority Numbers (RPNs). The RPN is the product of severity (S) x difficulty to detect (D) x occurrence (O). Each one is evaluated with a scale from 1 to 10 and the highest RPN is 1000 (i.e. 10x10x10). That indicates failure is not detectable by inspection, very severe and the occurrence is almost sure. So, RPN enables to focus on the highest risks.
2. Methodology and Experimentation

The present work is based on the Aluminium Smelter in Vedanta Limited (VL), Jharsuguda, India. The plant has two smelting units (capacity of total 1.75 MTPA). The firm has collaborated with GAMI, China. It adopts rigorous health and safety measures for the machines as well as for the employees. Most of the machines are maintained through the CBM. Aluminum smelter has mainly four sub units; Green anode plant (GAP), Pot room/pot line, Cast house, Rectifier and switchyard. In pot-line, there are four important machines; pot trending machine (PTM), Induced draft fan(ID fan), Compressor and Cooling tower. In this paper, the condition monitoring of Induced Draft fan (ID fan) using vibration analysis has been described.

2.1 FMECA of Aluminium Smelter Plant

FMECA Analysis is done for all individual machines and the same is reviewed once in a year which is a normal practice in Smelter Plant of Vedanta Limited. After considering of all three parameters, the RPN of all essential machines are evaluated and are mentioned in Table 1. The said FMECA analysis says that ID fan is the critical equipments of the Smelter Plant.

| SN | Equipments   | S  | O  | D  | RPN | Remark       |
|----|--------------|----|----|----|-----|--------------|
| 1  | PTM          | 8  | 6  | 4  | 192 | Very Critical|
| 2  | ID fan       | 6  | 7  | 5  | 210 | Very Critical|
| 3  | Compressor   | 5  | 7  | 3  | 105 | Critical     |
| 4  | Cooling tower| 5  | 5  | 3  | 75  | Non Critical |

Note: For this analysis, (i) RPN ≥ 150 is considered as very Critical, (ii) RPN in between 150 and 100 is considered as critical, (iii) RPN <100 is considered as Non critical.

3. Condition monitoring of ID fan of Aluminium Smelter

During the electrolysis process, the oxygen from Alumina (Al₂O₃) reacts with the carbon in the anodes, forming carbon dioxide which bubbles off. Besides these, other unwanted fumes are also being generated, which pose health hazards to the people working in Pot Line. To remove these fumes, ID fan is used. It evacuates the hot fumes from the pots to the Fume treatment plant (FTP). After treatment in FTP to remove the hazardous elements, the residual gases are discharged to atmosphere.

3.1 Specification Details:

Motor Power: 1400KW, Speed: 990 RPM, Motor’s NDE (Non-Drive End)/ Outboard Bearing: NU 1032, Motor’s DE (Drive End)/ Inboard Bearing: NU 1034 & 6034, Fan DE & NDE(Both Inboard & Outboard) Bearings: 22236, Vibration velocity (RMS) limit (as per OEM); Normal: below 4.5 mm/s, Sub critical: 4.5-6.5 mm/s, Critical: above 6.5 mm/s.
Figure 1 (a): Induced Draft (ID) Fan set up

Figure 1 (b): Diagram of an ID Fan (Schematic)

3.2 Diagnostic Symptoms

The ID Fan is monitored through the vibration analysis. The data are recorded and analysed by using accelerometer and AMS Suite Software. A case study (i.e. condition monitoring of ID fan-3, Pot line-1 of Smelter-1) was carried out during February 2020 and has been considered here. Vibration measurement has been done in three different directions namely; horizontal (H), vertical (V) and axial (A). The RMS values are shown in Table 2. Similarly, the vibration spectra are shown in Figure 2 and Figure 3.

Table 2: RMS value of vibration (in mm/s)

| Location       | Direction | 8th Feb | 10th Feb | 15th Feb | 22nd Feb | 27th Feb | 28th Feb | 1st Mar |
|----------------|-----------|---------|----------|----------|----------|----------|----------|---------|
| Motor Outboard (NDE) | H         | 3.274   | 3.448    | 3.634    | 6.194    |          |          |         |
|                | V         | .419    | .406     | .757     | .818     |          |          |         |
|                | A         | 1.130   | .882     | .603     | 1.230    |          |          |         |
| Motor Inboard (DE) | H         | 4.760   | 3.004    | 3.036    | 5.646    |          |          |         |
|                | V         | 1.089   | .929     | .678     | 1.215    |          |          |         |
|                | A         | .733    | .812     | .397     | .994     |          |          |         |
| Fan Inboard (DE) | H         | 4.585   | 3.356    | 2.816    | 5.103    |          |          |         |
|                | V         | 1.064   | .417     | 1.119    | 1.182    |          |          |         |
3.3 Observations and Analysis

i. After evaluating the vibration (rms) readings (from Table 2), it was observed that (on 22nd Feb.) the motor drive end & non-drive end vibrations amplitude in the horizontal direction were comparatively higher than the vibration values of other directions and very much nearer to the critical limit. That indicates that there is some problem in rotating masses of ID fan.

ii. It is observed from the spectrum (Figure 2) that the vibration amplitude at rotational frequency/speed (i.e. 994 cpm) is quite high. It indicates there is unbalance of rotating mass.

iii. There are no peaks at non-synchronous frequency. So, there is no possibility of bearing defect.

As per recommendation, balancing of fan impeller has been done. It is observed that due to handling of hot gases/fumes, an impeller-blade is worn out, thus making the impeller unbalanced. After balancing of the impeller, the ID fan was put into operation. Subsequently, the vibration measurement in was taken & the RMS value was found to be normal as indicated in Table-2 on 28th Feb. The 1xRPM amplitude in the vibration spectrum taken after the correction (Shown in Figure 3) has also decreased considerably. In last 6 years, for the first-time balancing has been carried out for a FTP-ID Fan. All the remaining ID fans in smelter plant are normal.
4. Summary

Condition monitoring is used to find out the forthcoming defect (or abnormality) of the machine and machinery element. Among all techniques, vibration analysis is very strong and reliable technique for condition monitoring of rotating machineries like; ID fan in Aluminium smelter plant etc. Vibration measurement and analysis can be online or off line. If the measured values deviated from the usual trend by a certain extent, then the data and trend are studied thoroughly. According to the trend and symptoms, the appropriate measures are suggested for the suitable maintenance. The timely repair and maintenance increase the availability of plant machineries and equipments. Ultimately, the condition monitoring helps in improving the efficiency, reliability and safety of the plant.

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