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Root Cause Analysis for the Failure of a Forced Draft Fan in a Petrochemical Industry

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Abstract:- Fans are probably the simplest types of rotating machinery. In many industries the stoppage of a fan used for creating a forced draft would cause a complete plant shutdown. This paper uses root cause analysis for finding out the reason for the failure of a forced draft fan based on a study conducted in a petrochemical industry. This force drought fan is used for supplying air from atmosphere to the boiler. The boilers is used for producing the steam required for the entire plant and also for generating most of the Power required for the plant to run. As failure of the boiler is critical problem, it was found out that vibration was the cause for it and vibration in turn caused bearing failure. In order to reduce vibration levels within the fan setup, some improvements are suggested.

Keywords:- Forced draft fan, Route cause analysis, Fish bone diagram, Pareto chart, Vibration.

I. INTRODUCTION

Beneath every problem their lies certain cause for it. In order to solve a problem, one must identify the cause of the problem and take steps to eliminate the cause. If the root cause of a problem is not identified, then one is merely addressing the symptoms and the problem will continue to exist. For this reason, identifying and eliminating root causes of problems is of utmost importance (Andersen and Fagerhaug 2000; Dew 1991; Sproull 2001). In this paper a root cause analysis methodology based on the combination of Pareto analysis and fishbone diagram is presented. The fishbone diagram is used to sort the potential causes of the failure while organizing the causal relationship. The Pareto analysis is used to identify the major causes. The Pareto analysis, which is also known as 80–20 rule, is named after the Italian economist Vilfredo Pareto. The principle states that for many events, roughly 80% of the effects/problems come from 20% of causes. The Pareto analysis helps focusing the attention on the most important causes instead of wasting time and energy on minor ones. This methodology is able to help the designers focus the attention on the most important fundamental causes and discover opportunities for sustainability improvement. The root cause analysis is done on the failure of a forced draft fan in an industry which produced Caprolactum. Caprolactum is used as the raw material for the manufacture of Nylon-6, which finds extensive application in textiles and engineering products. To its high quality the production have been acknowledge as among the best in the world. The plant has a captive power plant which houses three boilers of capacity 60 tonnes/hr. each. Steam is generated at 110 kg/cm2 abs. and 510 degree Celsius. At normal conditions, two boilers are operated, providing a total of 110.227 tonnes of steam per hour. When maximum power is required, all three boilers together produce 151.116 tonnes of steam per hour. The plant capacity is 16MW and in normal situations 8MW of power is produced. Full capacity of plant is utilized when there is shortage of power from government power supply. To produce 15MW of power, steam requirement is 129 tonnes per hour. At normal operation (for 8MW), steam requirement is 96.5 tonnes per hour.

Draft is defined as the difference between atmospheric pressure and the static pressure of combustion gases in a furnace, gas passage, flue or stack. Mechanical draft is created by the use of mechanical fans. They may push the air and combustion gases through the boiler, in which case they are called forced draft fans. Figure 1 shows the forced draft fan under study. The air supplied by the FD fan helps in burning the furnace oil which is atomised and sprayed in to the boiler. The rest of the paper is organised as follows: Section 2 includes the problem definition and explains how critical this forced draft fan is to the working of this industry. Section 3 describes the methodology used for identifying the root cause of the problem and section 4 states the required recommendations. In section 5 concluding remarks are stated.

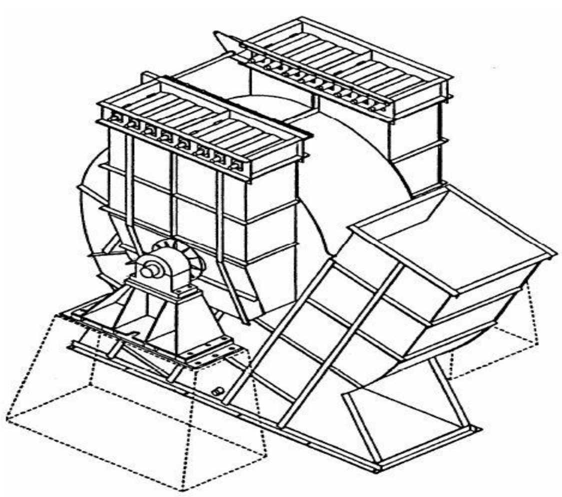

Fig. 1: Forced draft fan

II. PROBLEM DEFINITION

Even after producing 24X7, the industry is not able to meet its demand in the market and it is running under a loss. In order to reduce losses, unwanted stoppage of production should be eliminated. The failure of a forced draft fan is the current problem being faced. FD fans are used to supply fresh air for combustion into the boiler. The whole system is being shuts down due to the failure of a forced draft fan, causing a serious shortage of steam. Steam is required to generate power and the lack of it causes a serious power crisis. After a shutdown it is very expensive to restart the plant as each major pipe lines and critical equipment's should be checked. Before permitting the full-scale operation of the plant test runs are needed to ensure safety. This process takes a lot of time and money. The working of the forced draft fan is very critical for the boiler to function and the failure of this fan during normal operation conditions can cause a lot of financial loses. Breakdowns are the most common causes of efficiency loss in manufacturing. Eliminating unplanned down time is critical to improving the financial health of the industry. In order to eliminate fan breakdowns it is required to determine the root cause for its failure and appropriate methods to be adopted for its smooth functioning.

A. Forced draft fan

The forced drat fan used is a centrifugal fan, the fan blades are mounted in an impeller that rotates within a spiral housing. They are designed with two inlets dampers, and normally run at constant speed with flow and pressure controlled with inlet dampers. Backward curved blades are used which have an aerofoil shape and are most widely used in power plant operations. The motor shaft is connected to the impeller shaft with the help of a grid coupling. The working of the fan helps to create a forced draft. The created draft pushed the air and combustion gases through the boiler and then into the chimney.

III. METHODOLOGY

Root cause analysis (RCA) is a process designed for use in investigating and categorizing the root causes of events. The working process to identify the root causes is shown in figure 2. The possible causes of failure are described with the help of a fishbone diagram. It is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. In figure 3 the causes are categorized into four main sections: material, equipment, machine and labour. These four section form the side bone leading to the centre bone, which points towards the head which represents the effect 'Failure of FD fan'. Each side bones have secondary bones which represent the causes within the primary bone. An outer branch is a cause of the inner branch it is attached to, vibration in the machine is responsible for the failure of the FD fan.

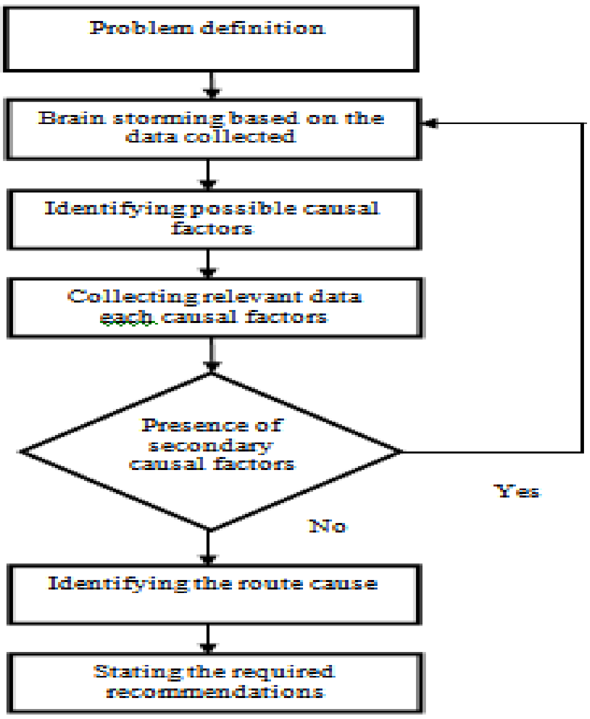

Fig. 2: Methodology

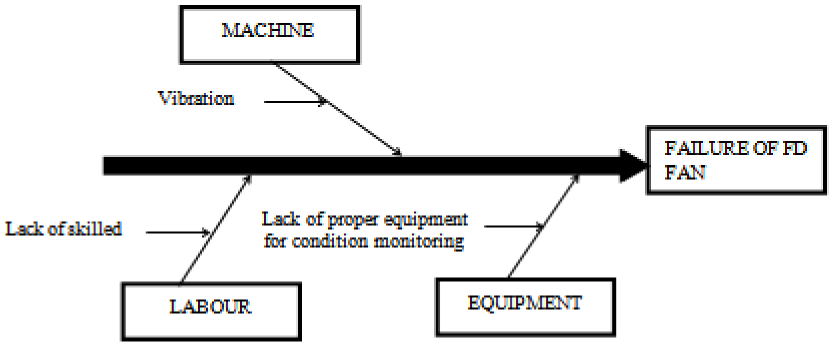

Fig. 3: Fish bone diagram

The data obtained from the maintenance log sheet are plotted on a Pareto chart in figure 4. It can be seen that 80% of the problem is due to machine faults.

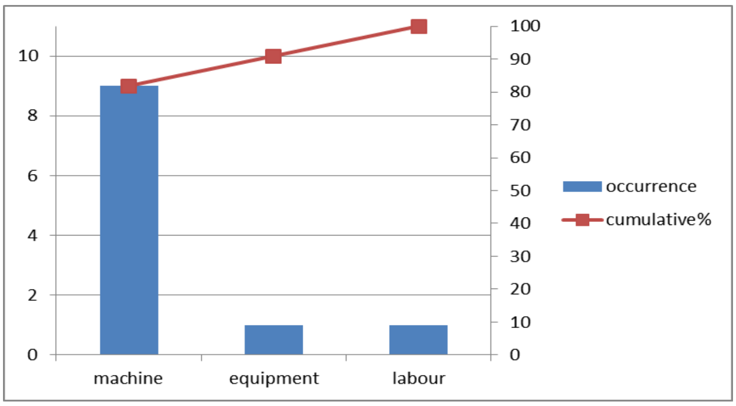

Fig. 4: Pareto chart

Vibration is defined as the movement of a body about its reference point. In machines, vibration can indicate problems or deterioration in the equipment. Machine vibration can be defined as a dynamic response to a dynamic force and an increase in force is extremely detrimental to bearing [13]. i.e the life of the bearing decreases due to vibration. A spectral analysis was conducted to find out the causes of vibration near the inboard bearing section. Spectrum readings were taken in the vertical, horizontal and axial direction. The spikes in the spectrum were concentrated around the 1xRPM and 3xRPM range, which indicates the unbalance and misalignment in the machine. The deterioration of machine components is found out by comparative analysis. Comparative analysis directly compares two or more data sets in order to detect changes in operating condition of machine. The obtained spectrum reading was compared with the previous data collected and three problems were identified. They are

1. Unbalance of the impeller
2. Misalignment of coupling
3. Misalignment of base & fastener failure

The various problems within each case are listed out in the fish bone diagram shown in figure 5.

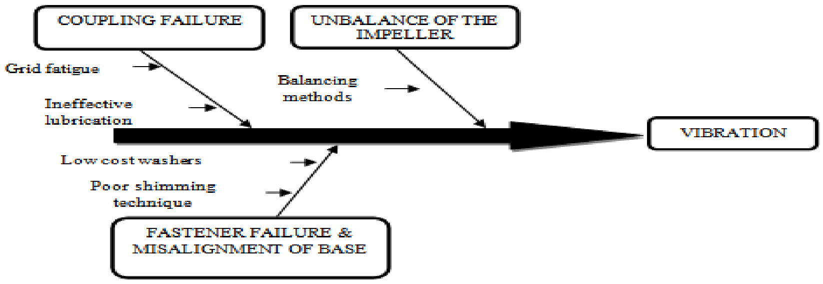

Fig. 5: Fish bone diagram

The industry maintenance log sheet was inspected to find any previous failures regarding the three causes. It was found that there were nine cases, where the maintenance crew were alerted for increase in vibration during the past 2 years.

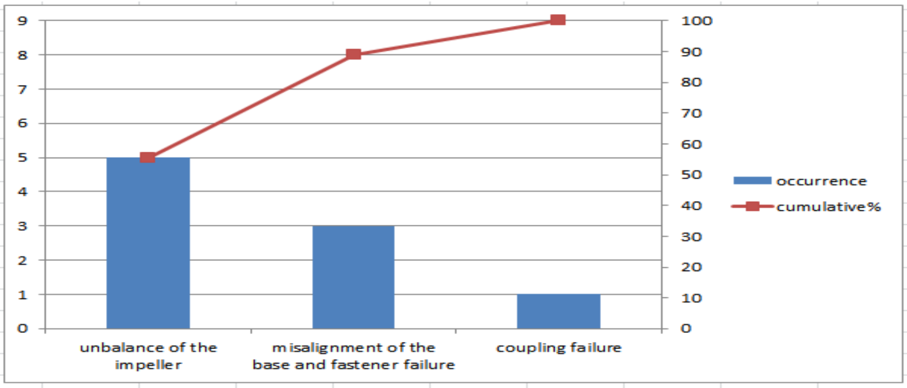

Fig. 6: Pareto chart

In order to highlight the major problems a Pareto chart was constructed, which is shown in figure 6. It can be noted that 80% of the vibration is due to unbalanced impeller and misaligned base and fastener failure. Impeller unbalance is caused due to material erosion or corrosion on the impeller blades. Erosion on the blades is caused due to suspended particles in the air. Erosion and corrosion cannot be controlled as the industrial environment is polluted.

Therefore it can be concluded that forced draft fan failure is caused due to bearing damage and it can be avoided by eliminating unbalance in the impellor and misalignment of base & fastener failure.

IV. RECOMMENDATION

In order to eliminate downtime of the forced draft fan it is necessary that unbalance and misalignment should be reduced. In order to reducing the unbalance in the impeller and misalignment of base & fastener failure the following recommendations should be considered.

1. Install an active balancing system.
2. Use quality shim’s for aligning the base.
3. Use wedge lock washers to tighten fasteners

A. Active Balancing Systems

Active balancing can be defined as correcting an imbalance in machinery while in operation. It is much faster and more effective than conventional "off-line balancing techniques. By controlling vibration at its origin, active balancing systems can eliminate motion control problems before they spread throughout a structure. The balancer is installed permanently onto the rotating shaft, sensors continuously monitor the vibration levels while running. When an increase in vibration is detected above a pre-determined level, the controller initiates an advisory message as to the change in state of the unbalance. It then instructs the balancer to make an automatic balance correction. Balance adjustments can be made during start-up, normal operation and shut-down. The Figure 7 shows the basic set-up of an active balancer.

The balancing systems provide the ability to continuously monitor the state of balance of the rotating system. Rather than "covering up/masking," a balance problem, the balancing system continuously reports the state of the system's unbalance, thus providing diagnostic information used to predict system health and optimize service outages. [5]

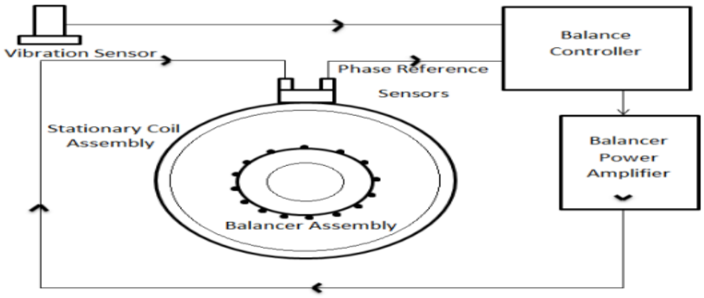

Fig. 7: Layout of an active balancer [14]

B. Aligning the base

The base is aligned by pacing small pieces of metal in between the gaps. This thin piece of metal is called as a shim. It helps in providing a better fit and also a levelled surface. It was found that the workers used hand cut sheet metal to adjust the alignment of the forced draft fan base and alignment is done based on rough ideas. The end result is a less precise alignment. Stacking up of shims can result in soft foot. The term "soft foot" is the common term used for the improper contact between a machine casing, and the baseplate used to support it. Soft foot is a common issue when aligning rotating equipment. It is a major cause of repeatability problems in shaft alignment measurements. In addition to alignment quality and repeatability problems, it can be a cause of machinery vibration. In order to avoid such problems it is advisable to use high quality pre-cut steel shims. The Figure 8 below shows a pre-cut shim.

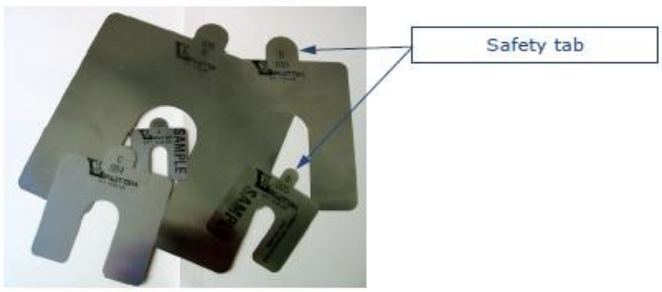

Fig. 8: Pre-cut shim [10]

1) Shimming techniques

The following shimming techniques should be followed for proper base alignment [10]

1. The number of shims used under a foot should be reduced to 3 or at the maximum to 4 as excess number of shims under a machine foot leads to increase risk of exceeding the allowed soft foot tolerance.
2. Always sandwich the thinner shims between the thicker ones to protect them. This helps to increase the life of the shims.
3. Make sure that the shims don't get caught in the threads of the bolt.
4. Always handle the shims by grasping them at the safety tab.

C. Fastener

A fastener is a hardware device that mechanically joins two or more objects. Here in our case threaded fasteners are used to bolt the Forced draft fan on to the base. If the bolted joints are loose, it leads to heavy vibration, which affects the smooth performance of high speed rotating parts. The bolts often come loose due to dynamic vibrations. The bolt always tends to loosen due to the angle of the thread. In static conditions loosening is prevented due to friction on the thread form bolt or nut surfaces. Any movements between the parts and the joints jeopardize the security. When the material under the nut vibrates laterally the nut starts to loosen and the tension stops.

Methods used for securing bolts is based on increased friction on the threads and towards the material used. This can be done by using a nylon insert in the thread plain washer or using spring washer. These methods were proven inefficient by a German engineer Gerhard Junker who showed that transverse vibrations cause loosening of bolts. Experiments were conducted on the junkers transverse vibration test machine and found that the preload decreased readily. The Junker vibration test meeting DIN 65151 (Dynamic testing of the locking characteristics of fasteners under transverse loading conditions - vibration test) standards is a common and reliable method for testing and comparing the security of bolted joints. The" Junker's" transverse vibration-loosening test provides a simplified method for broad scale testing and inspection of the transverse vibration (loosening) properties of fasteners. The test machine is able to generate relative motion in the clamped parts perpendicular to the axis of the fasteners. The Junkers method provides quantitative results relating the variables of clamp-load, number of cycles, and amplitude. The Figure 9 given below shows a transverse vibration test machine.

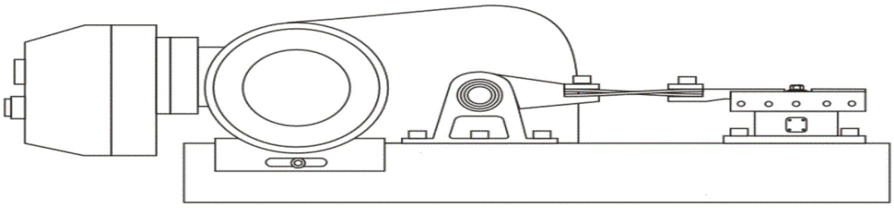

Fig. 9: Junker’s vibration testing machine [12]

In order to have a tight bolted joint and to reduce loosening, wedge lock washer should be used. The wedge-shaped lock washers have wedge (cam) surfaces on the inside and radial ribs on the outside. They are installed in pairs, cam face to cam face. When the bolt is tightened the teeth grip the mating surface. The washers lie still during tightening when the sliding is toward the upper washer. Since the teeth causes some extra tightening resistance. While unfastening, the teeth grip and the washer slide over the cams where the friction is lower. The Figure 10 shows a wedge lock washer. The cam angle is greater than the pitch of the bolt consequently the cam action generates a small increase of the force before the bolt is completely unfastened.

Fig. 10: Wedge lock washer [11]

While unfastening there is an increase in bolt force due to the wedge surface. This property does not allow the bolt to become loose. The tension does not reach the yield point while unfastening. There is no risk of stretching the bolt. A bolt locked with wedge lock washers doesn’t turn due to dynamic loads, it can never vibrate when loose. The cam action causes tension and not friction which results in the bolt to get locked.

V. CONCLUSIONS

By using root cause analysis it was found out that the bearing failure in the fan was mostly due to imbalance in the impeller & misalignment of base and fastener failure. It is recommended that the active balancing system can be implemented to monitor and correction imbalance in the rotating system. It simultaneously alert’s the maintenance department about any increase in vibration. Due to current unhealthy financial structure of the industry, it is recommended that such preventive measures should be taken to ensure long life for the bearings and this will help in predicting the life of the bearing in a better way. It is also suggested that by following proper shimming techniques and by replacing ordinary bolt washer with wedge lock washers, vibration can be reduced. This method ensures better life and reduces the vibration in the forced draft fan to a large extent.

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