

Vibration Reduction through Centrifugal Fan Balancing in Painting Line Manufacturing

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Abstract: In the context of predictive maintenance, vibration analysis provides insight into the condition of rotating components by interpreting vibration amplitude and frequency characteristics. This helps maintenance professionals identify and classify damage before it reaches critical levels. According to ISO 10816, vibration severity can be systematically evaluated to determine whether a machine is operating within acceptable limits. This study successfully investigated and resolved high vibration levels in a rigid-mounted centrifugal fan used in a cement plant. Initial vibration measurements revealed critical levels of unbalance and misalignment, with horizontal amplitudes as high as 7.50 mm/s at the vertical fan drive far exceeding ISO 10816 acceptable limits. A structured static balancing procedure was then conducted using trial weights (5 g, 17 g, and 20 g), with the 5 g weight yielding the most stable response.

Keywords: Exhaust fan centrifugal, Fan, Fan Balancing, Painting booth, Vibration.

1. Introduction

Exhaust fan is one of the most widely used tools in the industrial world. Almost every industry uses exhaust fan as a way to support existing production processes. Exhaust fan works to absorb air in the room to be released outdoors, while at the same time pulling fresh air out into the room. Centrifugal fans are essential to the operation of painting line manufacturing plants, where they are responsible for managing airflow, regulating painting booth and mill temperatures, and supporting dust collection systems [1]. These fans typically operate in dusty, high-load environments with rigid mounting conditions factors that increase their vulnerability to vibration-related faults. High vibration levels in such fans can lead to a cascade of mechanical failures, reduced reliability, and unplanned downtime, all of which have a significant impact on production and maintenance costs. In addition, the exhaust fan can also adjust the amount of air that will be distributed in the room [2]. Excessive vibration in rotating machinery can cause unacceptable levels of noise and, more importantly, substantially reduce the life of shaft bearings [3].

Hence, the ideal would be to remove all causes of vibration and run the unit totally "smooth". Unfortunately, in practice, the ideal cannot be achieved and, whatever one does, some inherent cause of vibration, or unbalance, will remain. The best one can

do is to reduce this unbalance to a level that will not adversely affect the bearing life and will reduce noise levels to an acceptable level. The process of reducing the out-of-balance forces that cause vibration in rotating machinery is called "Balancing". The unbalance is caused by an effective displacement of the mass centre line from the true axis caused by some mass eccentricity in the unit [4]. The process of "Balancing" is the removal or addition of weight to the unit such that this effective mass centre line approaches the true axis. Where balancing grades or levels are referred to here, and in subsequent sections, they are referenced to ISO1940.

Any rotor with an uneven distribution of mass about its axis of rotation has an unbalance. A rotor with an unbalance caused by an extra mass m [5]. A similar effect is created by out-center machining, nonuniform winding in armature, blades of different sizes on rotors, internal flaws in casting and uneven density of material etc. when the rotor rotates the extra mass m exerts a centrifugal force [6]. This centrifugal force moves around with the rotating mass and causes deformation to the shaft and vibration to the system. Since excessive vibrations are objectionable, we try to reduce them and this is done by the unbalance.

The vibration characteristics of a machine can describe the condition of unwanted movements in machine components [7]. Vibration in fans is generally related to various mechanical factors, such as impeller imbalance, flow disturbances, and wear on certain components [8]. Rotational imbalance will cause high-level vibrations at the same frequency as the shaft's rpm. Using this technique, a rotating machine can be monitored at a specific position to determine its condition. To overcome this problem, a balancing process is needed, namely adjusting the mass distribution on the impeller or blower, in order to reduce vibration to a minimum and ensure more stable operational performance [9]. Therefore, the impeller should be balanced dynamically, in two planes of correction [10].

To correct imbalance, two primary balancing methods are applied: static balancing and dynamic balancing. These differ in procedure, precision, and application depending on the machine's design and operating environment.

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A. Static Balancing

- a. Static balancing involves adjusting the mass distribution of a stationary rotor so that its center of gravity aligns with the axis of rotation. It is particularly beneficial for:
- b. Low-speed, rigidly mounted centrifugal fans where imbalance is primarily static.
- c. Situations with limited access or safety constraints, where rotating the fan is impractical,
- d. Field conditions with minimal resources, due to its simplicity and low cost.
- e. However, static balancing has limitations:
- f. It cannot correct couple or dynamic imbalance, which is more prevalent in longer or flexible rotors.
- g. Residual vibration may persist at higher speeds or in rotors with distributed mass asymmetry.

B. Dynamic Balancing

Dynamic balancing analyzes the rotor in motion and corrects both static and couple unbalances. It is ideal for:

- a. Medium- to high-speed centrifugal fans and rotors with flexible shafts.
- b. Comprehensive balancing across multiple planes, resulting in more precise vibration correction,
- c. Extended machine life, through reduction in bearing and seal stresses.
- d. Despite its accuracy, dynamic balancing presents several challenges:
- e. It demands specialized equipment and technical expertise,
- f. Requires the rotor to be run under controlled conditions—posing safety and access concerns, especially in dusty, high-temperature environments like cement plants,
- g. Increases maintenance cost and downtime compared to simpler methods.

2. Methodology

This research begins with conducting field studies to determine the current state of the centrifugal exhaust fans of painting line and the historical analysis of the damage that has taken place so far as well as the refinement efforts have been made. Methods used are visual methods or direct observations to exhaust fan units and direct interviews. From the check carried out, find out what the problem is in the centrifugal exhaust fan. One of the preventative maintenance efforts carried out by the parties is to analyze the condition of the motor and pump (state monitoring) using visual vibration monitoring and cleaning at the impeller [11].

Visual observations were made on the fan or motor components damaged during disassembly. Vibration data collection was conducted on two parts: one side measuring bearing 1 and two, and the other side measuring the electric motor that drives the fan. Three measurements were collected on each side: vertical, horizontal, and axial. The locations and directions of vibration data collection are shown in the figure

below.

The results obtained from vibration testing are in the form of vibration magnitude values, but this data must first be processed into a vibration spectrum to analyze damage symptoms. The vibration values are read by the sensor in mm/s using acceleration, which is interpreted in an accelerometer graph each time [2].

Once the spectral graph is obtained, the vibration values are analyzed and compared to the ISO 2371 standard, as shown in Figure 2. The analysis is performed according to the centrifugal safety limits and the motor category used. Problem identification and selection of appropriate treatment for motor and pump problems are obtained from the analysis of the vibration test data graph.

VIBRATION RATION AMPLITUDE VIBRATION VELOCITY V rms (mm/sec)	MACHINE SORT			
	I	II	III	IV
0 – 0,28	A	A	A	A
0,28 – 0,45				
0,45 – 0,71				
0,71 – 1,12				
1,12 – 1,8	B	B	B	B
1,8 – 2,8				
2,8 – 4,5	C	C	B	B
4,5 – 7,1	D	D	D	D
7,1 – 11,2				
11,2 – 18				
18 – 28				
28 – 45				
> 45				

Note :
 Class I is small motor (power less than 15 kw).
 Class II is medium motor (power between 15 - 75 kw).
 Class III is high motor
 Class IV is high motor

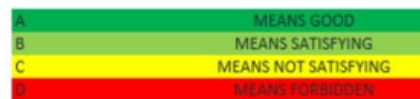


Fig. 1. Rank of machine vibration (ISO 2371)

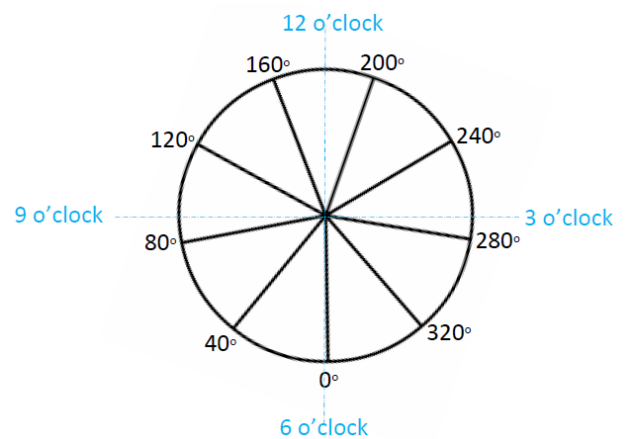


Fig. 2. Impeller divisions for static balancing reference points

Surface Preparation with the use of wire brush to remove contaminants and buildup of materials from the impeller to ensure accurate balancing and secure placement of weights. The

impeller was manually rotated and allowed to settle. The spot at 6 o'clock position was identified as the heavy spot and marked as 0° presented in figure 3. The impeller was divided into nine 40° intervals, corresponding to the 9 blades. At 12 o'clock was designated for trial weights as it is directly opposite the heavy spot. A 5g trial weight was mounted at 12 o'clock. The fan was manually rotated to balance the high sport. Subsequently, 17 g and 20 g were tested. The 20 g weight gave the best settling behavior, effectively offsetting the heavy spot. The fan was assembled back and operated with the 20 g trial weight at 12 o'clock and vibration measured and recorded.

3. Result & Discussion

This section presents and discusses detailed findings from vibration analysis, mechanical intervention, and static balancing performed on a painting booth centrifugal fan. As outlined in the methodology, a structured diagnostic and corrective process was used to reduce excessive vibration to acceptable operational levels. The primary objective of this chapter is to demonstrate how a systematic approach, combining mechanical correction, shaft alignment, and static balancing, effectively mitigated a severe vibration problem and restored fan performance to acceptable ISO 10816 standards.

At the beginning of the analysis, the fan exhibited extremely high vibration levels at all three measurement points, indicating critical operational conditions. These readings significantly exceeded the ISO 10816 acceptable limits for industrial machinery, especially considering the rigid fan mounting.



Fig. 3c. Initial vibration check (axial)

This severe condition required an immediate and thorough mechanical inspection and alignment and balancing intervention on the exhaust fan system. The vibration values were presented in table 1.

Table 1
Initial vibration results

Measurement Point	Horizontal (mm/s)	Vertical (mm/s)	Axial (mm/s)
Exhaust Fan 1	4.60	7.50	5.20



Fig. 3a. Initial vibration check (horizontal)



Fig. 4. Impeller before cleaning

The procedure for reducing fan vibration begins with dismantling the exhaust fan, followed by cleaning the impeller using a scraper and wire brush. the process can be seen in the Fig. 4.



Fig. 3b. Initial vibration check (vertical)



Fig. 4. Dismantling fan

Next procedure, with surface preparation and cleaning then manually rotating the impeller to determine the heavy spot which was marked as point 0° while Opposite this, was 180° identified as the light spot and therefore the most appropriate location for placing a trial counterweight.



Fig. 5a. Cleaning impeller



Fig. 5b. Cleaning impeller



Fig. 5c. Impeller after cleaning

A sequence of trial weights was tested for static correction. 5 g weight at 12 o' clock showed minimal effect. 17 g improved the settling balance but not satisfactorily. 20 g weight demonstrated the most significant correction during manual settling. The 20 g trial weight was mounted at 12 o' clock and the fan were reassembled for operational testing.



Fig. 6. Drill process



Fig. 7. Apply 5g weight

Based on the positive results of the 5g weight test, the weight of the ring significantly impacts the impeller's rotational balance. The vibration test results are shown in the table 2.

Table 2
Final vibration results

Measurement Point	Horizontal (mm/s)	Vertical (mm/s)	Axial (mm/s)
Exhaust Fan 1	0.60	1.90	2.80

The vibration test results can be seen in the figure below:



Fig. 7a. Final vibration check (horizontal)



Fig. 7b. Final vibration check (vertical)



Fig. 7c. Final vibration check (axial)

4. Conclusion

Impeller mass balancing plays a critical role in improving the efficiency and durability of a blower system. Accurate balancing significantly reduces vibration levels, as demonstrated by these test results. This study successfully investigated and resolved high vibration levels in a rigid-mounted centrifugal fan used in a cement plant. Initial vibration

measurements revealed critical levels of unbalance and misalignment, with horizontal amplitudes as high as 7.50 mm/s at the vertical fan drive far exceeding ISO 10816 acceptable limits. A structured static balancing procedure was then conducted using trial weights (5 g, 17 g, and 20 g), with the 5 g weight yielding the most stable response.

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