Chapter 2 Literature Review & Problem Identification

2.1 Introduction:

For condition monitoring engineers in industry, frequent high vibration of centrifugal blowers is a very common phenomenon and especially of those blowers which are with the pollution control units. In this project work the high vibration is related to centrifugal blowers of the motor mounted category ones. Researchers, condition monitoring engineers or maintenance engineers in their published works, past or recent, have not categorised vibrations, fan type wise, but lot of pioneering and effective work has been done on vibrations of general category centrifugal blowers especially with high motor ratings. To understand the phenomenon of vibration in motor mounted blowers there should be a clear understanding at first the cause of vibration at centrifugal blowers. After studying and understanding the causes of vibration in centrifugal blowers with higher motor ratings it can be extended to the motor mounted variable speed blowers with much lower motor ratings as apart from some constructional and motor rating differences the working and application of both the blowers are same.

2. 2 Vibration in Centrifugal Blowers:

Neel Rao [5] had listed the common vibration problems in centrifugal blowers. According to his observation there are 6 major types of vibrations in centrifugal blowers which have been listed as: mechanical loose connections, crack in shaft and impellers, rotor mass imbalance, motor shaft misalignment, critical speed and defective bearings. From field experience we know the list is not exhaustive as there are many other issues which cause vibration of centrifugal blowers. A vibration sensor manufacturing company

[6] in their catalogue has spoken of the same causes of vibration as noted by Neel Rao but they have added one more to the existing list and that is resonance. To all vibration field engineers it is known that in all type of blowers specially those which are mounted on a steel base frame resonance plays a significant role. Donald R Smith et all [7] in their research work on centrifugal blower vibrations have added further areas from where vibration can originate. They have listed the areas as: ‘complex inter action between various parts of the fan-duct foundation system’ ,’natural frequency near running speed’ ‘disc(impeller) wobble resonance ‘ and ‘reduction of soil stiffness causing foundation resonance’ The last reason is significant to centrifugal blowers running in the open area but in this project work the blowers that we have taken as case studies are all under a shed and there were no excavation work near the site so this reason for high vibration does not apply in this case. Disc wobble resonance is a new dimension they have added to the list but that too is relevant to blowers with large impellers. Motor mounted blowers are small blowers and the impeller sizes are barely a meter in diameter. So the high vibration due to disc wobble also does not apply in the cases of motor mounted blowers. Asad Said Juma et all [8] had observed that misalignment is one of the major causes for vibration in centrifugal blower. In a motor mounted blower we can rule that out also as the blower is directly mounted on the motor so there is no possibility of misalignment. In motor mounted blowers there is of course a load on the motor shaft and vibration can originate from there itself. William R Finley et all [9] discussed of electrical and mechanical related causes for high vibration. The electrical-mechanical causes that he has mentioned are typically of larger size motors related with bush bearings and the same is not relevant to blower mounted motors. Blower mounted motors are usually below 37 kW rating and the rotors are mounted on antifriction bearings. In the same paper the author has discussed of mechanical failure as coupling unbalance a cause of vibration problem but

again this is not relevant to motor mounted blowers as it has no provison for coupling as the impeller is directly mounted on the motor. In the same paper he has highlighted the issues like rotor bar failures causing vibration problem but these are generally for large size motors above 100kW. Smaller motors have moulded rotor so the failing of rotor bars and causing vibrations does not arise. William R Finley et al [10] in another work related to vibration listed a series of action to check and take on a running motor, of any size, to ensure that no vibration is being generated from the motor itself. The check points are very relevant and the same was implemented at the blower motors. However his findings in the published work on bearing related vibration to be looked into more details as by loading the impeller directly on the rotor bar there is a cantilever type load on the motor drive end bearing and there is an possibility of abnormal vibration in the motor which cannot be detected from the list he has given. Glenn H Bate [11] in one of his work on vibration of electric motors had made a trouble shooting table in which he has listed all possibilities of vibration causes in an electric motor some relevant to motor mounted blowers are listed below (Table:2.1)

Table: 2.1 Trouble Shooting for Motor Vibrations

Vibration Cause	Frequency	Dominant Axis	Phase Relation
Unbalanced rotor shaft	1X RPM	Radial	Static Unbalance 0^0 Couple 180^0 Radial Dynamic 0-> 180^0
Bent shaft	1X,2XRPM	Axial	180^0 Axial 0^0 Radial
Mechanical Looseness	1X,2X RPM	Radial	Variable

A very important aspect has now been discussed is that of the phase angle determination which helps substantially in diagnosing the real source of abnormal vibration.

Summarizing the review so far, we observe, that in this project work the basic problem was of frequent high vibrations of motor mounted blowers which have small size motors

below 37 kW in comparison to the general centrifugal blowers with higher motor rating. Literature review so far yielded that not much work has been published on motor mounted blower vibration as such but at the same time it was observed there is no dearth of available literature on general centrifugal blower vibrations. Best way it is to correlate the causes for high vibration of the large size centrifugal blowers that with the motor mounted variable speed blowers and make a short list of the probable causes of vibration of the motor mounted centrifugal blowers.

In survey we have eliminated the cause s for high vibration of large centrifugal blowers which many researchers and practising engineers had listed like : impeller wobble, coupling unbalance, misalignment , clearances in bush bearings , rotor bar failure etc. as because by construction the motor mounted blowers does not have these features in their design and manufacturing. Till now only three sources of high vibration that are common to both type of blowers has been detected as: rotor unbalance, mechanical and mechanical looseness of structure and unbalanced rotor. Another relevant issue is also that of resonance however that is practical problem in any vibrating element.

B A Kardile [12] in his research work on bearing life improvement of centrifugal blowers has discussed few issues which are quite common and being practised by all maintenance engineers but the relevant point he had discussed was:

‘Machine vibration has several categories of causes that we have discovered after so many repairs, but it is useful now to review them to gain more confidence in the diagnosis. The Major categories of diagnoses are – • Design defects • Manufacturing defects • Operational stresses • Maintenance actions • Aging Design defects are mostly structural related with active resonances built-in because of improper sizing and proportioning of the parts statically, the structure seems good, but it remains dynamically weak. This is not

discovered until the machine is energized and brought up to the required speed. This is more common than it should be, but the designers are not well equipped to predict or test for natural frequencies. In addition, the owners' foundation or base has a significant effect on natural frequencies, which the designer has little control over. Hence, resonances are best detected during start up testing and corrected on-site with strategic stiffeners added.'

The issue of resonance of structure discussed by B A Kardile is very relevant to the motor mounted blower high vibration has the blower along with the motor is manufactured by the original equipment manufacturer on a common base and during installation at site it is mounted on a department made structure which has been grouted/bolted to the RCC foundation. During the failure investigation this aspect of vibration cause should be specially looked upon for this could be the principle cause of failure if other causes of vibration are not dominating.

From the above discussion we find that of all the probable causes listed for high vibration in the motor mounted blowers some solutions have been given in Table:2.1 like rotor unbalance ,bent shaft etc, but no detailed discussion to what could be termed as 'mechanical looseness' which many researchers have hinted upon as a source of resonance.

In their product catalogue Vibrationsteknik AB [15] has given a very good account of mechanical looseness and also with a trouble shooting chart quite similar to Table: 2.1

"Mechanical looseness has two parts rotating looseness and non-rotating looseness. Rotating looseness which is related to excess clearance in rolling element bearings generates 1X harmonics, which sometimes stretches to 10X. If the high harmonics are dominating, collisions can be suspected. Non-rotating looseness causes the highest vibration in the direction where the stiffness is the smallest. The stiffness is usually least

in the horizontal direction, but it depends on the physical layout of the machine. Loose foundation can be causes of loose bolts, rust or cracks [12]."

The journal has also provided a fault finding chart (Table: 2.2) quite similar to the one of Table: 2.1

Table: 2.2 Trouble shooting for Mechanical Looseness

Vibration Cause	Frequency	Dominant Axis
Loose Foundation	1X RPM	Tangential
Bent shaft	1X,2XRPM	Axial

Frequency of 1 X rpm is an indication for loose foundation is a misnomer. Robert J Sayer [16] in one of his published work observed:

'That the frequency of the dynamic force caused by an unbalanced rotor will be equal to 1x the rotational speed of the blower. It is a pure harmonic force and, thus, will not contain any harmonic multiples unless some other condition, such as mechanical looseness is also present. The magnitude of the dynamic force produced by an unbalanced rotor will increase with the square of the rotational speed (F=mr2).The above characteristics for rotor imbalance can be used to diagnose whether excessive vibration is simply caused by a large unbalance force or the result of the excitation of a resonance. Since the dynamic force produced by an imbalance is harmonic (sinusoidal), it remains constant at any given speed. It is a force vector that rotates with the fan wheel. Thus, the difference in phase between the maximum vibration in the horizontal and vertical directions should be nearly 90^0. If the phase is either 0^0 or 180^0, excessive vibrations are most probably due to resonance. Since the magnitude of the dynamic force produced by the imbalance remains constant at any given speed, the magnitude of vibration in the vertical direction should not be significantly different than the horizontal direction. Differences in the directional stiffness (mechanical impedance) of supporting structures

will result in a horizontal/vertical vibration ratio slightly different than unity (1.0). Large horizontal/vertical vibration ratios are indicative of resonance"

It is evident from the observation of Robert J Sayer that both unbalance and mechanical looseness will have the same spectrum at 1X and if we check the phase difference that will confirm whether this is an unbalance force or resonance force. There is an Illustrated Vibration Diagnostic Chart which combines the spectrum analysis with the phase analysis to confirm the frequency status and the same has been extensively used during the vibration analysis of the motor mounted blowers. The charts have been included in Appendix G and give a good guide line.

The causes for high vibrations typical for motor mounted blowers has been discussed correlating with the vibrations as observed of various researchers on high motor rating centrifugal blowers and the causes for high vibration of motor mounted blowers in correlation with the vibration of the large centrifugal blowers can be listed as:

1. Bent rotor shaft
2. Rotor unbalance
3. Mechanical Looseness
4. Structural defect
5. Motor abnormality like loose junction box, loose base bolts etc.

The aspect of bearing vibration remains yet to be observed.

Wu Hao et all [17] had made an interesting study of vibration analysis of rolling element bearing-rotor system of an air blower but it was more of an academic study of the bending stiffness of the tapered roller bearing and not on the practical issue of cause and elimination of vibration generation. In an interesting research by B Notohardjono et all

[18]discussed of monitoring and detecting ball bearing faults but those are common issues in all rotating machine but not specific for motor mounted blowers in which the drive end bearing of the motor is more loaded than the non-drive end and prone to causing vibration after certain period of operation.

From the above two observations it can be concluded that the vibration causes and detection will be similar to any rotating machineries.

, What is still left to be addressed is the relation between speed and the blower and the outlet air damper position on the blower vibration. These two aspects have been included as in the motor mounted blowers in this project does at time operate on variable rpm as per process requirement and also the output at time is throttled for better combustion at the burners. As these are unique for motor mounted blowers we have to find their impact on the vibration with the experimental study itself.

2.3 Objectives of the Present Work

From the literature survey it is evident that though substantial research study & experiment has been done on large centrifugal blowers there remains a knowledge gap of vibration analysis for the motor mounted centrifugal blowers.

To find the reason for the high vibration fluctuation in these small sized blowers an experimental study with an actual blower ,off-line ,has to be carried out and with the same parameters of the in-operation blowers are to be replicated like -the RCC base , different supporting structures, outlet damper opening at various degrees and of course the blowers to be operated at different speeds.

Operating with these parameters relevant data to be collected, analysed and a probable solution to be derived at.

This will be the objective of the present work.