FANS AND BLOWERS

Table of Contents

List of Figures

List of Tables

1.0 SCOPE

This data sheet contains loss prevention recommendations related to fans and blowers. The terms “fan” and “blower” are considered synonymous for the purposes of this data sheet, and are applicable to axial and centrifugal flow machines with single-stage and multiple-stage configurations.

1.1 Changes

October 2024. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Loss prevention recommendations described in this data sheet apply to blowers, ventilation, cooling tower and pollution-control fans, as well as boiler forced-draft and induced-draft fans.

2.2 Equipment and Processes

2.2.1 General

The following loss prevention measures are recommended for fan and blower equipment.

2.2.1.1 Balance rotating parts impeller and rotor prior to installation.

2.2.1.2 Install components in accordance with the instructions of the original equipment manufacturer (OEM).

2.2.1.3 Verify that forced-draft and induced-draft fan rotors were tested by the manufacturer. Report results in FM Risk assessment report. Overspeed testing at the factory is important to ensure the long and safe operating life of the fan rotors.

2.2.1.4 Properly align moving parts and drivers.

2.2.1.5 Operate within OEM specifications. Ensure operation for a given application, capacity, and varying speed match values on the characteristic curves.

2.2.1.6 Operate fan within normal performance curve limit. Ensure adequate flow-through to avoid stall and abnormal condition.

2.2.1.7 Provide inlet filtering where applicable to prevent foreign objects damage and contaminants.

2.2.1.8 Monitor vibration level at each point at least daily, and log reading weekly. Vibration measurement should be trended monthly and compared to manufacturer’s vibration limits. Trending is important to tool in detecting degenerative balance and bearing degradations.

2.2.1.9 Where a steam turbine is the primary force used to drive fans, provide controls and safety devices to prevent overspeed and loss of lubrication. Ensure proper bearing selection and lubrication program.

2.2.1.10 Maintain proper cooling and filtration systems for lube oil.

2.2.1.11 Perform infrared scanning inspections of bearings/motors.

2.2.1.12 Perform motor load monitoring, and trend analysis of operational parameters.

2.2.1.13 Perform regular inspection, testing and maintenance of fan and blower system equipment. Follow OEM guidelines and procedures.

2.2.1.14 Have on hand an approved manufacturer welding procedure for the impeller and the casing. Welders qualified to these procedures should be readily available whether in-house or contractor. Repaired impellers should be rebalanced per OEM procedures.

2.2.1.15 Perform nondestructive examination (NDE) biennially on fans and blowers, except where used in industries where the gases transferred by the fans and blowers are hot and/or erosive (e.g., cement kilns and finishing mills) where annual NDE should be considered. This includes but is not limited to the following:

- Penetrant testing (PT) and/or magnetic particle testing (MT) examination to blade and shroud fillet welds
- PT or MT examination of the blade-to-hub groove welds

- Ultrasonic (UT) thickness readings on the blades and shrouds

2.2.1.19 Use a manufacturer approved procedure to perform erosion cladding of blades and shrouds.

2.2.1.20 Ensure proper rebalancing of the impeller following any cladding or re-cladding procedure.

2.2.1.21 Follow manufacturer's recommendations for vibration alarm and trip settings criteria.

2.2.2 Protective Devices

Provide fans and blowers with protective devices, alarms, and trips in accordance with Table 1.

Table 1. Protective Devices, Alarms, and Trips for Fans and Blowers

Description of Fan	*Protective Device*	*Alarm*	*Trip*
Fans with hydrodynamically-lubricated bearings	Low lube-oil pressure	×	×
Rolling-element bearings with circulating lube-oil systems (splash-bath systems)	Thermocouple on bearing race	×	×
	Low oil flow	×	
	Low oil level in bearing housing	×	
	Low oil level in tank	×	
Grease-packed bearings (above 100,000 cfm, or 50 m^3/s, capacity)	Thermocouple on bearing race	×	×
Variable-pitch fans	Low hydraulic oil pressure	×	×
Centrifugal fans over 100,000 cfm (50 m^3/s) capacity circulating oil systems	Vibration instrumentation on all bearings	×	
All variable-pitch, axial-flow fans	Vibration instrumentation on all bearings	×	
Fans with grease-lubricated bearings	Vibration monitoring by handheld instrumentation		
Fans with installed filters	Filter pressure drop	×	

2.3 Operation and Maintenance

2.3.1 Inspection, Testing, Maintenance, and Monitoring Programs

Fans require frequent inspections to detect and correct irregularities that might cause failure. Establish and implement a fan and blower inspection, testing, and maintenance program. See Data Sheet 9-0, *Asset Integrity*, for guidance on developing an asset integrity program.

Fans also have to be properly balanced, both statically and dynamically, per OEM specifications to ensure lasting operation. Check this balance after each scheduled maintenance shutdown, with the fan running at full speed.

2.3.1.1 Monitoring and Inspection Frequencies

Adhere to the monitoring and inspection frequencies in Table 2.

Table 2. Recommended Monitoring and Inspection Frequencies

Performance monitoring	
Centrifugal fans over 100,000 cfm (50 m^3/s) capacity	Daily
All variable-pitch, axial-flow fans	Daily
Vibration monitoring	
Installed instrumentation, visual readings	Daily
Installed instrumentation, log data	Weekly
Hand-held instrumentation, read and log data	Weekly
Check drive-belt tension	Quarterly
Visual inspection of impellers, blades and dampers	Semi-annually
Major inspection (including nondestructive examination and check of bearing alignment)	
Centrifugal fans over 100,000 cfm (50 m^3/s) capacity	Biennially
All variable-pitch, axial-flow fans	Biennially

Note 1. Annual NDE should be considered for fans and blowers used to ransfer hot and/or erosive gases.

2.3.1.2 Performance and Condition Monitoring Programs

Performance and condition monitoring programs allow operators and maintenance personnel to observe/ monitor the operating conditions of the equipment and intervene when it is necessary, giving warning of abnormal operation.

2.3.1.2.1 If a condition monitoring program is used, ensure it includes the following:

A. Continuous vibration monitoring devices and trip capability

B. Lube-oil monitoring and periodic analysis

C. Speed monitoring/overspeed protection, where applicable

D. Evaluation of critical components using NDE methods

E. A maintenance and overhaul program that considers equipment design/construction, application, and size as well as other parameters, such as the highest risk critical components of the machine (in general, the tasks and their frequencies are defined by the original equipment manufacturer)

F. Operation of equipment close to optimum efficiency. See Data Sheet 10-8, *Operators*, for operator guidance.

2.3.1.2.2 Provide performance monitoring for all fans of over 100,000 cfm (50 m^3/s) capacity, and for all variable-pitch, axial flow fans.

If fan blades or inlet guide vanes become coated excessively with adhesive material, there is a risk of thrust-bearing wiping or blade fatigue cracking. If there is excessive erosion or corrosion, the structural integrity of the impeller may be compromised, either in its fatigue strength, or simply in its ability to withstand the centrifugal forces. There have been cases where badly eroded fans have broken up under centrifugal force.

Heavy coating breaking off is a hazard that can create a large unbalance. The resulting unbalance loads can damage bearings,and, in extreme cases, the impeller itself.

2.3.1.2.3 Take corrective action to solve the problem if the fan efficiency decreases, or the flow rate and static pressure are reduced below the OEM design and operation requirement.

2.3.1.2.4 Trend the differential pressure drop across the suction filter, and provide an alarm when the pressure drop exceeds a value that is characteristic of the particular type of filter being used. This should be established with the assistance of the filter manufacturer.

Filter pressure drop is a performance parameter. Excessive blockage of a filter may increase the flow distortion through the fan, and there is a danger of aggravating a blade resonance and subsequent fatigue cracking and fracture.

2.3.1.2.5 Operate the fan at the proper blade setting. For adjustable or variable-pitch fans, the operating procedure will include the setting instruction.

In the case of axial-flow fans, deposits that reduce flow capacity may drive the fan toward stall or flutter.

2.3.1.3 Vibration Monitoring

2.2.1.3.1 Where fixed vibration instrumentation is in place, check fan vibration at each bearing at least daily, and log weekly.

2.3.1.3.2 When hand-held instrumentation is used, the readings should be taken and logged weekly.

2.3.1.3.3 In the case of centrifugal and axial-flow fans of over 100,000 cfm (50 m^3/s) capacities, adhere to the vibration monitoring procedure recommended in Data Sheet 17-4, *Monitoring and Diagnosis of Vibration in Rotating Machinery*, should be in effect.

2.3.1.4 Blade Inspection

2.3.1.4.1 Check fan blades periodically for buildup of sticky deposits, and for evidence of excessive erosion or corrosion. Also check integrity of wear plates (welded or mechanically-fastened). Replace wear plates and fasteners in severe abrasive environments periodically, as determined by inspection.

2.3.1.4.2 In severe environments, measure the thickness of centerplates and shrouds periodically, and pay particular attention to the joints between the blades and their supports (shrouds or centerplates). If appreciable corrosion, erosion or thinning is detected, consult the fan manufacturer for a determination as to whether the fan may be continued in service.

2.3.1.4.3 Keep fan blades clean to avoid unbalanced conditions, which could damage bearings. Wire brush cleaning is often used, but on some installations where deposits accumulate rapidly, permanent wheel cleaners having water or steam nozzles can be installed in the fan housing. These can clean the blades while the fan continues to operate.

2.3.1.4.4 Examine fan blades during major inspections. Use appropriate nondestructive methods to check for the presence of fatigue cracks, particularly along blade-to-shroud and blade-to-backplate welds and along the free edges of shrouds and backplates. Also check the condition of the backplate-to-hub joint, i.e., condition of bolts or rivets, or the condition of a welded joint.

2.3.1.5 Damper Inspection

2.3.1.5.1 Lubricate damper bearings periodically to prevent them from binding. Failure of damper blades may cause blades to fall into the fan rotor and do considerable damage. Some of these failures have been due to corrosion of a supporting spindle to such an extent that the aerodynamic loading caused it to break off. Periodic inspection is recommended to catch such corrosion before it has progressed too far.

2.3.1.5.2 Exercise dampers and variable inlet guide vanes semiannually and at every major overhaul and repair to detect and correct any looseness or binding.

2.3.1.6 Inspection of Blade-Control Components

Overhaul the variable-pitch operating system every two years. Conduct inspections and maintenance during the overhaul period in accordance with Table 3.

Table 3. Inspection and Maintenance During Major Overhauls

Component	*Maintenance*
Blade thrust bearing:	Remove, clean, inspect for wear or deterioration.
Slide blocks:	Clean and inspect. Replace, if worn.
Blade shaft seal:	Inspect and replace, if worn.
Hub cover seals:	Replace.
Control piston:	Inspect wearing surface and seals.Replace, if necessary.
Blade shaft bushings:	Inspect and replace, if worn.
Hydraulic power unit	Peplace at four-year intervals unless leaks are evident.

The hydraulic power unit need not be removed at less than four year intervals, unless leaks are evident.

2.3.1.7 Drive Belt Tension

The proper maintenance of drive belts is very important. If tension is not maintained properly, the loading on the fan bearings may be excessive. Shaft failures have also been attributed to excessive belt tension.

2.3.1.7.1 Inspect fan belts for tension every three months. Adjust tension by installing a belt relatively loosely at first and checking for slip after the unit is at speed.

2.3.1.7.2 Operate the fan for a few minutes, turn it off, and check the sheave grooves for heat built-up. If they are hot, the belt has been slipping. Low rpm and low ampere readings are other indications of slipping. If slip occurs, tighten the belt in small steps until no slipping occurs.

2.3.1.7.3 Check the condition of the belts. Replace if they show signs of excessive wear or of brittleness. Always change belts in sets to ensure correct alignment and uniform tightness.

2.3.1.8 Bearing Alignment

2.3.1.8.1 Check the alignment of fan bearings and their drivers at every major inspection. Bearing offset misalignment is the principal cause of shaft cracking and fractures, as well as of coupling damage.

2.3.1.8.2 If an installation has a bearing alignment problem, either because of the need to realign the bearings periodically after alignment checks, or because there is a history of shaft fracture, cracking, or coupling distress, check the bearing alignment annually. Alignment problems may also indicate a degrading blower bearing pedestal or foundation. Support integrity should be checked after an unexplained blower failure.

2.3.2 Repair

2.3.2.1 Weld Repair of Fans and Blowers

Follow industry best practice and use certified repair procedures to repair fan and blowers;use approved welding methods to repair cracks that have been caused by fatigue. It is normally inadvisable to weld fatigue cracks because a welded joint does not restore fatigue strength. However, since fatigue progression in fabricated steel impellers with backplates and shrouds is not usually rapid, it is possible to detect it before complete fracture occurs.

However, the fact that these joints are subjected to fatigue, and have probably developed fatigue cracks requiring the repair, emphasizes the requirement for sound welding procedures. This is also of particular concern, because it is sometimes very difficult to obtain the necessary access to the cracked area to perform the optimum weld repair.

2.3.2.1.1 Use certified repair procedures for double-bevel groove shielded-metal arc weld shown in Figure 1. Prepare the surface by machining, grinding or chipping to the configuration shown, and ensure full penetration is achieved to avoid incomplete fusion (grape formation). The latter has been seen in fans that have had fatigue fractures originating in repaired areas. If too large an electrode is used for the initial passes at the root, the fusion between successive beads may be incomplete.

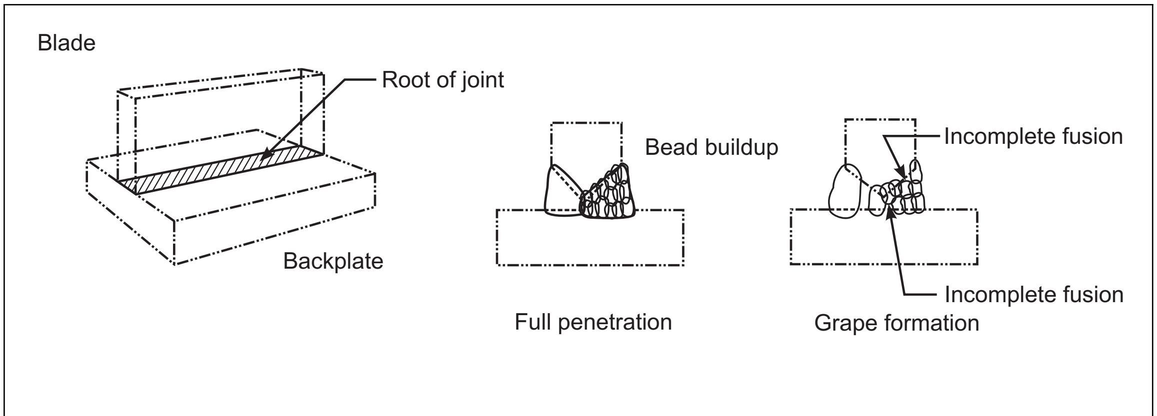

Fig. 1. Double-bevel groove welding.

2.3.2.1.2 Another source of faulty welding is the use of a weave bead from side to side along the fillet. Welds should be built up in longitudinal or stringer bead passes. Ensure welders performing fan repairs of this type are certified. Refer to Appendix C for the applicable standards for weld procedure. Use written welding procedures developed by the fan manufacturers.

2.3.2.1.3 Use single fillets when airfoil blades are involved in the weld repair though it may be difficult to achieve a satisfactory weld, in which case it may be advisable to use reinforcing pads as shown in Figure 2. These permit a very sound joint.

2.3.2.2 Open Radial-Bladed Impellers

Do not weld repair fatigue cracks in the radial-bladed impellers. In some cases, they are made of cast steel, which is usually not readily welded. A new fatigue crack may progress too rapidly in the absence of a backplate and shroud. However, if the crack is in the blade itself, a weld repair is feasible.

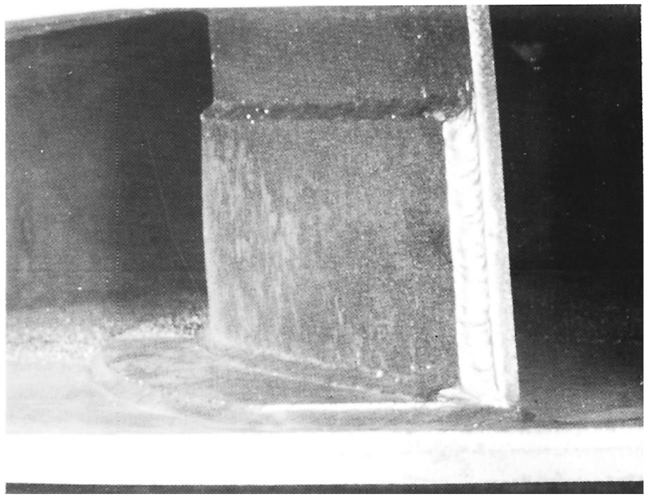

Fig. 2. Reinforcing pads.

2.4 Contingency Planning

2.4.1 Equipment Contingency Planning

When a fan or blower breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable fan or blower equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

In addition, include the following elements in the contingency planning process specific to fans and blowers:

- Fan and blower design/construction information based on the process
- Fan and blower component repair/replacement options, focusing on blades/impellers, shafts, and bearings
- Fan and blower drive systems

2.4.2 Sparing

Sparing can be a mitigation strategy to reduce the downtime caused by a fan or blower breakdown depending on the type, compatibility, availability, fitness for the intended service, and viability of the sparing. For general sparing guidance, see Data Sheet 9-0, *Asset Integrity*.

2.4.2.1 Routine Spares

Routine fan or blower spares are spares that are considered to be consumables. These spares are expected to be put into service under normal operating conditions over the course of the life of the fan or blower, but not reduce equipment downtime in the event of a breakdown. This can include sparing recommended by the original equipment manufacturer. See Section 3.3 for routine spare guidance.

3.0 SUPPORT FOR RECOMMENDATIONS

Fans and blowers consist of a bladed rotor or impeller that moves a quantity of air or vapor by adding sufficient energy to the stream to initiate motion. The power required depends on the volume of air or gas moved per unit of time, the pressure difference across the fan, and the efficiency of the fan and its drives.

Fan efficiency and performance is best expressed in fan curves, which provide static pressure (head), shaft horsepower, and static efficiency as functions of capacity or volumetric flow rate.

Centrifugal fans are suitable for high-static, low-flow rate applications. They are usually equipped with wear liners when there is heavy dust loading in the gas. In contrast, axial flow fans are more suitable for use where static pressure requirements tend to decrease as flow requirements decrease. Certain applications where pressure requirements may suddenly increase at reduced flow conditions must be carefully reviewed in order to make sure changes do not cause fans to stall.

Electrical motors are normally used for fan drives because they are less expensive and more efficient than other drives. A steam turbine drive costs more than an electrical motor, but is less expensive than any of the variable speed electrical motor arrangements in sizes more than 50 hp (37 kW).

3.1 Root Causes of Component Failure

3.1.1 Impeller Vane Cracking and Fracture

Impeller blade or vane cracking is caused by resonant vibration. An impeller vane is a thin, curved, flat plate of irregular outline; it may be supported on opposite edges by the shroud and back plate. On the other hand, it may have three free edges as in the case of the radial-bladed impeller.

Resonant impeller blade vibration results from two concurrent circumstances. First, the blade must have a resonance at operating speed. In other words, its natural frequency must be a low-order multiple (2×, 3× or 4×) of running speed, or a multiple corresponding to some set of evenly spaced stationary objects (such as inlet guide vanes) in the flow path; second, the circumferential flow distortion must be sufficiently severe to generate vibratory stresses in the blade in excess of the fatigue strength, or alternatively, the fatigue strength must be insufficient to withstand the forces and moments generated in the blade by the vibration. This last consideration is particularly important in connection with fans.

In most cases of fracture due to blade resonance in turbo-machinery, the time to crack initiation and subsequent crack progression is relatively brief, and it is impossible to rely on inspection for loss prevention. Centrifugal fans are an exception, primarily because extensive cracking may take place before the impeller becomes unable to resist the centrifugal forces. Periodic inspections by nondestructive techniques are a viable means of detecting cracking before it has progressed to fractures, and weld repairs are permissible, since fan rotors are usually fabricated by welding.

Vibration monitoring can also have a large role in loss prevention; after cracks have progressed extensively through an impeller, sufficient unbalance may exist to produce a noticeable increase in bearing vibration. It may be possible to do a weld repair on the fan before fracture, with extensive consequent damage, takes place.

3.1.2 Cracking and Fracture of Shrouds and Back Plates

Shrouds and back plates are thin plates of irregular outline, spanning between adjacent blades. The shroud is a curved plate while the back plate is flat; in the case of a forward-curved impeller, it may behave as a circular flat plate supported at the rim (by the blades), and at the center by the hub. Such a plate has a number of diametral modes of vibration.

3.1.3 Shaft Fractures and Cracking

Most incidents of cracking and fractures of shafts are caused by rotating bending (relative to the shaft). A unidirectional load is applied to the shaft by one of the following:

A. Offset bearing misalignment

B. Excessive belt tension

Relative to the shaft, the load rotates backward, producing alternating stresses in the shaft. The shaft cracks or fractures as a result of high-cycle fatigue.

Figure 3 shows the principle of fatigue in a shaft due to offset misalignment. Offset misalignment occurs if one (or more) bearing(s) in a train of three or more bearings is (or are) not perfectly in line with the others.

The alternating tension and compression in the shaft at a location of stress concentration willresult in the initiation of a crack. Additional cracks may develop and progress, linking up with each other and leading eventually to complete fracture of the shaft or coupling.

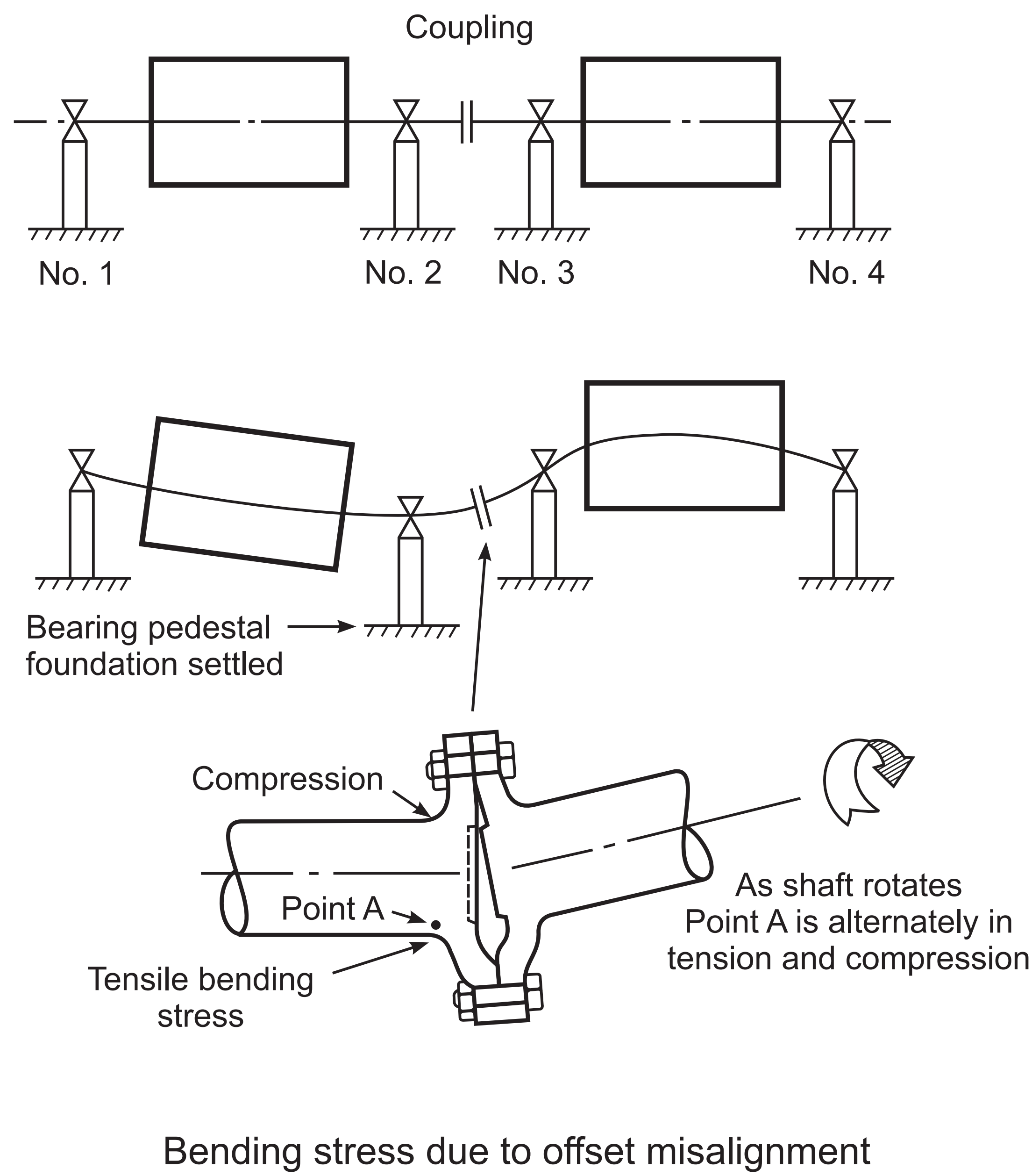

Fig. 3. Bearing offset misalignment.

It is essential to realize that there is no warning of cracking due to offset misalignment. No bearing vibration is produced, as can be seen by an examination of Figure 3. In the figure, bearing pedestal No. 2 has settled, pulling the shaft downward. A vibration pickup placed on this bearing cap will not see an alternating load since the load on the bearing is always in one direction-upward. Therefore, there will be no vibration response. The only way to prevent cracking of this type is to check the bearing alignment periodically at intervals based on historical data, and to correct misalignment by shimming bearings as necessary.

If, instead of a settled No. 2 bearing, a drive belt is responsible for the transverse load on the shaft, the result will be the same. Therefore, it is important that drive belts be maintained properly.

3.1.4 Bearing Failure

Most fans use anti-friction bearings (ball and roller-bearings) because there are usually relatively high thrust loads involved. Large installations may use sleeve-type sliding bearings.

Lube-related bearing failures do not constitute a large fraction of the losses. However, there may be a substantial loss potential (relative to the value of the fan) if bearings are not lubricated properly.

The purposes of lubrication of antifriction bearings are as follows:

1. Maintain an oil or grease film between the balls or rollers and the cage, or retainers, to prevent rubbing action with its resultant friction heat.

2. Reduce friction between the rolling elements and the raceways.

3. Act as a coolant to remove excess heat from the bearing, and as a cleaner to remove microscopic wear particles from the raceways.

4. Act as a rust preventative by coating all surfaces to discourage corrosion, and seal in the bearing enclosures to prevent infiltration of dirt, rust, moisture, etc.

Sleeve-type bearings rely on a flow of oil to maintain a hydrodynamic film between the bearing liners and the journal on the shaft.

3.1.4.1 Grease Lubrication

Grease-lubricated bearings are packed at the factory, but will require re-lubrication periodically. Until a body of experience is accumulated to make a judgment as to whether a different schedule is desirable or satisfactory, the recommendations of the manufacturer should be consulted. One manufacturer indicates that the initial lubrication should be good for 1000 hours of operation.

Grease should be flushed from the bearings at every major dismantle, and replaced with fresh grease.

In all greasing activities, the manufacturers recommend the type of grease to be used. It should be high quality and noncorrosive. For extremely hot, cold or wet environments, special greases may have to be used. The bearing manufacturer or grease supplier should be consulted in these cases.

Following are some guidelines for grease lubrication:

1. To avoid overheating, the quantity of grease used should not be excessive.

2. The grease fitting should be cleaned thoroughly before greasing to prevent the new grease from carrying dirt or foreign matter into the bearing.

3. Relief holes or drains should be open before greasing.

Figure 4 shows the application method for a grease-lubricated bearing. Grease is applied through the crosspin fitting on top of the closure cap, and the old grease is expelled through the drain at the bottom.

3.1.4.2 Hydrodynamic Lubrication

Hydrodynamically lubricated sleeve bearings require relatively little maintenance. These bearings are capable of running for 12 years or more without replacement. The Babbitted surfaces should be inspected periodically for evidence of scoring, wear, fatigue, or corrosion, which may be caused by water-contaminated oil. Clearances should be checked.

The oil system should be properly maintained to achieve optimum bearing lives. Filters should be cleaned regularly and replaced before they deteriorate. Filters, when removed, should be examined carefully for identification of particles trapped by them. For instance, the presence of minute particles of copper, tin or lead alloy in unusual quantity may indicate that the Babbitt of the bearings is deteriorating.

Commercial laboratories can perform spectrometric analysis of samples of lubricating oils. In this test, the sample is analyzed for concentrations of a large number of metals. The usual use of the test is to plot concentrations over a period of time. An upward trend in the concentration of any one element usually means a deterioration of some component of the machine. The source of the element can frequently be identified readily and a decision can be made to inspect the component at some appropriate time. Intervals for such analyses are usually adjusted based on historical metal-wear rates.

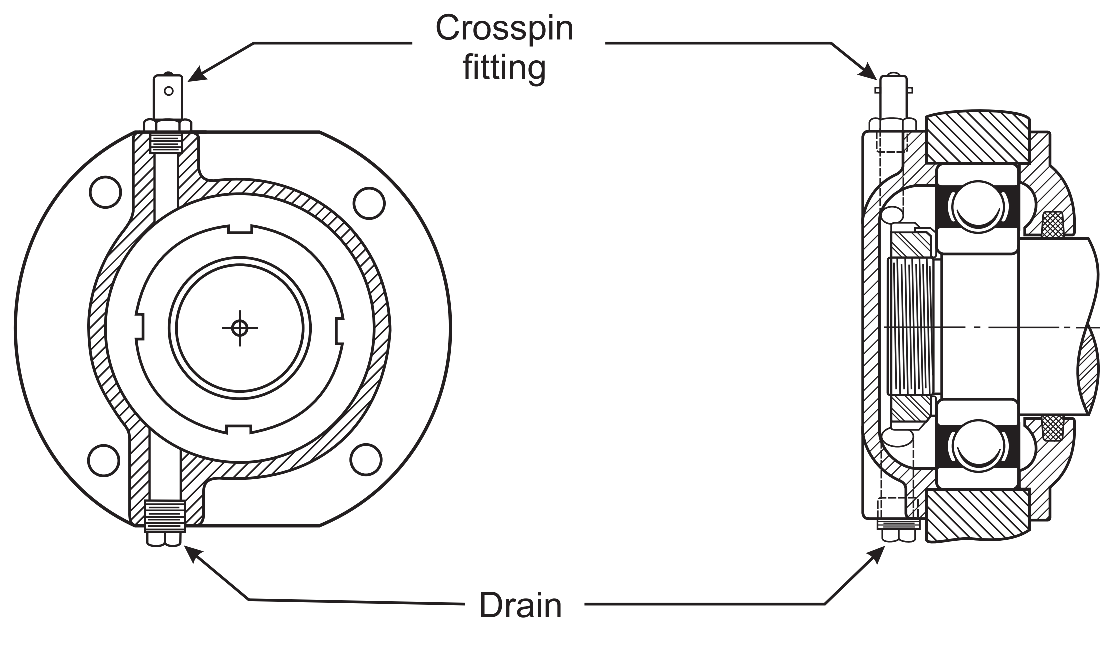

Fig. 4. Grease-lubricated bearing.

3.1.4.3 Circulating Oil Systems for Rolling-Element Bearings

The guidelines for maintaining lubrication systems for sleeve bearings also apply to circulating oil systems for rolling-element bearings. The bearings may have life limits as specified by the manufacturer, and they should be replaced on schedule. Vibration monitoring can help detect rolling-element damage, and periodic spectrometric analysis of the oil may reveal spalling of the metal of rolling elements or raceways. Silver in the oil may indicate that plating is wearing off the cages.

3.2 Failure Modes

3.2.1 Propeller Fans

3.2.1.1 Propeller Blade Fracture

Most cases of loss of propeller blades involved fracture of a blade; these divide evenly between high frequency fatigue cracking of metal blades due to resonant vibration, and cracking and splitting of fiberglass blades. The cause of the latter phenomenon is not known.

3.2.2 Axial-Flow Fans

3.2.2.1 Flutter of Axial-Flow Fan Blades

Most fractures of variable-pitch axial-flow fan blades follow crack progression in high frequency fatigue due to a very destructive, self-excited vibration known as flutter.

Flutter is an aeroelastic instability where aerodynamic forces deflect a blade, and the blade deflection, in turn, changes the aerodynamic forces in a direction that makes them more severe. This has a bootstrapping, or ‘‘negative damping,’’ effect, and the blade amplitude can build up unchecked to a destructive value. Flutter is a problem peculiar to all types of airfoils.

The only way to avoid flutter is to make sure that variable-pitch blades are adjusted to minimize incidence whenever significant changes in volumetric through-flow are anticipated. This should always be done under the guidance of the fan manufacturer.

3.2.2.2 Bearing Failure (not Lube-Related)

The bearing failures in axial flow fans have involved rolling-element bearings which slip on the shaft This mechanism is typified by a loss, involving a seven-stage, axial-flow blower for a red liquor fluidized bed furnace. The front bearing arrangement comprised two ball-bearings, one of which took the rotor thrust, while the other took the radial load. The former had a radial clearance in the housing to make sure it did not take radial load. The latter was a self-aligning ball bearing. The bearings were grease-lubricated.

The manufacturer's recommendations for maintenance involved periodic inspection and ''buttering'' of the bearings with grease. Four months after such maintenance was performed, the bearing seized while in operation. It was possible to cut the bearings off the shaft, which was found to be scored. A new set of bearings was installed and the blower was put back into service. Shortly thereafter the bearings were observed to be glowing hot. They were removed and it was found that the shaft at the races was polished to below its minimum tolerance-based diameter. A new shaft was installed.

The most probable cause of the two incidents (seizing and overheating) was spinning of the inner race of the radially-loaded bearing on the shaft Shaft and inner race tolerances should be established so that a positive interference fit exists when the blower or fan is operating and the bearing is running at its normal temperature, to avoid backward spinning of the race on the shaft If this is not achieved, frictional heat may build up and the bearing may seize or, at least, become overheated.

In the case of oil-lubricated bearings where oil can flow all around the races and remove the frictional heat, the result may be a polishing of the shaft to below its minimum dimension, without seizing or overheating. The external evidence of such a mode of failure is high vibration. This was the case in a particular loss, in which the shaft was worn down 0.042 in. (1 mm). If the bearing is grease-lubricated, the grease is more confined to the ball or roller and cage area, and the heat of friction as the race spins on the shaft can build up more readily.

This is a design flaw, involving improper selection of dimensions and tolerances. It can only be recognized when it occurs, and steps taken to correct the dimensioning. Sometimes a tighter set of bearing tolerances may be available, and the problem can be corrected by using them.

3.2.2.3 Lubrication

Axial-flow fans employ rolling element bearings almost exclusively, because of the high axial thrusts that can be generated. Ball-bearings have high thrust load capability. The smaller fans have grease lubrication; large variable-pitch fans have splash-bath lubrication systems. These employ compact hydraulic and bearing oil pumping units; they rely on a continuous gravity feed of oil from the top of the sump, through the bearings, as well as the location of the oil return line, to maintain the proper level in the sumps.

The protective system consists of the following:

1. Low flow alarm

2. Low sump level alarm

3. Thermocouples installed on the bearing outer races (all bearings) connected to high metal temperature alarms and trips

4. Low reservoir level alarm

5. Sump oil level sight glass

6. A sight glass in bearing-oil return line that always show oil flow.

There is also a low hydraulic oil pressure alarm for the protection of the control system. Without hydraulic pressure, the proper blade settings may not be maintained, and there may be a danger of blade flutter.

Rolling element bearings can operate for hours with inadequate lubrication; therefore, reliance on periodic visual monitoring of the sump level is justified. An excessive number of such incidents may result in reduced bearing life, however. Deteriorating bearings can be monitored by means of vibration instrumentation.

3.2.3 Blade-Jamming in Turbomachinery

Recognition of this mode of failure when it occurs can assist greatly in determining the initiating event in the failure sequence.

3.2.3.1 Summary

A. Blade-jamming occurs when a blade, or a piece of a blade, fails and becomes wedged between the stationary shroud and the remaining blades, decelerating the rotor very rapidly.

B. Blade-jamming can generate very high tangential loads and torques on both rotor and housing.

C. The load and torque developed can be sufficient to rotate the housing by breaking anchor bolts on one side, or by pulling them out of the foundation, and in some cases sufficient to move and skew the housing sideways.

D. The forces and moments may be transmitted out of the turbomachinery to the driver and its housing.

E. The jamming torque on the rotor is sometimes sufficient to break the shaft, subsequent to which the rotor may be propelled out of the housing by the unbalance force due to the broken blade or blades.

F. Bearing-seizure can also generate a very high decelerating torque (but not a force), which can break the shaft and rotate the housing, failing the anchor bolts on one side. There would be no primary forces to propel the freed rotor, move the housing, or damage the driver.

3.2.3.2 Discussion

Blade-jamming occurs when a loose blade (or some foreign object) becomes wedged between one or more of the remaining blades on a wheel and the stationary shroud, decelerating the rotor rapidly. When this happens, a very high tangential force is developed at the blade tips. This force produces three effects:

A. A very large decelerating torque on the shaft, sometimes sufficient to break the shaft;

B. A very large torque in the opposite direction on the machine housing; this torque tends to rotate the housing, and is sometimes sufficient to break the foundation bolts on one side or to pull them out of the concrete; and

C. A very large lateral force on the machine housing at the point of blade-jamming. Depending on the symmetry of the rotor support system this force may or may not be balanced by forces at the rotor bearing supports. If it is not balanced, there will be a large skewing moment on the housing, tending to twist it in plan view, and possibly a net lateral force tending to shift it sideways.

The significance of blade-jamming is that it explains dramatic subsequent damage which might otherwise mask the real initiating event. Thus, when the damage discussed herein is found, evidence of prior failure should always be sought.

3.2.3.3 Effects of Blade Jamming

Figures 5a through 5e show the nature of blade jamming and its effects. Figure 5a shows how a broken blade may jam between the tips of the other blades and the stationary shroud, dragging the rotor to a stop. Figure 5b shows the forces on the rotor: a drag force at the blade tips and corresponding reactions at the bearings. Since the drag force and the reactions are in different planes, a torque is developed as shown. This is sometimes sufficient to fracture the shaft as shown in Figure 5c.

Figure 5d shows the forces applied to the housing. The rotor applies a tangential force to the housing and lateral forces at the bearings. The combination of all this results in a torque on the housing and a moment as shown in the plan view of Figure 5e. This figure also shows the resulting displacement consisting of rotation of the housing about one edge of its base and a skewing (twisting). There may also be a lateral shift of the housing on the base.

When displacement of the housing as shown in Figure 5e occurs, blade-jamming should be suspected immediately. The shaft may or may not break. Bearing seizure is the only other phenomenon capable of developing the torque normally required to rotate the housing of an industrial machine.

The rotation of the housing will always be in the direction of rotation of the rotor. However, the plan-skewing can be in either direction or it may not occur. If the bearings are reasonably symmetrical about the axial location of the blade-jamming, there should be no skew. In the case of a cantilevered rotor (Figs. 5a-e), the skew will be as shown in Figure 5e if the maximum drag load develops at the bottom of the fan housing. If it develops at the top, the skew will be in the opposite direction. If it develops vertically at the top or downward at the sides, there will be very little skewing.

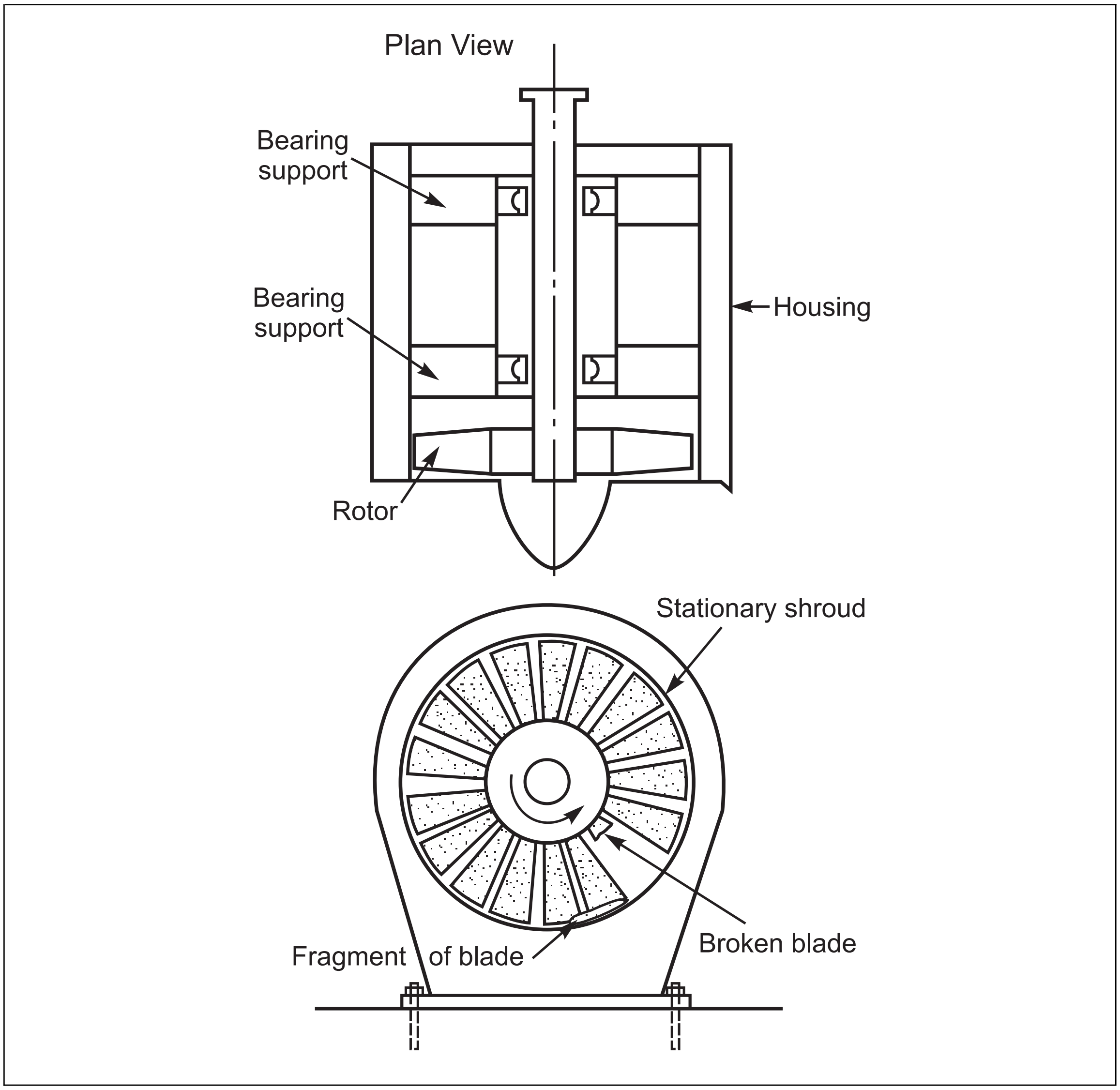

Fig. 5a. Initiation.

3.2.3.4 Bearing Seizure

Rotors can also be decelerated by seizure of a bearing. This is probably more common with sliding (journal bearings). The process of seizure of a rolling-element bearing is complex, since the shaft must seize in the inner race, the rollers must weld to both inner an outer races, and the outer race must be restrained in its housing. This is very rare, but it may occur.

Bearing seizure may break shafts and/or may rotate the housing as in Figure 5e (lower figure), but, since it develops a pure torque with no force component, it should not skew the housing as in the upper figure of Figure 5e. Thus, if the housing is moved laterally and/or skewed, the cause is blade-jamming rather than bearing-seizure.

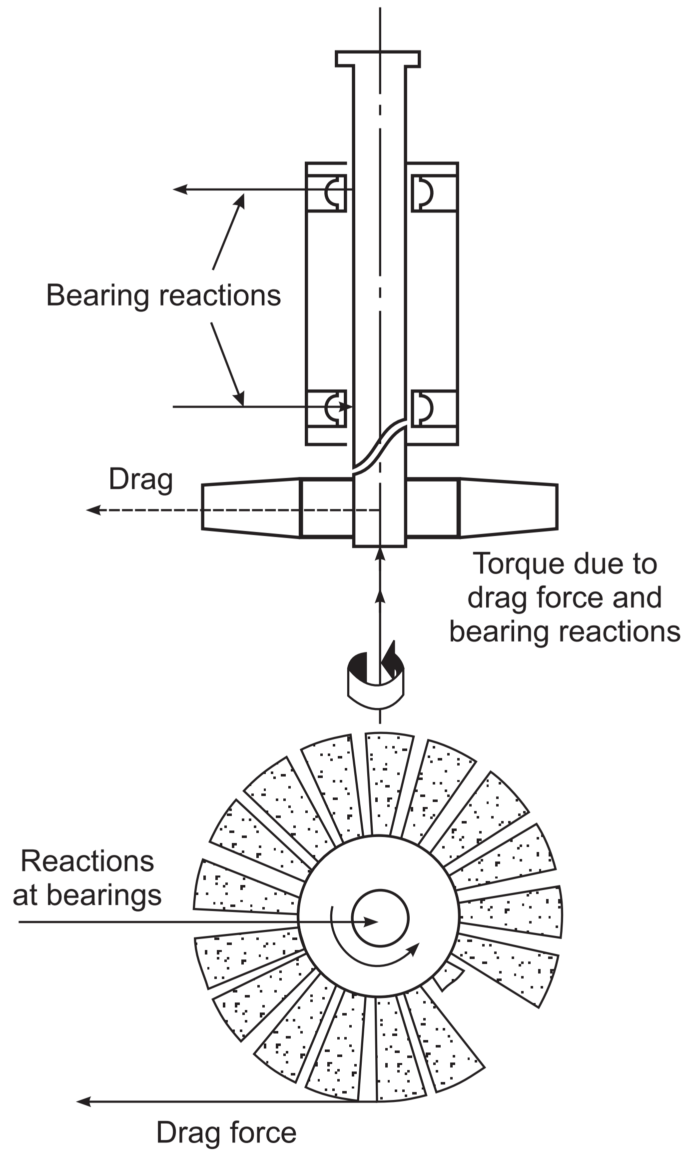

Fig. 5b. Forces on Rotor.

3.2.3.5 Conclusions

When the following damage exists, blade-failure followed by jamming should be investigated:

A. Shaft failure in torque

B. Entire rotor propelled out of housing

C. Foundation bolts broken or pulled up on one side

D. Housing moved and/or skewed on foundation

E. Gouging in or smearing on stationary shroud over rotor

F. Severe damage to bearings at driver

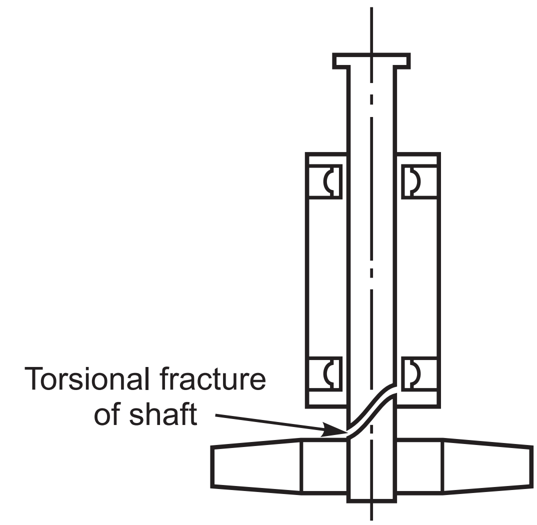

Fig. 5c. Damage to Rotor

3.3 Routine Spares

The following are common routine spares for fans and blowers. Store and maintain the routine spares per original equipment manufacturer recommendations to maintain viability. Refer to Data Sheet 9-0 for additional guidance.

• Couplings

4.0 REFERENCES

4.1 FM

Data Sheet 9-0, *Asset Integrity*
Data Sheet 17-4, *Monitoring and Diagnosis of Vibration in Rotating Machinery*

APPENDIX A GLOSSARY OF TERMS

There are no defined terms in this document.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2024. Interim revision. Minor editorial changes were made.

July 2020. Interim revision. Updated contingency planning and sparing guidance.

October 2016. Interim Revision. Clarification to recommendation 2.2.1.18 regarding NDE testing on fans and blowers and a note to Table 2, Recommended Monitoring and Inspection Frequencies, were added.

January 2012. Major changes include the following:

- Performance monitoring systems were addressed.
- Protective devices were reviewed and updated.
- Fan and blower class types and applications were updated.
- Protection and condition-monitoring recommendations were revised.
- Loss prevention measures and recommendations were updated.

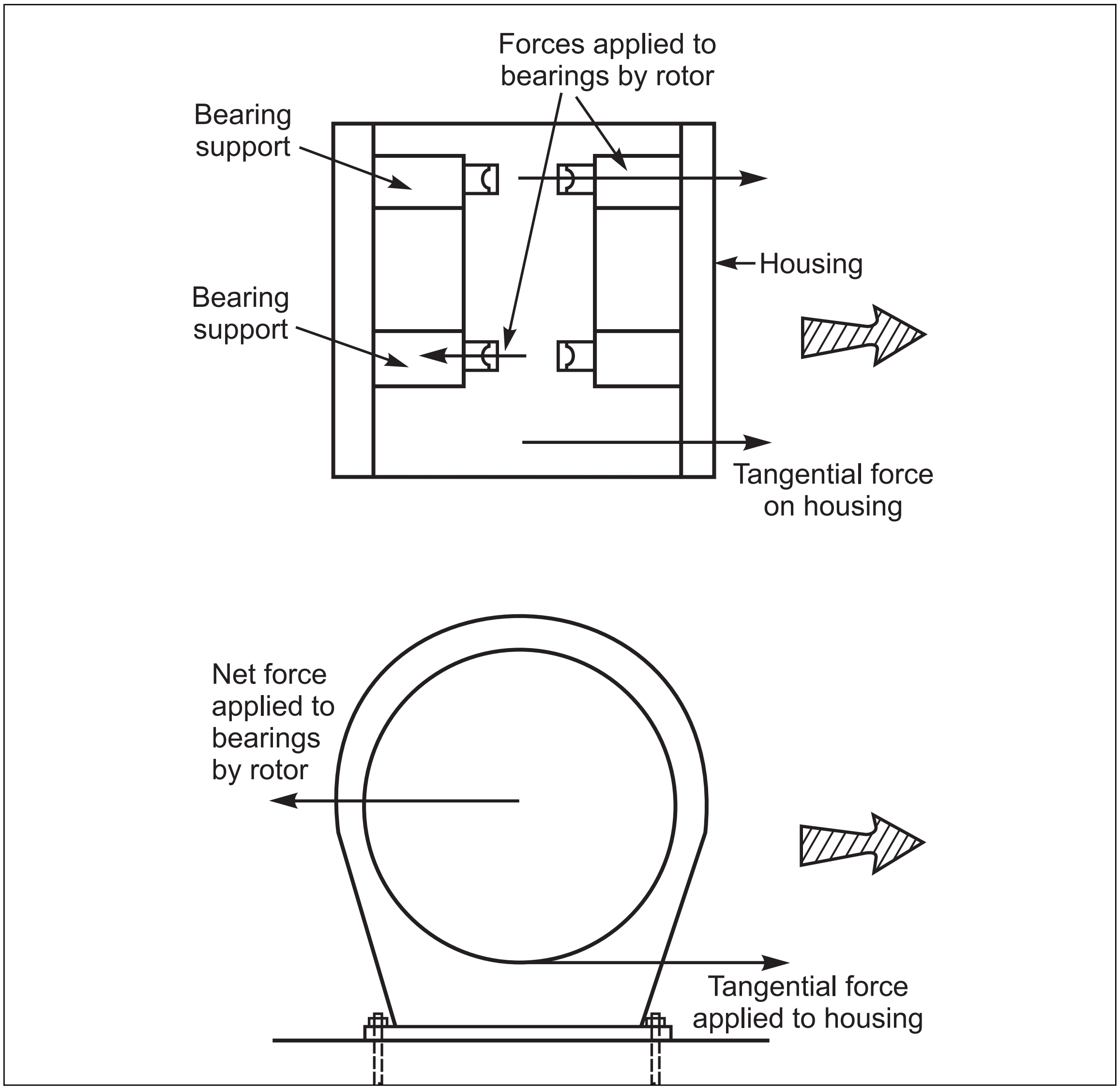

Fig. 5d. Forces on housing.

- Loss history was updated.
- Clarifications were made to unit performance and efficiency.
- The document was reorganized and editorial changes were made.

September 2000. This document has been reorganized to provide a consistent format.

APPENDIX C SUPPLEMENTAL INFORMATION

A fan or blower is a mechanical rotating device that uses blades or an impeller to move a quantity of air or gas, and increase the velocity through a stationary volute or to create an increase in discharge pressure above the initial inlet pressure.

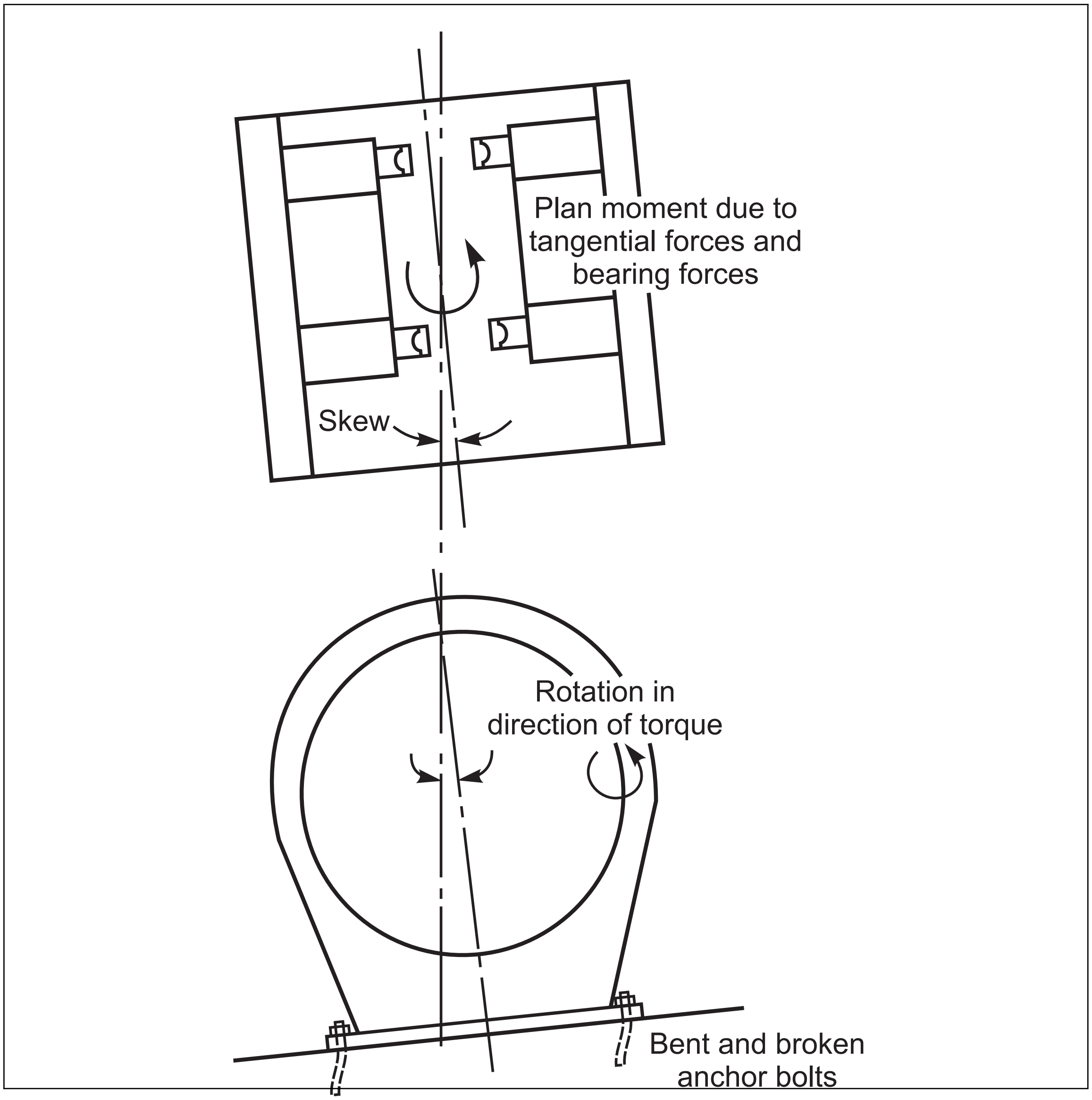

Fig. 5e. Movement of housing.

C.1 Basic Fan Types

C.1.1 Axial

The movement of the vapor is parallel to the centerline of the shaft. Axial fans are used throughout the world operating in industrial processes and variety of applications. They are suited to supplying higher flows at lower pressures, and they are classified as:

A. Variable pitch axial fans are used for specialist applications in mining and tunnel ventilation. In the power industry these fans are used for boiler and flue gas desulphurization “FGD” booster applications.

B. Non-variable pitch, fixed-pitch fans have a wide range of applications. These fans are particularly suitable for use in high-specification ventilation, cooling, and drying systems.

C. Mixed-flow fans combine the characteristics of both axial and centrifugal fans. These fans are heavy-duty compact machines, ideally suited for handling dust-laden gases, and a compact range that gives higher pressure rises than can be obtained from similar sized axial fans.

C.1.2 Centrifugal

The movement of vapor is tangential to the centerline of the shaft. Centrifugal fans are also used throughout the world operating in industrial processes and applications. They are more suited to supplying lower flows at higher pressures (low specific speed duties). The main fundamental design criteria are assessed as follow:

A) Centrifugal fans are more resistant to erosion by gas-borne dust and can be fitted with substantial replaceable liners and/or hard surfacing.

B) Centrifugal fans can tolerate much higher temperatures, and temperature fluctuations, than variable-pitch axial fans

C) At lower loads, the higher efficiency of a variable pitch axial fan cannot be matched by constant-speed centrifugal fans.

D) Layout and available space in an installation may be the determining factors for which type of fan to use, as axial and centrifugal fans have significantly different footprints.

E) Electrical supply; the higher inertia of a centrifugal fan will require a higher current to start the fan from rest, which may be a significant factor if there is a constraint in the electrical supply to the plant.

F) Noise Level; both fan types tend to generate similar levels of noise for a given duty, with lower frequencies more dominant in the centrifugal fan, and mid-frequencies in the axial. Noise from a variable-pitch axial fan will reduce at lower loads, whereas noise will increase from a constant-speed centrifugal fan when inlet vanes or dampers are closed.

C.2 Fan and Blower Applications

Fans and blowers are usually designed for particular applications. Specifications may include:

- Specific flow conditions and characteristics
- Volume of flow Available space
- Motive power possibilities
- Desired efficiency
- Air temperature and level of impurities

In general, fans and blowers are used in a variety of industrial applications, and some are quite large and complex. They are used in coal mines as ventilation fans, as well as in steel refinery blast furnaces, and chemical, cement, and power plants; in cooling towers, for gas recirculation, and bag house operations for large grain processing facilities. They may be boiler forced and/or induced draft. These large units are generally not off-the-shelf items and some may require long lead times to repair or replace.

APPENDIX D BIBLIOGRAPHY

Air Movement and Control Association, Inc. (AMCA). *Fan Application Manual, Part 3: Field Performance Measurements.* Publication 203.

Air Movement and Control Association, Inc. (AMCA). *Fan Application Manual, Part 1: Fans and Systems.* Publication 201.

American Welding Society (AWS). Structural Welding (Steel). AWS Standard D1.1.

Jorgensen, R. (Editor). *Fan Engineering: An Engineer's Handbook on Fans and Their Applications.* Howden Buffalo, Inc.