Paper machine bearing failure

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ABSTRACT: *Most failed bearing components exhibit classic forms of damage normally associated with inadequate lubrication. These include glazing, frosting, surface wear, heat discoloration, and fatigue spalling. Some abnormal condition resulting from improper bearing handling, installation, or maintenance may cause or contribute to the failure. Considering areas of the paper machine where problems may occur, the author discusses prediction of bearing failures, determination of the mode of failure, and implementation of corrective measures to increase bearing service life.*

KEYWORDS: *Analysis, bearings, failure, machine components, machinery, maintenance, paper machines, paper making equipment, preventive maintenance.*

Determining the true cause of bearing failure requires substantial knowledge in analysis of rolling element bearings. An attempt to perform an analysis on a failed bearing may produce satisfaction or frustration. Satisfaction obviously results from correctly determining the failure mode. Frustration stems from only "guessing" at a possible mode of failure.

Although sophisticated condition monitoring equipment may predict imminent bearing failure, the final justification to stop a paper machine to investigate a suspected bearing problem must be based on sound judgment coupled with practical experience. This decision when to remove a bearing from the paper machine is only one component of the total situation. Analyzing and correctly ascertaining the mode or modes of failure is the other requirement of a successful scenario. Thus one would obviously remove a bearing from service before catastrophic failure, if monitoring equipment registered an abnormal vibration level corresponding to a bearing defect frequency. Replacing the bearing is a proper course of action. Determining the conditions causing the bearing to fail is also necessary, however. Any technician performing an analysis of a failed bearing must have sufficient experience or proper guidance. Otherwise, there is a possibility that any corrective actions will not prevent future bearing failures.

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A failed bearing "does not lie." Although the bearing only "knows" the conditions it experienced, it normally contains all the clues to identify the parameters causing failure. Finding and identifying these clues can sometimes be a tedious process even for a prospective bearing manufacturer. Simply finding the cause does not guarantee that the next bearing installation will perform better. One must implement the proper predictive and preventive techniques. Coordinating these corrective actions is not only gratifying but also profitable, since increased bearing service life ensures increased paper machine productivity.

Discussion

A recent two-year study of failed bearings from all types of applications returned for performance analysis has provided some interesting statistics. "End user errors" was the description for over 86% of these bearings. **Table I** lists the most common causes of premature bearing failures in this category.

Table II shows the locations on a paper machine using bearings and the common reasons for bearing failures in each case. Most bearing failures exhibit some form of surface distress and damage from water and abrasive particle contamination. These failures can come from several factors simultaneously acting on the bearing during operation.

Bearing failures can occur on the paper machine despite predictive and preventive maintenance techniques. For proper analysis of a failed bearing, one must know what constitutes normal vs. abnormal bearing operating conditions.

The first step in the failure analysis process concerns the total appearance of the tracking pattern "load zones" present on the internal bearing component surfaces. **Table III** shows internal tracking patterns for a variety of bearings. Any person performing a bearing analysis must understand the loads applied to the bearing position in the paper machine, since the internal bearing component surfaces reflect the actual operating conditions.

When performing an analysis, one must first separate normal from abnormal patterns. **Table IV** describes abnormal load zones. Viewing and analyzing the internal load zones provides two clues to the failure analysis process. The first is an indication of the bearing load. The second is an indication of any abnormal application conditions.

One or more abnormal load zones will usually cause premature bearing failure. Often bearings subjected to adverse application or machine operating conditions typically exhibit lubrication failure. The bearings may also exhibit various stages of surface distress on the internal rolling surface or the sliding surface. A bearing will typically react to abnormal operating conditions similarly to excessive heat generation within the bearing. Internal heat generation leads to viscosity reduction in the lubricant separating the internal rolling and sliding surfaces. On a microscopic level, this viscosity decrease reduces the fluid film thickness separating the component surfaces causing metal-to-metal contact. The friction and surface damage from this condition causes a further increase in bearing operating temperature with continuing reduction in lubricant viscosity and fluid film thickness. Operation under these conditions seriously jeopardizes the bearing and ultimately results in premature bearing failure. In this situation, it is very easy to diagnose the problem incorrectly as relating to

I. Failure analysis percentages

Operational errors	
Inadequate lubrication	34.4
Contamination	19.6
Overload	6.9
Other	4.8
Chemical and electrical	4.5
False brinell	1.9
Misalignment	1.0
Contacting other stationary components	0.8
Total	74.0
Bearing installation errors	
Other	4.8
Misaligned with bearing seat	3.9
Improper internal clearance reduction	3.1
Damage from shock	2.3
Housing defect	1.7
Shaft or bearing seat out of specification	1.0
Incorrect position (free/held)	0.8
Total	17.7
Storage and handling errors	
Impact	1.3
Contamination	0.7
Oxidation	0.3
Other	0.5
Total	2.8
Other Errors	
Other defects not found or justified	5.5

II. Common causes for bearing failures on the paper machine

Breast roll	*Drying cylinder*
Surface distress	Surface distress
Rust or corrosion	Fragment denting
Fragment denting	Etching by additives
	Cracked inner ring
Wire roll	Preload
Surface distress	Oval housing
Rust or corrosion	
Fragment denting	*Felt roll*
	Surface distress
Forward drive roll	Rust or corrosion
Surface distress	Fragment denting
Rust or corrosion	Grease oxidation
Fragment denting	
	Rope wheel
Suction roll	Grease oxidation
Surface distress	Surface distress
Rust or corrosion	
Fragment denting	*Yankee dryer*
Smearing	Surface distress
	Etching by additives
Press roll	Corrosion
Surface distress	Cracked inner ring
Rust or corrosion	
Fragment denting	*Yankee press roll*
Fretting corrosion	Grease oxidation
Oval housing	Surface distress
	Rust or corrosion

III. Internal tracking patterns

	Normal raceway internal load zones exposed to radial load			
	Inner ring rotation		*Outer ring rotation*	
Bearing type	*Inner ring*	*Outer ring*	*Inner ring*	*Outer ring*
Single row bearings:				
Deep groove ball	360°	90°–120°	90°–120°	360°
Angular contact ball	360°	360°	360°	360°
Cylindrical roller	360°	90°–120°	90°–120°	360°
Taper roller	360°	90°–360°	90°–360°	360°
Double row bearings:				
Double row angular contact	360°	90°–120°	90°–120°	360°
Self aligning ball	360°	90°–120°	90°–120°	360°
Spherical roller	360°	90°–120°	90°–120°	360°
Taper roller	360°	90°–360°	90°–360°	360°

IV. Examples of abnormal load zones

IR rotation	*OR rotation*	*Tracking, appearance, and location*	*Possible causes*
X		Skewed from "centered" position	Misalignment
X	X	Offset to one side of the ring	Thrust
X	X	360° load zones on both rings of bearings with internal clearance	Excessive clearance reduction, improper shaft, and housing fits
X		360° load zones on OR, 120° load zones on IR	Unbalanced loading
X		Two separate load zones on outer ring	Out of round, oval, or pinched in housing

(IR = inner ring, OR = outer ring)

V. Maximum bearing temperatures

Grease lubricated: Up to 82–88°C (180–190°F)
Static oil bath: Up to 93°C (200°F)
Circulating oil: Over 93°C (200°F)

lubrication. Since removal of most bearings from service is not fast enough to prevent a catastrophic failure, bearings often exhibit severe damage and heat discoloration. Inadequate lubrication or improper lubrication practices may not be the only explanations for premature bearing failure.

The following is a possible example of an incorrect diagnosis of a failed bearing. A felt roll in the dryer section used a spherical roller bearing installed on the roll shaft with a light "line-to-line" interference fit. Due to this light fit, the inner ring began to creep during operation. This led to a loss of "fit." The shaft turning in the bearing bore generated excessive heat at this interface. Eventually the heat transferred to the internal bearing component surfaces. This affected the lubricant by reducing its viscosity below the value necessary for proper operation. Then internal component metal-to-metal contact occurred and generated more heat to reduce further the effectiveness of the lubricant. The bearing was operating in a lubricant starvation condition. This caused excessive wear, cage fracture, and eventual bearing seizure. When finally removed from service, the bearing exhibited component surfaces with severe wear, heat discoloration, and smearing with roller and cage material.

The technician responsible for this felt roll in the machine incorrectly concluded that the bearing had inadequate lubrication or that the type or amount of grease was incorrect. He inferred this from the severe amount of wear, heat discoloration, and smeared surfaces visible on the bearing component surfaces. Using his reasoning, a company would have expended much effort and capital to correct a nonexistent problem. Proper diagnosis of the actual cause—an improperly specified shaft fit—is necessary to prevent future problems.

VI. Bearing failures and preventive measures from damage during installation

Category of damage	*Short term effects*	*Long term effects*	*Preventive measures*	*Appearance*
Before bearing installation:				
Vibration	Light scuffing between rolling elements and raceways	Fretting corrosion or equally spaced spalling	Store bearings in a vibration free environment	Fig. 1
Humidity	Surface oxidation, static etching	Rust, premature spalling	Humidity levels in storage should not exceed 55%. Avoid rapid changes in storage temperature.	Fig. 2
Impact	Brinelled rolling elements and raceways	Premature spalling	Commonly caused by dropping. Avoid rough handling of bearings and rolls.	Fig. 3
Inspection	Scuffing, nicks and dents on internal surfaces	Excessive noise or premature spalling	Limit the amount of bearing inspection	Fig. 4
During bearing installation:				
Impact with tool	Brinelled rolling elements/races Deformed internal components Cracked rings	Premature spalling Cage fracture Spalling	Use proper and reliable tools for bearing installation. Use hydraulic assist whenever possible.	
Installing by forcing on wrong ring	Brinelled rolling elements/races	Premature spalling	Always apply force to the ring which has the interference fit	
Incorrect reduction of radial internal clearance:				
Too little	Insufficient fit between inner ring and shaft	Fretting or polished surfaces	Measure shaft diameter for size and roundness vs. specification	Fig. 5
Too much	Excessive stresses generated in inner ring Preloaded bearing Excessive operating temperature	Cracked ring or spalling Excessive operating temp. Lubricating problems or spalling	Use feeler blades when installing spherical roller bearings and use the proper tools for bearing installation. Internal clearance reduction for SRB to specification *(5)* or recommended shaft and housing fits.	Fig. 6 Fig. 7 Fig. 8

SRB = spherical roller bearing

Predictive maintenance

Vibration analysis

The above example poses an obvious question. Is it possible to detect an abnormal bearing operating condition before catastrophic failure? The answer is yes, if the technician at the paper mill responsible for analyzing damaged rolling element bearings has the necessary experience and tools to perform his task.

The use of vibration monitoring equipment on the paper machine is the preferred method for detecting and analyzing the condition of the rotating components today. This also includes rolling element bearings. Vibration analysis determines bearing damage caused during operation by analyzing the vibration signature produced by the inner ring, outer ring, rolling elements, and cage. Any unusual pattern generated at a suspected frequency is cause for immediate concern. In addition, the level of vibration measured at a location may dictate justification for a machine shutdown and roll change.

One must also remember that vibration monitoring equipment does not guarantee prediction of a bearing failure. One still requires training and experience in diagnosing bearing failures. Vibration signatures of the newly installed bearings are necessary for the various rolls on the machine. Although this requires time, it is invaluable in reducing bearing failure analysis time. Since the database contains the actual machine vibration signature, it will eliminate any extraneous vibration reading unrelated to the bearings. After establishment of a benchmark, a comparison of future vibration readings will assess the condition of the bearings. This allows removal from service before catastrophic failure.

As use of condition monitoring equipment grows, more paper mills are collecting vibration histories for their rolls. These mills create journals comparing the actual bearing failure mode with its characteristic vibration signature. This type of information is another tool to predict future bearing failures.

VII. Bearing failures and preventive measures for improper shaft and housing fits

Category of damage	*Short term effects*	*Long term effects*	*Preventive measures*	*Appearance*
Improper shaft and housing fits: Insufficient fit on shaft:				
Too light	Inner ring turning/creeping	Fretting, polishing, and heat generation	Measure both the shaft and housing bore diameters for size, roundness, and profile vs. the original specification. Use recommended shaft and housing fits for the various rolls on the paper machine.	Fig. 9
Too heavy	Excessive ring hoop stress. Excessive clearance reduction.	Cracked inner ring. High operating temperature and lubrication problems.		
Insufficient fit in housing:				
Fit too loose	Possible ring turning in operation. Possible cocking of ring in housing bore during operation (FS dryer bearings).	Excessive heat generation and lubrication problems. Edge load problems from excessive misalignment.		Fig. 10
Fit too tight	High bearing operating temperature	Excessive heat generation and thrust load failures		
Improper shape of shaft/housing:				
Out of round	Excessive roll runout	High vibration, excessive bearing operating temperature		
Taper in housing bore	Possible loss of fit during operation. May limit FS dryer bearing expansion.	Lubrication problems. May also result in thrust failures and ring fracture.		Fig. 11
Chatter	Insufficient fit or vibration problems			Fig. 12
Irregular bearing seating surface	Excessive vibration. Loss of fit.	Premature spalling or fractured rings		Fig. 13

FS = front side

Lubricant analysis

Another popular method for determining the condition of the rolling element bearings on a paper machine is by lubricating oil analysis. This technique analyzes the condition of the bearings on the paper machine lubricated with circulating oil by examining the amount of contamination in the lubricating oil. Besides providing an indication of the condition of the bearing components, the analysis also suggests oil degradation—reduction of viscosity, oxidation rate, loss of additives, etc. One can use this information to decide whether to change the oil in the system, increase lubrication maintenance, or replace the bearing.

Contaminants in the oil—moisture and solid particles—cause the most troublesome operating conditions for rolling element bearings on a paper machine. Table I shows that contamination accounts for almost 20% of all bearing failures. The figure is probably even higher when considering rolls on the paper machine. Contamination also probably plays a significant role in the 34% bearing failure category labeled as inadequate lubrication.

An example of this situation occurs when water is present in the lubricant during bearing operation. Even in small amounts, water can reduce the viscosity of the lubricant below the required minimum value. This places the bearing in jeopardy from inadequate lubrication. Another potentially catastrophic situation occurs when water is present in the grease or oil surrounding a bearing with the roll in a static condition. Examples of this occur during roll storage or machine shutdown. In this static condition, water attacks the component surfaces and causes a gray-black, corrosively etched or pitted appearance at equally spaced rolling element locations. After their return to service, these locally damaged areas increase stress. When loaded by the rolling elements, they will spall at an alarmingly fast rate. Unless one quickly removes the bearing from service, the spalling progresses around the entire circumference of the component surfaces

VIII. Bearing failures and preventive measures for inadequate lubrication

Category of damage	*Short term effects*	*Long term effects*	*Preventive measures*	*Appearance*
Paper machine operating conditions:				
Rapid heating during startup	Excessive inner ring stress	Cracked inner ring	Follow the recommendations for proper internal clearance reduction listed for dryer bearings (spherical roller bearings). Use bearings with case hardened inner rings. Check to ensure bearing properly selected for applied loads. Verify lubricant selection is adequate for application.	
High nip loads	High operating temps. Possible bearing overload.	Lubrication problems, edge loading, premature spalling		Fig. 14
Increased machine speed	High operating temperature	Lubrication problems, premature spalling		
Increased dryer temperature	High operating temperature	Lubrication problems, premature spalling.		
Superheated steam	High operating temperature, possible excessive stress in inner ring or miocro-structure change	Cracked inner ring or ring growth possibly resulting in loss of fit on shaft.		
Excessive wash down	Etching of component surfaces	Corrosion, lubricant viscosity breakdown, premature spalling	Better sealing, more frequent regreasing or oil changes. Add water separators.	Fig. 15
Inadequate lubrication:				
Viscosity too high or low Grease amount too high or low Oil quantity too high or low Incorrect grease type	All these conditions result in increased bearing operating temperature, leakage, or grease purging. Too high viscosity may lead to skidsmearing.	Lubrication problems, inadequate viscosity at the bearing operating temperature, premature spalling	Correct viscosity for the application, correct type and amount. Follow relubrication schedule, establish proper oil flow rates for dryers.	Fig. 16

IX. Bearing failures and preventive measures for contamination

Category of damage	*Short term effects*	*Long term effects*	*Preventive measures*	*Appearance*
Contamination:				
Solid particle	Fragment denting, wear on component surfaces	Excessive noise, high operating temperature, lubrication problems, premature spalling	Better sealing, more frequent relubrication intervals	Fig. 17 Fig. 18
Water:				
Rotating bearing	Lubricant film thickness too thin, high operating temperature	Excessive noise, premature spalling	Water separators, open housing drains during relubrication, more frequent relubrication intervals or oil changes,	Fig. 19
Nonrotating bearing	Water displaces oil film etching, high operating temperature	Premature spalling	water content not to exceed 200–500 ppm	Figs. 20–23

and essentially erases the original damage caused by static water contamination. From these two cases, contamination—primarily moisture—clearly may account for approximately 40–50% of all bearing failures occurring on a paper machine.

Although earlier work studied the damaging effects of solid particle contamination *(1)*, some current work is examining bearing life prediction using the level of contamination in the lubrication system. There are two guidelines for cleanliness using theoretical and practical experience. One is the solid particle content according to ISO 4406 Class 15/12 or NAS 1638 Class 6 or better. The other is water content below 200–500 ppm.

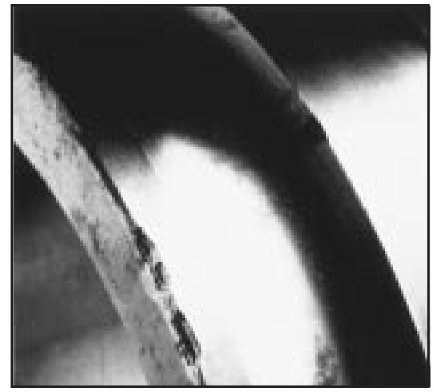
Temperature monitoring

Another predictive technique concerns temperature measurement. An abnormal bearing operating condition normally increases bearing operating temperature. While providing an insight to potential bearing problems, this technique does not show the actual conditions of the bearing components as well as

1. Damage caused by false brinell

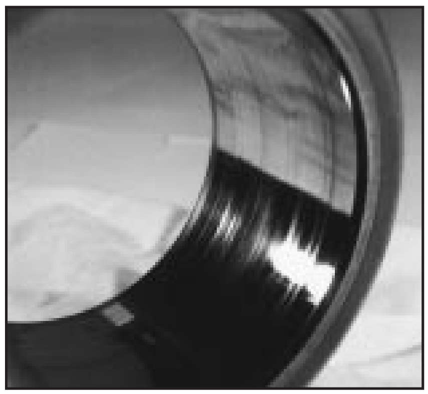
2. Surface oxidation

3. Brinell damage



4. Damage caused by inspection

5. Insufficient interference fit on shaft

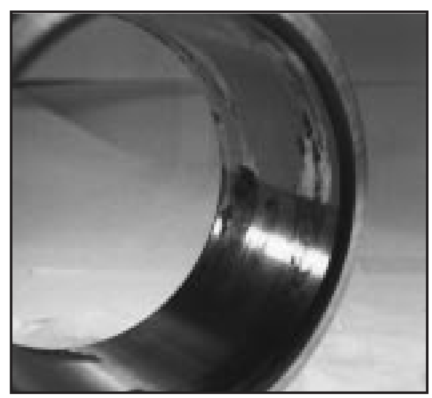


6. Excessive interference fit

7. Excessive clearance reduction

8. Excessive operating temperature

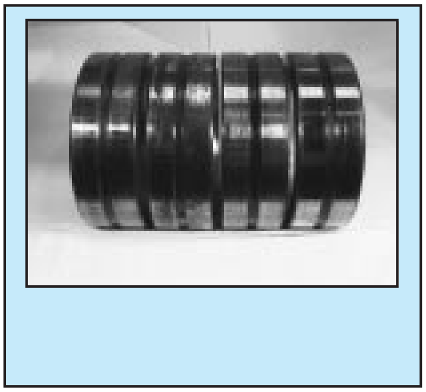
9. Improper fit on shaft



the techniques of vibration monitoring and lubricant analysis. One can use temperature measurement to monitor an application, however. From the recorded measurement, it is possible to justify a machine shutdown and bearing replacement. **Table V** shows guidelines for the recommended maximum bearing operating temperature ranges for particular applications. Remember that these are bearing operating temperatures and not housing temperatures. When measuring the temperature on the housing, add 8–11℃ (15–20°F) to obtain a true bearing temperature.

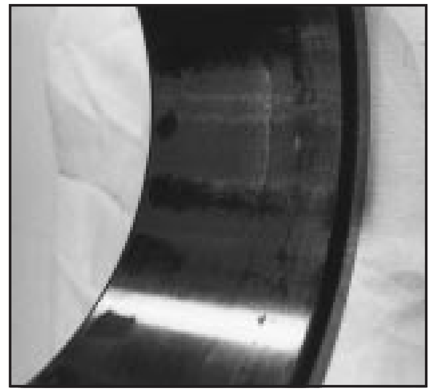
The value in the table for circulating oil is the operating temperature in the bearing checked in the oil exit line and not the actual bearing operating temperature. Dryer bearings lubricated with circulating oil typically have bearing operating temperatures of 121°C (250°F) and higher. The viscosity of the oil at the oil operating temperature in the bearing is the governing factor to determine the kappa (k) factor and the subsequent theoretical bearing life.

10. Housing fit too loose



11. Thrust load failure

12. Chatter on shaft journal or in housing bore



13. Irregular seating surface

14. Edge loading

15. Corrosion from excessive wash down

The use of synthetic greases or oils often will allow the bearing to operate at higher temperatures than the ranges indicated in the table. Due to the higher viscosity index of these materials compared to mineral oils, one may increase the temperature ranges as much as 11–17°C (20–30°F) when using synthetic products. Before implementing such a change, however, contact the equipment manufacturer, lubricant supplier, or bearing supplier for recommendations regarding the lubrication system and its effect on bearing performance.

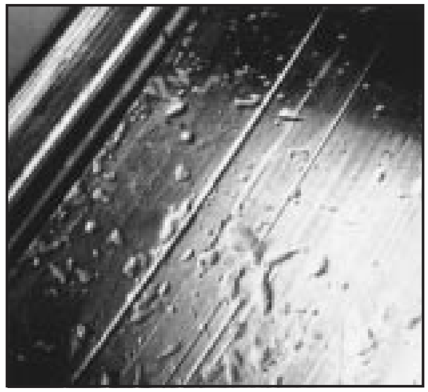
Temperature monitoring can suggest that there may be a bearing problem. It does not specify what is causing the problem, however. If an abnormally high bearing operating temperature remains unchecked, the bearing failure will eventually appear to result from inadequate lubrication. The same argument applies here to temperature monitoring as to vibration and oil sample analysis. If one does not remove the bearing from service soon enough, the resulting damage will undoubtedly hide the important clues needed to identify correctly the initial cause of failure.

Preventive maintenance

Identifying and correctly analyzing a bearing failure is half the problem of increasing paper machine efficiency. The other half concerns the corrective actions to increase bearing service life. As happens with improper diagnosis of a failed bearing, incorporating a change without reviewing all ramifications may adversely affect the life of the replacement bearing. For example, converting a lubrication system from static or circulating oil to grease because of leakage problems with the oil system can have a deleterious effect on the life of the replacement bearing and any other bearings lubricated with the oil system. Examples of other corrective actions requiring thorough review before implementation are changing grease or oil type, changing oil flow rates, and selecting a new bearing type. Specifying a replacement bearing with one that has different internal clearance than the one originally used in the application is an additional example.

Listing all types of corrective actions is beyond the scope of this paper. Any corrective action should not focus only on preventing future bearing failures. It should encompass all areas of the paper machine and involve multiple changes in the parameters associated with the bearing.

16. Inadequate lubrication or polishing wear

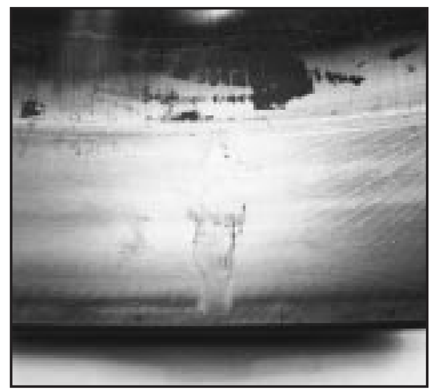


17. Fragment denting

18. Abrasive wear

19. Corrosive straining

20. Static corrosion



21. Onset of spalling initiated by static corrosion

This would include bearing type and lubrication system. The following section outlines some suggested preventive measures for specific types of bearing damage.

Bearing failures and their causes

A bearing technically fails when it reaches its useful service life and internal or external surface damage begins to occur. With help from bearing application engineers, machine builders design rolling element bearings using established guidelines to allow the bearings to achieve long service lives. The selection of bearings on all sections of a paper machine has a goal of 100,000-h lifetime with 200,000-h lifetime in the dryer section before fatigue spalling *(2)*. It is not common to reach the design bearing life because some abnormal operating condition usually affects the bearing and results in premature failure.

The bearing manufacturer is responsible for supplying the paper mill with a product that meets stringent design and quality standards. Once the bearing leaves the factory, however, it is the responsibility of the paper mill to ensure proper storage, installation, and maintenance of the bearing. Fatigue spalling is the normally accepted criterion for bearing failure. From the view of the paper mill, actual bearing failures are any form of bearing damage that impairs or jeopardizes the operation of a specific roll on the paper machine. Under these criteria, failed bearings may or may not exhibit the classic signs of fatigue spalling.

It is possible to group the bearing failures typically found in paper machines into major categories:

- Before bearing installation
- During bearing installation
- Improper shaft and housing fits
- Incorrect bearing selection and position
- Application conditions including paper machine operating conditions, inadequate lubrication, and contamination.

Tables VI through IX list some of these categories with a description of short and long term effects and the corresponding preventive measures necessary to reduce the risk of experiencing a future bearing failure. The tables also refer to **Figs. 1 through 23** for a visual representation of the characteristic damage.

Failures with drying cylinders and Yankee dryers

Spherical roller bearings are the most common bearing type for drying cylinders and Yankee dryers. The primary application that subjects a bearing to severe operating conditions occurs here. In this area, the obvious detriment to long bearing life is the high operating temperature that the steam flowing inside the cylinder journals generates. Machine builders recognize that the bearings will have exposure to high operating temperatures and poor lubrication conditions. They therefore select dryer bearings to obtain a useful rating life of 200,000 h. Under normal circumstances, dryer bearings rarely achieve their calculated life rating and prematurely fail for a variety of reasons. Common reasons are water contamination, static etching, and inadequate lubricant viscosity at the oil operating temperature in the bearing. There is another form of damage that is apparently due to thrust loading. This mode of failure is common for both drying cylinder and Yankee dryer bearings.

In dryer applications, the steam joint generates a small thrust load that is approximately 5–10% of the radial load. Most returned failed dryer bearings removed from both front and back positions exhibit some form of thrust load damage. Usually the bearing exhibits spalling on the inboard set of rollers and corresponding roller path surfaces. The outboard set has no damage except heavy fragment denting caused by the spalling debris.

When analyzing a dryer bearing that appears to have failed from excessive thrust load, one must remember that a dryer bearing rarely undergoes removal during the initial stages of failure. Instead the failure has progressed to the advanced stages of spalling with all the potential "initiators" erased or hidden. For example, surface initiated damages that create localized stress concentrators on the rolling element surfaces such as water etching—caused when the dryer is sitting idle even for short periods of time—and fragment denting—caused by abrasive particles or paper dust—quickly spall. The circulating oil system carries away the spalling debris. As a result, a detailed failure analysis including metallurgical analysis can only suggest some probable conclusions about the cause of these premature thrust failures. In these cases, there are four theories surrounding these failures:

22. Progressed state of spalling initiated by static corrosion

23. Advanced stage of spalling initiated during a nonrotating condition

- The failures are truly thrust load related. For the inboard set of rolling elements to support the load, several conditions must exist in the dryer. The front or "free" bearing would either be "bound" in the housing bore or incorrectly positioned in the housing so as not to accommodate axial dryer expansion. Considering that the inboard roller paths are failing, however, the bearing is not thrust loading when the dryer is expanding. It is thrust loading when the dryer is contracting or cooling. A second possibility of thrust overload can occur in front housings positioned on rockers or ladder bearings. Uneven rocker or ladder bearing wear or improperly located housing base plates could cause the front housing to bind when the dryer cools. Under these conditions, the back bearing will also have exposure to a thrust load, since this is the only location that can resist thrust load from the front bearing.
- Temperature on the inboard side of the bearing is greater than the outboard side. As dryer bearings normally operate under difficult lubrication conditions, any temperature differences created in the dryer will influence the viscosity of the oil and subsequent bearing service life. Since the inboard side of the bearing is near the dryer head, radiated heat from this surface may be influencing the temperature balance across the bearing. This situation would place a greater emphasis on the lubricant's ability to provide the bearing with sufficient oil viscosity at the elevated operating temperatures on the inboard side. As a result, what might be thrust loading in a failed bearing may be a lubricant starvation condition on the inboard roller path created by the elevated temperature on the inboard side.
- The inner ring of the bearing on the dryer journal may be flexing. The inboard roller path of the inner ring would first resist any form of journal flexure created by the dryer and its associated loading conditions. This could create an over-stressed condition on the inner ring that may eventually fail and appear as a thrust

load failure on the inboard roller path. Journal flexing is a rare situation. The forces developed during the corrosion process at the head to shell interface may influence dryer head and possible journal distortion, however *(3, 4)*.

- There may be thrust load from internal roller skewing. Another likely cause of thrust load failures in drying cylinder bearings may not be due to externally applied loads but internally generated thrust loads from roller skewing. By the nature of their design, the rolling elements in spherical roller bearings skew as they rotate on the roller path surfaces. Other bearing components—cages, guide rings, or guiding flanges—typically control the roller skew. In addition, the friction forces developed between the rolling elements and roller path surfaces may control roller skew. These are mainly a function of the internal component surface roughness and lubrication conditions present in the bearing. As lubrication is an obvious concern in rolling element bearings, any large temperature difference created across the bearing ultimately reduces the viscosity of the oil to a point where metal to metal contact occurs. This situation may upset the frictional force balance between the rollers and roller path surfaces and create a condition where the rollers skew in a negative direction. Eventually the bearing undergoes a self-induced thrust load. This will often result in a premature bearing failure. What may be a thrust load failure is again from insufficient lubricant film thickness or low oil viscosity at the oil operating temperature in the bearing.

Summary

Performing rolling element bearing failure analysis can be a simple process provided there is detailed information concerning the failed bearing before conducting the analysis. The obvious forms of surface damage are easy to spot. One can implement corrective actions to extend the service life of the replacement bearing. The difficulty in determining the mode or modes of failure in destroyed bearings becomes apparent when conducting an analysis on a severely damaged bearing. In these situations, one must use all the information obtained from the various condition monitoring equipment in place on the paper machine to determine the cause of bearing failure. In addition, the person performing the failure analysis must have a complete understanding of the functions of the various internal bearing components as they relate to the actual operating conditions applied to the bearing from the paper machine. Anyone following a systematic approach during the analysis can explore or eliminate various factors that can affect bearing performance using the visual characteristics exhibited on the failed bearing. TJ

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