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WHY MY BEARINGS FAIL*

Bimal Nathwani[1]

Abstract

This paper presents an overview of bearings failures with focus on steel mill applications such as continuous casting, rolling mills, multi-roll cluster mills and wire and rod mills. This paper will also provide countermeasures for prevention of these modes of failures.

Keywords: Fatigue; Flaking; Wear; Fracture; Denting; Corrosion; Creep.

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1 INTRODUCTION

Bearings used in steel mills are designed to take extreme abuse from the environment in which they operate. Over time, the operating conditions and maintenance practices can alter. This could mean detrimental effects on operating bearings and other components. For example, if a new grade of steel is set to cast without thorough review of the current operating equipment, it could result in premature failure of bearings or other components as a result of changes to the operating conditions. Premature bearing failures result in lost production, downtime and can drain on manpower and resources. This is why it is important to always have all bearings and components reviewed prior to altering mill conditions.

Historically bearings only reach their calculated life an estimated 3% of the time. The other 97% of the time, the bearings tend not run their entire life due to some form of failure. Typical failures can be divided into two sub-categories – subsurface and surface failures. Subsurface failures occur due to the repetitive cyclic stresses applied under the surface of the raceway eventually leading to flaking on the raceways and rolling elements due to rolling fatigue. These failures can be statistically estimated through bearing life calculations. Bearing manufacturers such as NSK continue to develop cleaner materials and manufacturing processes that can help improve the calculated life as steel machine manufacturers develop streamlined and high efficiency equipment.

Surface failures typically occur due to duress put on the raceways through improper lubrication, contamination, installation and misapplication of the bearings and can be considered as premature since they will not achieve the calculated life. Counter measures to premature failures generally deal with improvements in the application, installation, cleanliness and lubrication improvements. This paper focuses primarily on the surface failures sometimes referred to as premature failure.

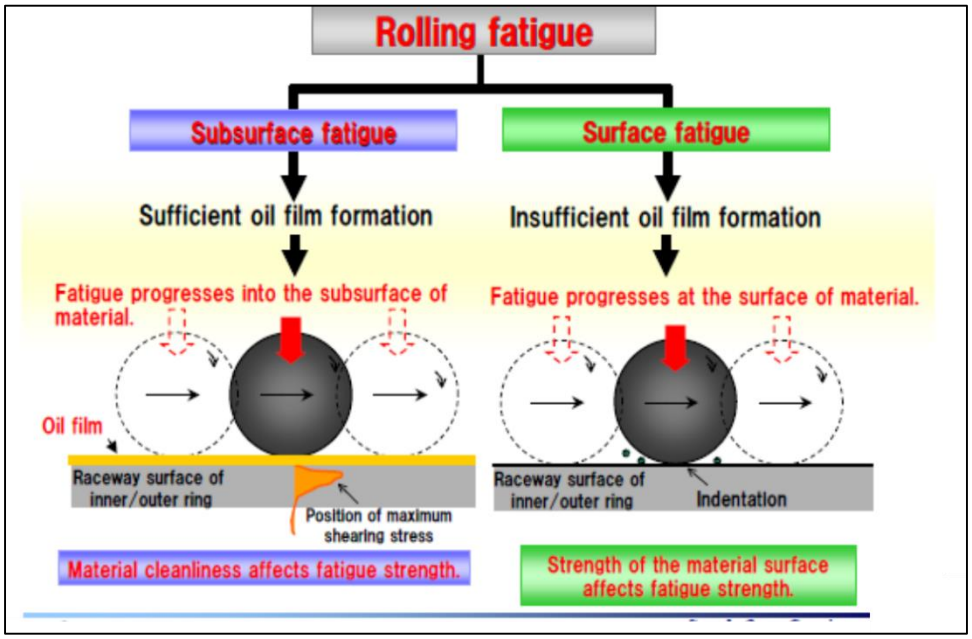

Figure 1: Subsurface and Surface Fatigue.

This paper will discuss various damage and failure modes of bearings used in steel mills as well as the countermeasures to consider in the operating environment of typical steel mill applications.

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2 MATERIAL AND METHODS

The materials and methods used for this paper are based on the applications and experiences from the supply and service of NSK bearings into the steel industry worldwide.

3 DISCUSSIONS

This paper discusses the failure types and countermeasures that can occur in typical steel mill applications specifically in continuous casting, rolling mills, multi-roll cluster mills and wire and rod mills.

3.1 Continuous Casting

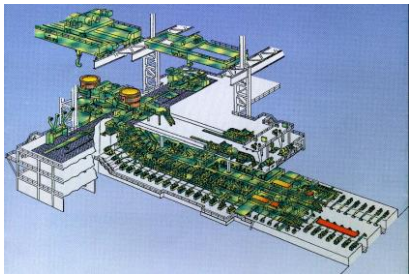

Figure 2: Continuous Caster.

Continuous casting operations in a steel mill are where the molten steel starts its journey through the mill process. This is a method of pouring molten steel from the furnace into a billet, bloom or slab. There are a number of failures that can occur in the bearings used in the continuous casting process. This paper will discuss flaking, fracture, wear, denting and corrosion. The bearings used in a continuous caster will usually see very high heat, water cooling, contamination (water and scale), speed and lubrication issues.

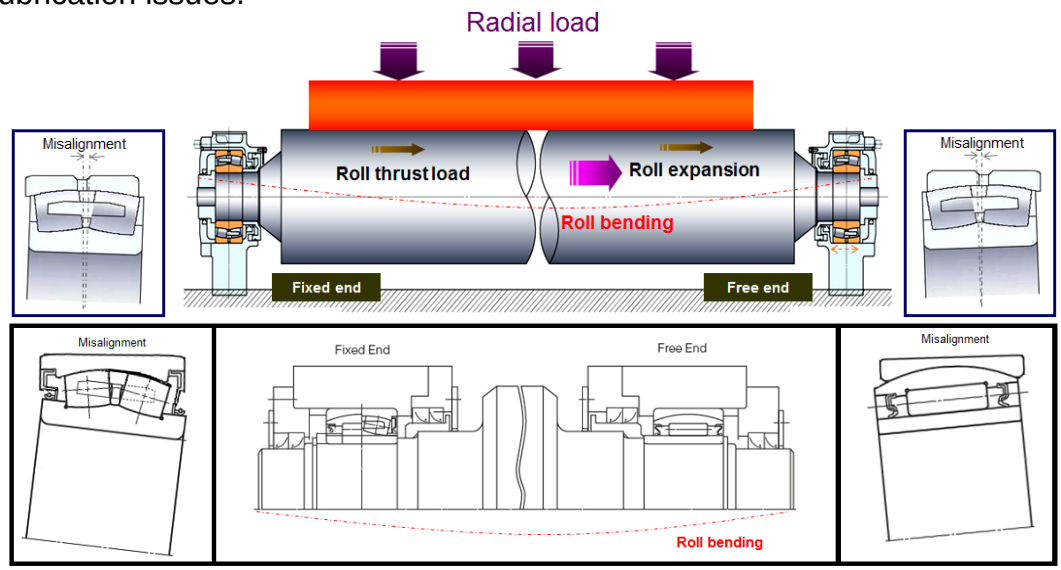

Figure 3: Guide/Pinch Roll Configurations.

Figure 3 shows the effects a casting slab has on a guide/pinch roll equipped with two standard spherical roller bearings and a guide/pinch roll equipped with Sealed-Clean self-aligning cylindrical roller bearing and Sealed-Clean spherical roller bearing.

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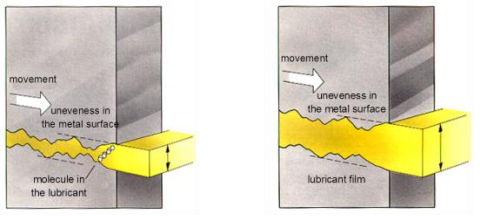
3.1.1 Failures – Flaking/Cracking, Fracture, Wear, Denting and Corrosion

Spherical roller bearings used in caster applications face extremely severe conditions and can suffer from wear. The bearings operate under very slow speeds and often suffer from insufficient lubrication or water impregnated lubrication. In addition flaking and cracking can occur on the outer ring raceway caused by a differential sliding between the two rows of rolling elements. Stress concentrations at the pure rolling point can also cause flaking and finally cracking can develop due to the bending stresses acting on the outer ring during operation.

The countermeasures to prevent this type of failure include improved sealing systems and improve lubrication methods (grease or oil lubrication) by insuring a proper lube film is generated (refer to Figure 4) and preventing water and scale contamination from entering the bearings.



Boundary Layer Lubrication.
(Thin film - about the size of the molecules that make up the oil)

Hydrodynamic Lubrication.
(Thick film - complete separation of the moving surfaces)

Figure 4: Proper Lubrication Film.

Proper lubrication film is important to prevent the surface asperities from contacting between the rolling element and raceways in order to prevent wear. Insuring that the correct type of lubricant is used is also important. The lubricant must be able to operate under the severe conditions faced by this application. Lubrication issues can often be part of the problem with most of the typical failures in castor applications.

For improved wear performance, bearing manufacturers continue to use their research to develop improvements in bearing materials to increase bearing performance in these severe conditions and become more wear resistant and improve bearing life.

Sealing is also important as it will prevent entry of water as well as foreign materials that can cause denting as well as corrosion issues from water ingress into the bearings. In these cases it is important to handle the bearings carefully, understand the loading and insure that the bearing fit surfaces on the shaft and housing are prepared to the recommended manufacturer standards.

Fracture can also occur particularly during installation if impact loading is subjected to the bearings or fits on the shafts and housing are not proper.

Water contamination not only breaks down the lubricant prevent the proper oil film from forming but can also induce rust and corrosion due to the high temperature and humidity while the bearing is stationary.

A summary of typical failures that can often occur in caster applications are shown in Figures 5 through 10.

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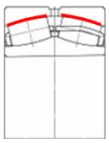
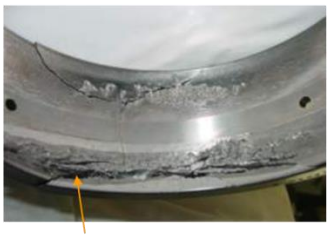
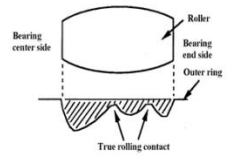
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
	 	Differential sliding specific to spherical roller bearings + Not enough oil film due to extreme low rotation speed, heavy load, high temperature and entry of water. Wear due to differential slip  Flaking due to stress concentration at true rolling lines  Expansion of the flaking Clack due to bending moment 	Improve sealing system, lubrication method, and use a lubricant with good oil film formation ability. Develop new bearing materials for improved performance in these applications: NSK SWR™ Bearings • Increased core hardness for increased fracture resistance • Lower maintenance costs and improved productivity • 3 times greater wear resistance with water-infiltrated grease • Up to 5 times greater life • Up to 7 times the wear resistance compared to standard AISI 52100 steel • Designed specifically for continuous casting machines

Figure 5: Flaking and Cracking in Spherical Roller Bearing Outer Rings.

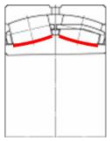
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
	 	Excessive load Poor lubrication, improper lubricant Progressing from rust, corrosion pits, and smearing. Entry of foreign debris	Check load condition Use a lubricant with a proper viscosity, and improve lubrication method. Improve sealing system.

Figure 6: Flaking and Cracking in Spherical Roller Bearing Inner Rings.

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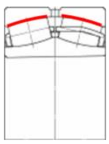
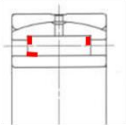
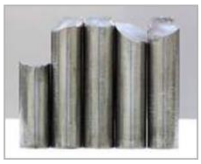
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
	 Damaged Outer-ring	Impact during mounting Improper handling	Improve mounting method (Shrink fit, use of proper tools)
		Poor handling such as dropping	Improve handling methods
	 Damaged Outer-ring rib	Excessive load	Reconsider the loading conditions.
	  Damaged rollers		

Figure 7: Fracture.

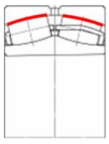
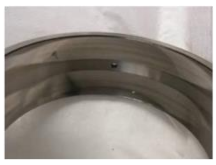
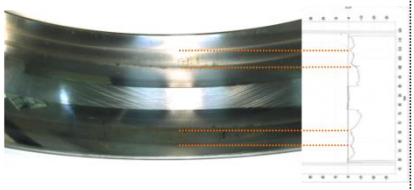
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
	  	Enter of foreign debris	Improve sealing system
		Poor lubrication.	Check lubricant and lubrication method
		Sliding due to irregular motion of rolling elements.	NSK SWR™ Bearings • Increased core hardness for increased fracture resistance • Lower maintenance costs and improved productivity • 3 times greater wear resistance with water-infiltrated grease • Up to 5 times greater life • Up to 7 times the wear resistance compared to standard AISI 52100 steel • Designed specifically for continuous casting machines.

Figure 8: Wear.

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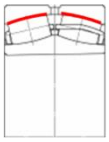
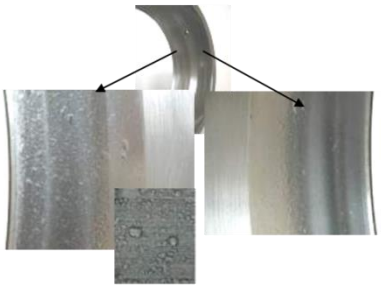
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
		Enter of foreign debris like a metallic particle.	Wash housing. Improve sealing system, lubrication method. Filter lubrication oil. **NSK** TOUGH STEEL™ • Advanced material properties • Innovative heat treatment technology • TF, NTF, HTF, STF, and WTF : material solutions available for a variety of environmental challenges • Available for spherical, cylindrical and tapered roller bearings, deep groove and angular contact ball bearings

Figure 9: Denting

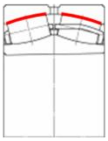
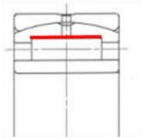
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
		Entry of water.	Improve sealing mechanism
		Improper lubricant.	Study lubrication method
		Formation of water droplets due to condensation of moisture..	Improve sealing mechanism
		High temperature and high humidity while stationary.	Anti-rust treatment for periods of non-running.
		Improper storage conditions.	Improve storage methods

Figure 10: Rust & Corrosion

3.2 Rolling Mill & Multi Roll Clusters

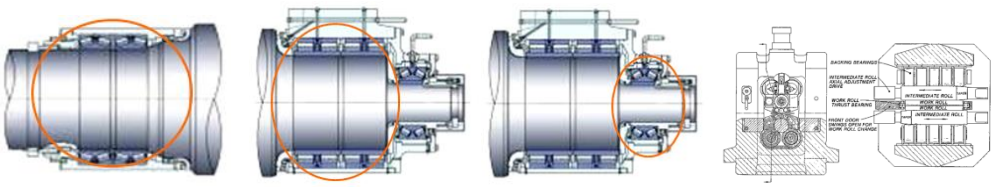


Figure 11: Typical Rolling Mill & Multi Roll Cluster Applications: Work Rolls, Back-up Rolls, Thrust Bearings and Z mills

Rolling mill applications for bearings typically consist of work rolls, back up rolls and thrust bearings. Rolling is categorized as hot rolling or cold rolling. The application conditions during hot rolling tend to be severe due to hot conditions, heavy loading, differential speed variations between stands, water and scale contamination. Cold rolling conditions are also challenging even though the steel begin cold – heat is

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generated through the rolling process. Additional concerns include water contamination and heavy loading.

3.2.1 Failures

Rolling Mill failures are typically seen through flaking, smearing, cracking, denting, seizure, corrosion and other types of failure modes such as creep. Flaking, cracking denting and corrosion failures have been summarized in section 3.1.1 and the failure modes that are evident in rolling mill bearings resemble the indications found on failures summarized for the caster bearings.

Smearing is a phenomenon that will occur when bearings are subjected to a light load and sudden acceleration or deceleration. This can cause an improper lubricant film to form resulting in the wear of the surface asperities between the roller and raceways. Smearing can be seen as circumferential streaks in the raceway of the bearings. Improvements in the lubrication to insure full film lubrication as well as minimizing severe running conditions can help prevent smearing.

Seizure can cause significant damage and cost a great deal in terms of down time, lost production and manpower costs. Causes of seizure can be due to poor lubrication, loading, fits and internal clearance. Countermeasures to seizure can include a review of the entire application and an inspection of the mating components such as the shafts and housings. Improvements in the lubrication system can also improve the prevention of seizure.

Another phenomenon that can often occur due to incorrect shaft or housing fits is creep. Creep occurs when there is metal to metal contact that can cause fretting of a bearing ring due to an improper fit. This often results in oxidization and in severe cases can cause the bearing ring to crack and propagate to seizure. Spiral grooves on the inner rings of large bore roll neck bearings can often be used to prevent wear from creep by allowing shaft lubrication to get to the mating surfaces between the bearing and the shaft.

Proper mounting practices are critical to the operation of the bearing. Installation damage can be detrimental to the bearing resulting in premature failures through propagation of cracks or scoring of the raceways during installation of separable bearings. Included in the installation is insuring that the mating components are to the correct specifications and free from damage. Scoring can also occur on the outer ring or faces of the bearings where improper fits, lack of lubrication or axial loads on the bearing faces from mating surfaces, particularly on thrust rollers in the rolling mill.

Additional rolling mill failures can occur due to uneven loading on the bearings which may result due to incorrect mounting, grinding of the inner ring on the backup roll bearings and possibly uneven loading on the bearings.

A summary of typical failures in rolling mill and multi cluster Z mill applications are shown in Figures 12 through 17.

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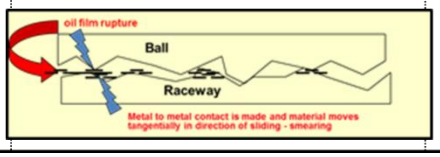
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
A CA CE E		High speed and light load. Sudden acceleration/deceleration Improper lubricant Entry water	Improve bearing clearance. Check operating condition. Improve lubrication method. Improve sealing mechanism.
			
			

Figure 12: Smearing

Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
A CA CE E		Poor lubrication Excessive load (Excessive preload) Excessive rotational speed Excessive small internal clearance Entry of water and debris Poor precision of shaft and housing, excessive shaft bending Irregular maintenance period. Unsuitable grease	Study lubricant and lubrication method Reinvestigate suitability of bearing type selected Study bearing clearance and fitting Improve sealing mechanism Check precision of shaft and housing Improve mounting method
			

Figure 13: Seizure

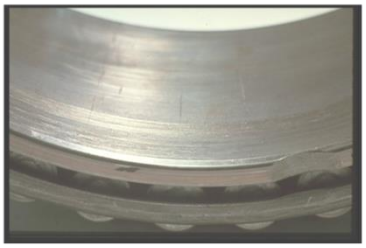
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
A CA CE E		Improper shaft fit Improper shaft lubrication Too high speed Acceleration/Deceleration, Reversing operation Too small load	Check shaft fit Use bearing with spiral groove in bore Improve shaft and lubrication

Figure 14: Creep

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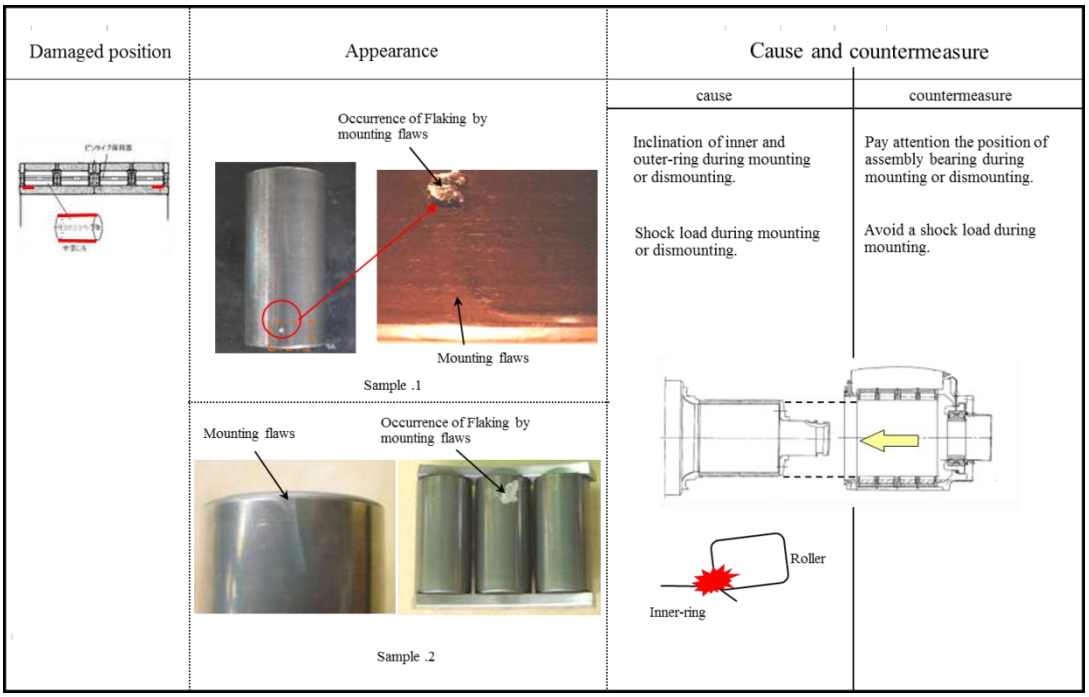

Figure 15: Mounting Flaws

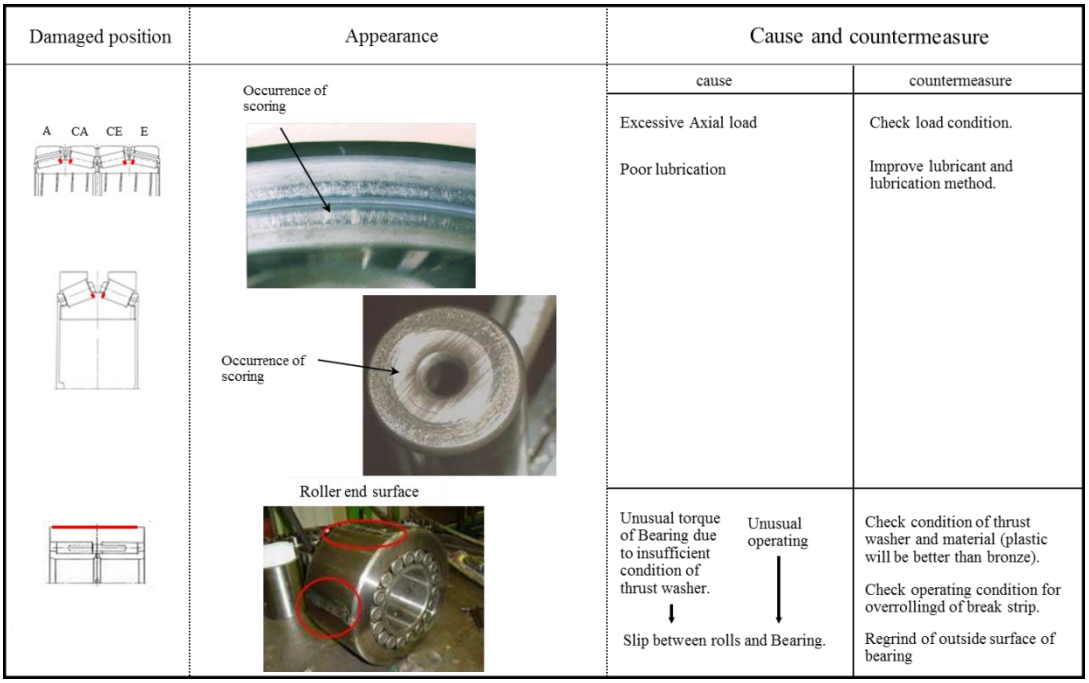

Figure 16: Scoring

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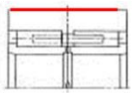
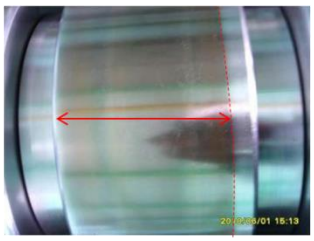
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
	 Uneven contact between outside surface and IMR	Wrong mounting Uneven contact load Poor shape of outside after re-grinding	Check mounting method Check parts around the bearing. Check load and operating condition Check result of dimension and shape after re-grinding

Figure 17: Uneven contact loading

3.3 Wire & Rod Mills

Wire, rod and bar mills operate similar to the rolling mills for plate and other product. Operating conditions in these mills tend subject the bearings to high temperatures, water spray, high loads, marginal sealing arrangements resulting in short bearing lives.

3.3.1 Failures

In addition to the failures presented in earlier sections, the wire and rod mills can also be susceptible to failures due to cage deformation. This can be caused by sudden acceleration and deceleration of the bearings causing the rolling elements to deform the cage pillars. Installation and shock loading can also cause damage to the cage. Countermeasures include insuring proper installation and loading conditions and if needed changes to more robust cage designs. A summary of the cage deformation failure can be seen in Figure 18.

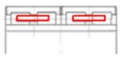
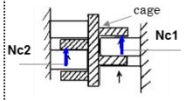
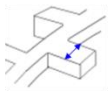
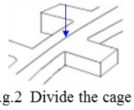
Damaged position	Appearance	Cause and countermeasure	
		cause	countermeasure
	 	Sudden high acceleration/deceleration during operation. Occurrence of excessive stress at the root of cage pillar by poor lubrication. Occurrence of differential speed of each row between Nc1and Nc2 by uneven wear on each race-way  Shock load during mounting or dismounting.	Check the operating condition. Change the cage design.  E.g.1 Increase the width of cage pillar.  E.g.2 Divide the cage into two peaces. Improve the mounting methods.

Figure 18: Cage Deformation

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4 CONCLUSIONS

Bearing failures can cause significant costs due to equipment downtime, lost production and manpower costs. They can also cause potential safety concerns. Maintaining proper lubrication, installation, sealing and monitoring practices can help improve bearing performance. This can result in efficient operations and reduced downtime and lost production. Understanding the cause of the bearing failures is important to help implementing countermeasures to prevent recurrence.
For applications presented in this paper, the cause of premature failures can be summarized as shown in Figure 19. This summary highlights the most dominate modes of failures observed.

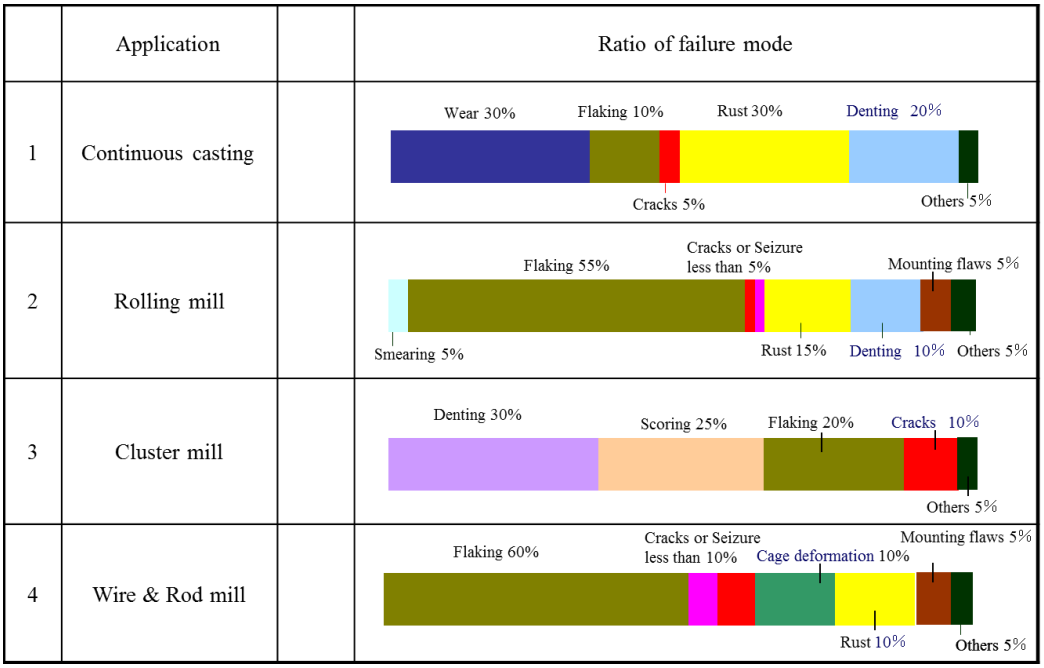

Figure 19: Summary of Classification of Failures for Steel Mill Applications

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Sources

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2 NSK Bearing Doctor
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5 NSK SWR Bearing Catalog
6 NSK Handling Instructions for Bearings

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