

## Failures of Rolling Bearings in Bar and Rod Mill

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### INTRODUCTION

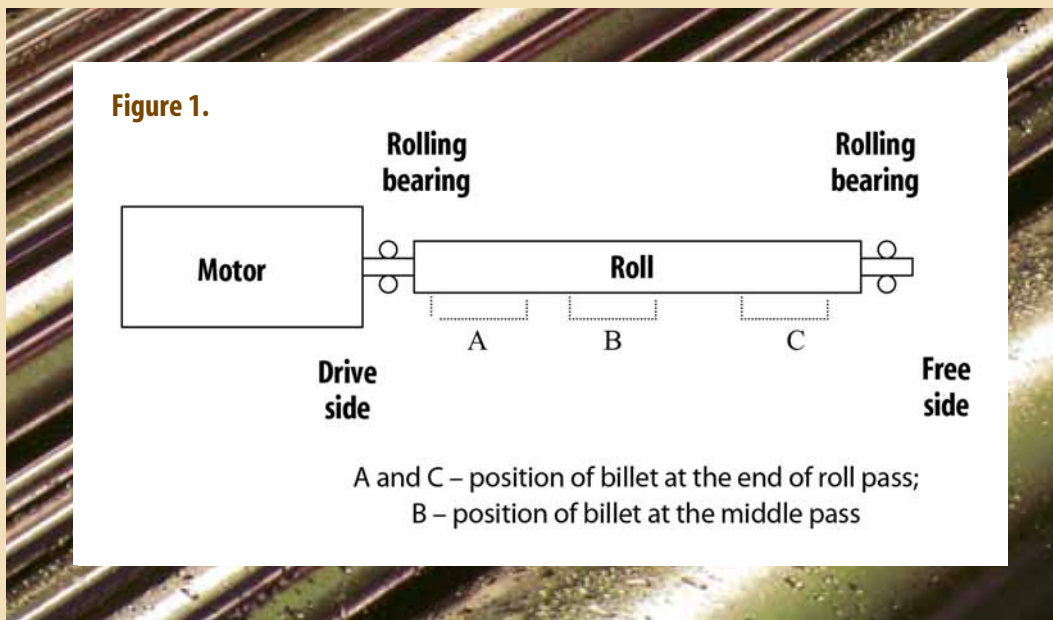
Bar and rod mills can usually be found in the steel-rolling process at a steelmaking plant. Pre-heated steel billets are rolled into the mill in order to produce channels, bars, rail beams, etc. The rolling stock is then forced into the grip of rolls, rotating in opposite directions. The two rolls, which are supported by rolling bearings, and a drive and adjustment mechanisms form a so-called roll stand. The successive reduction and shaping of the cross-sectional area takes place over several roll stands.

Even if a rolling bearing is correctly specified, fitted, lubricated and protected from contamination, it will eventually fail to operate because of fatigue induced by the repeated cyclical stresses (1). Premature failure may occur due to bad fitting, lubrication

breakdown, contamination or misalignment. Smearing (i.e., scuff marks, discoloration and metal transfer on non-rubbing surfaces) is often found on the ends of rollers and the corresponding guide face on the flanges. The cause is usually heavy load and/or poor lubrication (2).

The bar and rod mill under review is in continuous operation throughout the year. The mill experiences a high rate of bearing failures. Furthermore, bearing failures cause not only just one roll stand to stop, it also brings the entire production process in the plant to a halt, resulting in significant production losses.

Condition monitoring of the rolling bearings has not been practiced, and the suitable techniques of condition monitoring for rolling bearings are bearing temperature



Arrangement of rolling bearings, which support rolls of roll stand.

monitoring or vibration monitoring. Analysis of the level of bearing vibration allows us to predict and prevent failure.

Study of bearing failures has been undertaken and statistical data concerning failures has been collected for four years. The types of bearings failures, location of the failed bearings and the date of the failure were recorded. Analysis of failures is aimed at the identification of: (a) operating conditions such as geometry, load, speed, temperature, lubrication, environment and (b) likely engineering causes of failures (3).

This case study presents a study of failures in rolling bearings and recommendations on possible elimination of failures or frequency reduction in these failures.

## OBSERVATIONS

Bar and rod mill consists of 28 roll stands, grouped as follows: roughing section (1-3), intermediate section (4-10) and finishing section (11-28). Stands 1-3 are characterized by high-load and low roll rotational speed (5 rpm at stand 1). In stands 4-16 significant load still prevail. At the finishing section the load is low, but speed is high (3,000 rpm at stand 28).

The position of rolling bearings, used for support of the rolls, is shown in Figure 1. Spherical roller bearings, cylindrical roller bearings, angular contact ball bearings and deep groove ball bearings are mounted on the rolls. All the bearings are mounted on the cylindrical bore and the shaft except spherical roller bearings on stands 1-16, which is on the tapered shaft (taper 1:30).

The billets are preheated to 800-1,200 C and the bearings operate in a high-temperature environment. Based on inspection and observations, bearing temperature is estimated at 90 C. The rolls and bearings are subjected to shock loading because the billets are heated unevenly.

Also, the bearing housings are exposed to continuous water flow because water jets are used to cool the rolls.

To protect the bearings from water ingress and solid contaminants, sealing is provided by a non-contact seal-axial

labyrinth. Solid contaminants are in the form of steel scale, which peels off the rolling stock and is highly abrasive. The bearings are lubricated by grease, which protects the bearings from ingress of water, dirt and scale. For mounting and dismounting of the bearings, the oil-injection method is applied.

Inspection of the failed bearings (see Figure 2) revealed cracks through the inner and outer rings. The formation of cracks with part separation (see the broken ring in Figure 3) also was observed. In most cases, rings have cracks while cage and rolling elements are intact. Visual examination of failed raceways has shown that tracks have deep scratches and pitting marks. Smearing on the side of the ring's faces occurred.

The outer contact surface of the outer rings and bearing seating surface of spherical bearings exhibit dark discoloration, which is an indication of fretting-corrosion. Inspection revealed an evidence that outer ring of failed bearing has turned in clock's bore. As a result of the wear and effect of the unbalanced masses, the bore become egg-shaped.

The only damage on the rolling elements was pitting caused by solid contaminants.



Failed rolling bearing.



Broken outer ring of rolling bearing.

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Figure 4.



Broken roll.

No visible deterioration of the cages was seen except for one case of a collapsed cage. There were a few cases of burnt or seized bearings. In addition to bearing failures, broken rolls were recorded (see Figure 4). Most of the failures have occurred when passed at the roll end is used.

## ANALYSIS

### Statistical data, concerning bearing failures

For four years 103 failures of rolling bearings were recorded. The distribution of failures along the roll stands is shown in Figure 5. Most of the failures took place within stands 1-8. Roll stand 7 had recurrent failures. Almost 36% of all the failures occurred on stands 7, 11 and 18. Of all the failures considered, 67% occurred on the top rolls.

Distribution of the top rolls' failures (see Figure 6) shows that stands 7, 11 and 18 had 33% of the failures. The number of failures per year varies with time (see Figure 7, on page 24). The maximum number of failures, which occurred in the second year, was 42, and in the fourth year only 10 failures took place. During the period under review there were 13 cases of broken rolls (9 bottom rolls). On the drive side of the rolls 30 bearing failures were recorded, while on the free side 60 bearing failures were recorded.

There were 37 cases in which cracked rings (inner or outer or both) were recorded. Other findings included:

- Smoking, burnt, collapsed or seized bearings were observed in 22 cases.
- Smoke emission from the bearings was observed in 12 cases.
- Bearings turning in the housing bore or on the shaft were observed in four cases.

### Bearing fitting

Improper mounting of bearings can cause

premature bearing failure. Interference is the recommended fit for housing and shaft seating. For a cylindrical bore, the incorrect fit, for example excessive interference, reduces internal clearance and can cause cracking of rings. For tapered seating, excessive drive up results in cracks through the inner ring. On the other hand, loose fit in chocks or on the shaft results in a turned bearing and fretting-corrosion. Cracked inner and outer rings account for 36% of all the failures recorded.

### Bearing misalignment

A significant portion of bearing failures involves the top rolls. These failures are attributed to axial misalignment, angular misalignment, malfunction of adjustment mechanisms and wrong adjustment of roll settings. The bottom roll is fixed by the clamping of chocks to a roll stand and not many alignment problems emanate from the bottom roll. All the horizontal and vertical adjustments are made on the top roll. Through vertical and axial adjustment of rolls, misalignment can be introduced resulting in the roll being skewed.

The misalignment is indicated by smoke emitted as labyrinth elements rub and grease burns. Misalignment leads to uneven distribution of contact pressure over rolling elements, edge stresses, etc. Misalignment also can cause an increase in bearing load, resulting in shortening of bearing life.

### Loading

The 13 cases of broken rolls are attributed to overloading. A bar and rod mill is designed to roll 80x80 mm square billets. In practice, the mill has been used to roll 110x110 mm and 130x130 mm billets, which is overloading. The roughing section takes the bulk of the load. When the end of the roll pass is being used, roll breakage is more likely to occur. Shock loading, resulting from uneven heating of billets, contributes to overloading.

Predicted life of rolling bearings with 90% probability is given by (4)

$$L_{10} = \frac{10^6}{60n} \left[ \frac{C}{P} \right]^m \text{ hours}$$

where  $C$  is basic dynamic load rating,  $P$  is

equivalent load,  $n$  is roll rotational speed in rpm, and  $m$  is an empirical exponent. For spherical rolling bearing of designation 24052CCK/W33 (roll stand 3)

$C = 1.76 \text{ MN (2)}$ ,  $P = 655 \text{ kN}$ ,  $n = 16 \text{ rpm}$ ,  $m = 10/3$  and  $L_{10} = 3.2 \text{ years}$ .

For angular contact ball bearing of designation 305 – 262D (roll stand 16)

$C = 265 \text{ kN (2)}$ ,  $P = 33.5 \text{ kN}$ ,  $n = 350 \text{ rpm}$ ,  $m = 3$  and  $L_{10} = 2.7 \text{ years}$ .

Some bearings on bar and rod mill are known to have failed due to fatigue after 5 years of service. Overloading shortens bearing life and rolling bearings fail prematurely.

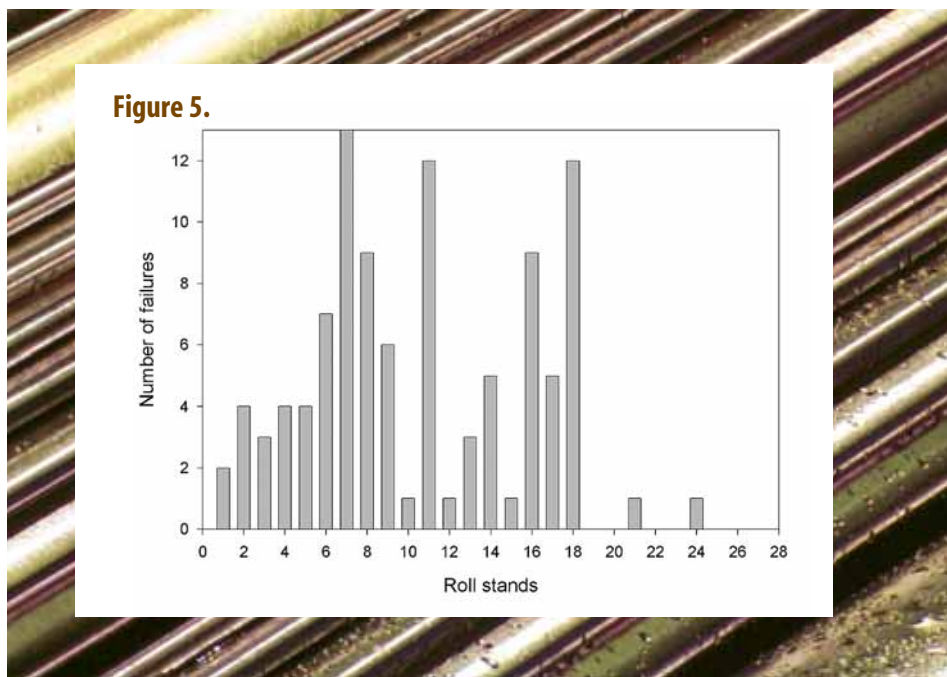
### Lubrication

Originally the bar and rod mill were lubricated by oil mist. Later, grease lubrication was adopted. Aluminum complex grease—heavy duty, elevated temperature grease of consistency No. 2, dropping point 260 C—is used. Four Ball Test Load Wear Index is 530 N.

Additives required for this application include rust inhibiting, EP additives and anti-oxidation. Bearings are re-lubricated by replenishment. The re-lubrication interval is one week. Failures such as seized, burnt bearings are attributed to poor lubrication. Outer rings were found to exhibit fretting-corrosion on the outer surface. Fretting is caused by ingress of water and relative motion (slip) of outer rings with respect to the chock, resulting from loose fit in chock bore.

### Contamination

Some premature bearing failures can be traced back to contamination problems. Initially, bearings may be subjected to contamination from the mounting procedure. Some contaminants include fine oxide scale entering the injection oil and bearing. Solid particles are harbored on the inner ring—roll journal interface and affect fit. Pitting on tapered journal, caused by solid contaminants, has been observed. Also, scoring marks, scratches and pitting on raceways and rolling elements are evidence of bearings being contaminated by solid particles.



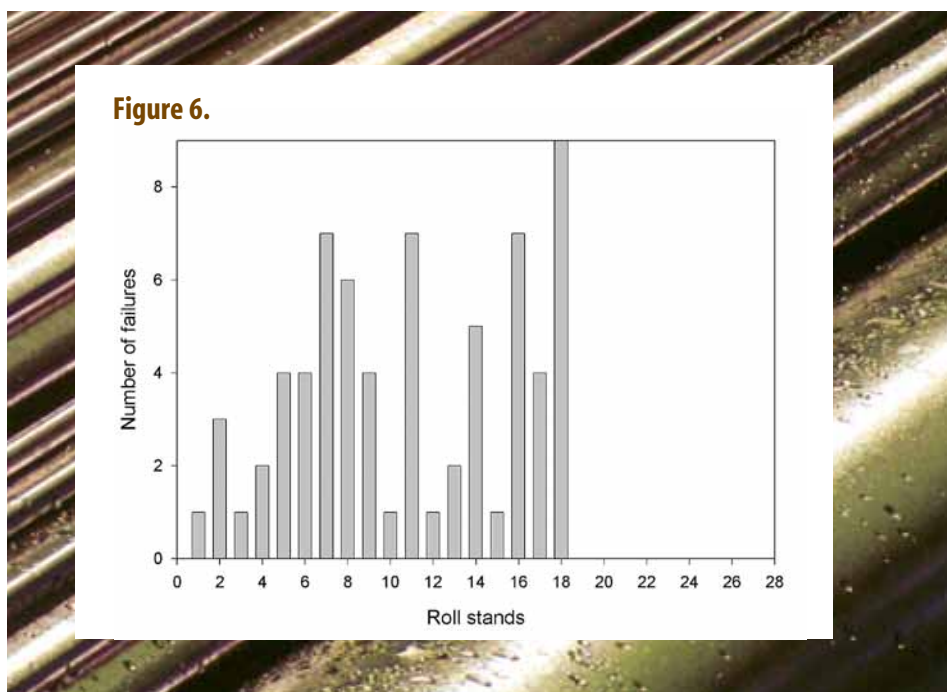
**Figure 5.**

Second, when rolling bearings are in operation, scale finds its way into bearings through lubrication holes. Labyrinths full of grease are effective seals, and it is unlikely that solid contaminants have passed through a labyrinth and entered the bearings. Also, water from cooling jets may find its way into bearings and accelerate fatigue failure.

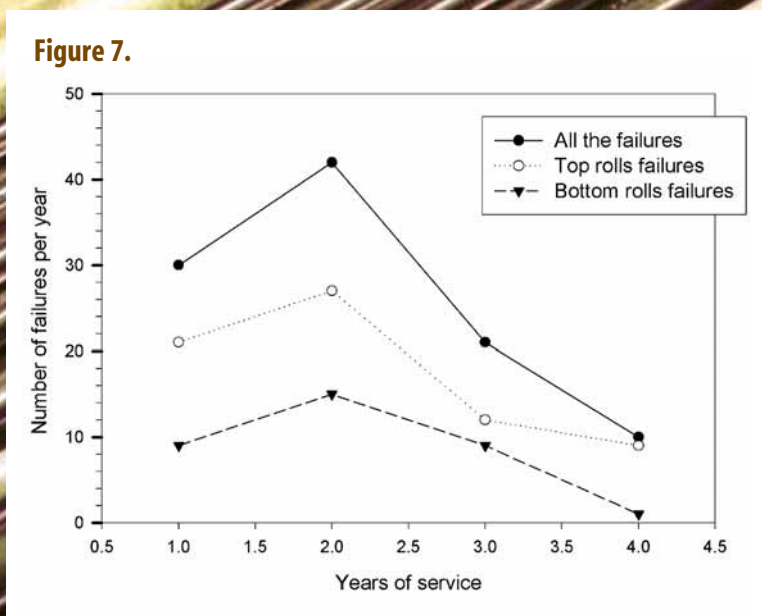
**Distribution of all the recorded failures along roll stands.**

**Distribution of failures, that occurred on top rolls, along roll stands.**

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**Figure 6.**



Number of failures per year versus time.

## CONCLUSIONS

Statistical data shows that roll stands 7, 11 and 18 experienced the highest rate of failures. The free side of the top rolls is identified as an area of the mill that has the highest likelihood of bearings failures.

Failures of rolling bearings are attributed to the following factors: mounting procedure, misalignment, overloading, contamination and lubrication. Failures due to the above causes are far more frequent than fatigue failure. Most of the rolling bearings failed prematurely before the predicted fatigue life is reached. Identified failures due to fatigue only indicate that reasonable life can be achieved. If condition monitoring

has been applied, imminent failure could be detected at an early stage and prevented.

To avoid cracked races, correct fitting procedures (for tapered seating correct drive up and for cylindrical seating adequate interference) are to be followed. Proper horizontal and vertical adjustments of rolls will eliminate failures due to misalignment. Grease used for bar and rod mill rolling bearing applications is adequate. Re-lubrication interval is suggested to be re-considered. Also, contamination during mounting of bearings must be eliminated.

In conclusion, two groups of problems which caused failures of rolling bearings in bar and rod mill were identified. In the first group there are structural problems related to mounting, misalignment and overloading of bearings. These structural problems are responsible for the majority of failures. In the second group there are tribological problems, associated with contamination and lubrication of bearings. The following measures are suggested:

1. Recondition the equipment of the bar and rod mill.
2. Introduce condition monitoring of rolling bearings, preferably vibration analysis.
3. Run the mill according to the specified loading limit. <<

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