REDUCING MILL CAPITAL COST BY ADOPTING THE MORGOIL KLX BEARING

[1] T. C. Wojtkowski
[2] G.F. Royo
[3] P. N. Osgood

Summary

Through the use of MORGOIL KLX bearing technology, Morgan Construction Company is once again at the leading edge of rolling mill bearing development. The newly developed KLX bearing has shown that it can more efficiently distribute rolling load within the bearing, allowing more than a 24% increase in load capacity. This increased capacity allows a smaller KLX thin-sleeved bearing to be used in place of a larger, more traditional KL design. The smaller bearing in turn drives a size reduction of the width and height of the mill; it also substantially decreases the size of the lubrication system. These attributes contribute to reducing the overall capital cost of a new mill. Operational costs are reduced by the correspondingly smaller lubrication system, since it requires less oil to fill and maintain. The increased roll neck section of the KLX bearing, as compared to the traditional KL bearing, contributes to higher product quality by increasing mill stiffness.

Keywords: oil film, journal, bearing

ABM – Joinville, Santa Catarina – October 26 to 28, 2004
Submitted by: MORGOIL Bearing Division, Morgan Construction Company

Introduction

The rapid escalation of construction and equipment costs for new flat mills demands innovative ideas to reduce capital cost and allow a shorter payback period on initial investment. Since the early 1930's, when the first MORGOIL® bearings were introduced, Morgan Construction Company has pioneered numerous technological improvements in modern oil film bearings. A new standard of performance has been set with the development of the highest capacity bearing available, the MORGOIL KLX™. The KLX bearing allows an overall reduction in size and cost of any new mill. Mill operators are rapidly utilizing this new technology because it allows them to lower their capital costs while continuing to improve product quality and reduce operating and maintenance costs.

Recent design improvements in MORGOIL oil film back-up bearings allow the new KLX bearings to carry more load in less space than traditional KL® bearings. These advancements allow the use of smaller components in mills where higher separating forces are required. This paper will briefly discuss the development of the technology that has enabled these improvements and then address the economic advantages of its use in new mills or mills undergoing major upgrades.

History

Enclosed hydrodynamic oil film bearings were an enabling technology when introduced in the 1930's, allowing rolling mills of the day to apply higher separating forces and produce products not possible with prior bearing technology. By the 1940's the primary bearing design had become the T type, long key oil film bearing, shown in Figure 1. The bearing journal (the rotating member) had a tapered sleeve with a non-locking taper. The long key on the taper served to fix the sleeve against rotation. The stationary member of the bearing is a bi-metallic bushing lined with a cast white-metal bearing alloy.

When comparing oil film bearings of different designs, it is convenient to refer to the maximum rated load in terms of average pressure. The average pressure is simply the load divided by the projected area of the bearings, as shown in Figure 2. Long keyed T bearings were rated for a maximum average bearing load of 20.6 MPa (3,000 psi).

Research in the 1970's showed that the long keyway in the sleeve of the T bearing caused excessive roll force variation, adversely affecting strip gauge. The long key was removed from the tapered neck of the roll and replaced by two small keys located off the taper. That design, the KL type keyless bearing, shown in Figure 3, became the standard high capacity back-up bearing for the 1980's and 1990's. The KL bearing, with a maximum bearing load of 24.5 MPa (3556 psi), is capable of roll force variation on the order of 10 tonnes. It allowed mills to roll all types of hot and cold products to the most demanding tolerances.

Research to Improve Oil Film Bearing Capacity

With improved back-up bearing accuracy no longer an issue in modern rolling mills, research at the MORGOIL Division of Morgan Construction Company focused on improving the capacity of the tapered neck oil film bearing. MORGOIL engineers anticipated that the next generation of flat mills would require higher rolling forces on smaller mills, continuing the trend toward higher capacity, lower cost equipment. A new higher capacity back-up bearing would be needed for these mills. In order to increase bearing capacity, additional basic research would have to be conducted on oil film bearings. This research would then drive the technological innovations needed to improve bearing performance.

To support this research Morgan Construction Company commissioned the worlds first and only full size Bearing Test Stand for the development of flat mill oil film bearing technology. The Bearing Test Stand, shown in Figure 4, is built around a full size 30”-75 KL bearing with a journal diameter of approximately 600 mm. This bearing and chock assembly are designed exactly as they would appear in an operating mill.

The Bearing Test Stand was designed with an AGC cylinder that applies up to 800 tonnes of force, and a variable speed drive system that can run from 3 to 1000 RPM. A 120-channel data acquisition system was installed so that pressure, temperature, strain, force, and cylinder position could be continuously monitored. Proximity probes were installed in each test bushing to measure oil film thickness in real time.

Development of KLX Bearing Technology

Initial testing of a conventional KL bearing at low loads (about 2.4 MPa average bearing pressure, or 10% or rating) and high speeds validated the instruments and experimental methods by closely matching the oil film thickness predictions of Boyd & Raimondi[1], a commonly accepted oil film bearing model validated between Sommerfeld numbers of 0.10 and 10. Measured film thickness at Sommerfeld numbers of about 0.10 and above show a high degree of correlation with theoretical models. However, mill operating ranges of load and speed produce Sommerfeld numbers that are well below the validated range of the Boyd & Raimondi model. Test results deviate significantly from model predictions in these areas, as shown in Figure 5. The deviation is particularly pronounced under combined high load (24.5 MPa average pressure) and low speed conditions. Oil film thickness measured in the KL bearing was found to be much greater than predicted by classical theory.

Data taken from strain gauges located on the inside of the tapered neck sleeve, shown in Figure 6, showed that the deviation from theory was due to small deflections in the sleeve under heavy loads. At very low loads the sleeve geometry exactly matched that assumed by the bearing models, and the measured test results closely matched those model predictions. As bearing load increases, very slight deflections of the sleeve redistribute the load over a progressively wider area, reducing the peak pressure in the bearing and increasing actual film thickness. Models based on classical hydrodynamic theory do not anticipate this very small but important change in journal shape, leading the models to grossly underestimate film thickness. The deviation of calculated oil film thickness from actual test data increases directly with increasing load.

Analysis of the test data led to the hypothesis that further encouraging the bearing to more efficiently redistribute pressure under increasing loads could allow a new sleeve design to carry more load in the same space. A thin walled sleeve was designed and installed in the Bearing Test Stand to test the theory. The new sleeve was designed with a more consistent cross section to help distribute the load evenly along the length of the sleeve, without changing the taper angle.

Strain gauge data taken from the thin walled sleeve shows that the new sleeve design leads to a more efficient distribution of load in the bearing, resulting in a wider load zone. Figure 7 shows a comparison of centerline strain gauge data between the KL and KLX sleeves. The data for both are compared at 15 RPM and average loading of 24.5 MPa. It can readily be seen that the load zone of the thin walled sleeve is about 10 degrees wider than a traditional sleeve under comparable loading conditions. The stress range in the sleeve (the total reversing stress in the sleeve during each rotation) is also less for the thin walled design, showing that increasing the load zone of the bearing actually decreases the fatigue stress in the sleeve. In summary, extensive testing has shown that the thin walled sleeve design extends the load zone and reduces stress range under all rolling conditions, allowing it to carry higher loads than the traditional sleeve design.

Comparison of Performance of KLX and KL bearings

Testing has shown that the KLX bearing, shown in Figure 8, more efficiently redistributes the applied load so that a maximum average bearing pressure of 30 MPa (4,350 psi) can be supported. This gives the KLX bearing a much larger operating envelope, as shown conceptually in Figure 9.

Comparing KLX and KL bearings of similar chock bore sizes shows that the KLX has a maximum hydrodynamic capacity of 24% to 29% more than the equivalent KL, as shown in Figure 10. This increased capacity can be used to build a physically smaller mill with more capacity, as shown in the following case study.

Case Study: 7 Stand Hot Mill

For this case study a hypothetical 7-stand hot strip mill finishing train is used as a base of comparison. The mill has a maximum total separating force (TSF) of 5200 tonnes in the first stand. The maximum speed of the mill is 1200 m/min, resulting in maximum back-up roll speeds from 13.7 RPM minimum in F1 to 260 RPM maximum in F7. The back-up roll barrel length is 2060 mm. For commonality of parts all bearings in all stands should be the same size. To minimize capital cost all bearings should operate on the same oil viscosity so that one oil system can be used.

Figure 11 shows the range of roll forces and speeds for all stands superimposed on the operating envelopes of three possible bearing sizes. The operating envelope of the first bearing, the 54”-76 KLX clearly encompasses the operating ranges of all stands and would be a good choice for this application. By comparison the equivalent size 54”-75 KL bearing does not have sufficient rating. The next larger size KL bearing that has sufficient rating is the 56”-84 KL. This bearing is a satisfactory selection for rating, but is larger than the similarly rated KLX.

A. Reduction of Capital Cost through use of KLX

Using the KLX bearing in this application can reduce the size of the mill, reducing capital cost, by affecting the following:

i. Mill Centerline Width and Roll Length: As shown in Figure 12, the roll width for the KLX mill is 150 mm less than the comparable KL. The distance between bearing centerlines is less by 116 mm. The differences in these critical dimensions allow the KLX equipped mill to be narrower, and less costly, than the KL equipped mill for the same length roll barrel.

ii. Minimum Chock Height and Roll Turn Down: As shown in Figure 13, the height of the chocks for the KLX equipped mill is 4.1% less than for the KL equipped mill. Reduction in chock height can be used to reduce the height of the mill stands, or it can allow space for other equipment in the mill window. Shorter chocks also allow more turndown of the back-up rolls.

iii. Reduced Lubrication System Size: Bearing oil requirements are proportional to bearing size. Since the KLX is a smaller bearing compared to the same capacity KL, the KLX equipped mill requires less oil. In this example the required oil flow rate for all stands was reduced by 16%, or a 328 lpm reduction for the 7-stand finishing train.

B. Reduction of Operational Cost through use of KLX

Implementation of the MORGOIL KLX reduces operating costs. The smaller lubrication system of the KLX bearing uses smaller components and requires less oil. The KLX equipped 7 stand hot mill needs 12000 liters less oil than the KL mill, reducing the tank size by 15000 liters. The KLX bearing also has a lower part count than its predecessor, reducing spare part requirements.

C. Improved Product Quality through use of KLX

The KLX bearing has a stiffer roll neck as compared to the KL bearing of similar capacity. Stiffer roll necks result in a stiffer mill, improving strip gauge quality. For this example the roll neck of the KLX is 13% stiffer than the comparable KL bearing.

Figure 14 shows a comparison of all the attributes of the two bearings in this case study. The rating of the KLX is higher, yet has a lower initial cost. The lubricant requirements are substantially less than the similarly rated KL. Minimum chock size, distance between stand centerlines, and mill width are all decreased through the use of the KLX. Product quality is improved by increasing the stiffness of the bearing though increasing the roll neck stiffness.

Through the use of MORGOIL KLX bearing technology, Morgan Construction Company is once again at the leading edge of rolling mill bearing development. The newly developed KLX bearing has shown that it can more efficiently distribute rolling load within the bearing, allowing more than a 24% increase in load capacity. This increased capacity allows a smaller KLX thin-sleeved bearing to be used in place of a larger, more traditional KL design. The smaller bearing in turn drives a size reduction of the width and height of the mill; it also substantially decreases the size of the lubrication system. These attributes contribute to reducing the overall capital cost of a new mill. Operational costs are reduced by the correspondingly smaller lubrication system, since it requires less oil to fill and maintain. The increased roll neck section of the KLX bearing, as compared to the traditional KL bearing, contributes to higher product quality by increasing mill stiffness.

---

1. “A Solution for the Finite Journal Bearing and its Application to Analysis and Design” A.A. Raimondi and John Boyd, ASLE Transactions, Vol. 1, No. 1, April 1958

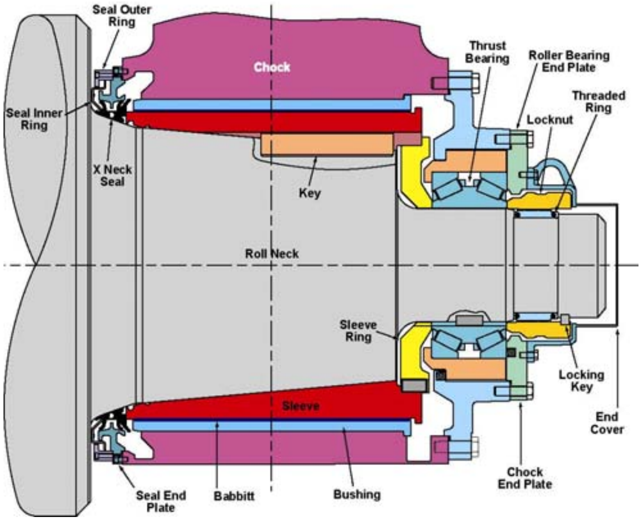

Figure 1: T type long-key oil film bearing for mill use: circa 1940 to 1960

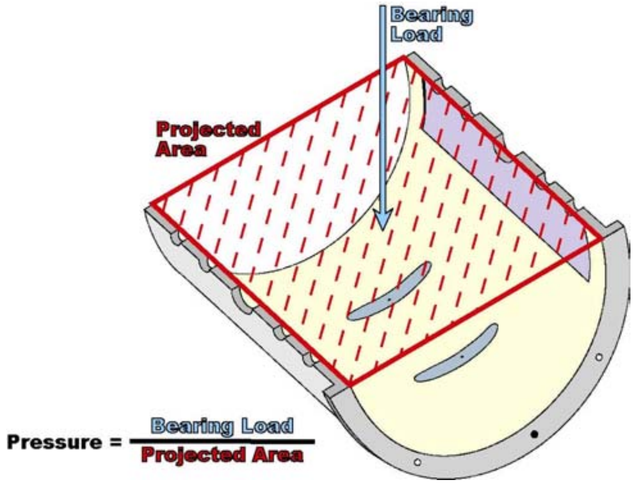

Figure 2: Concept of average pressure on bearing

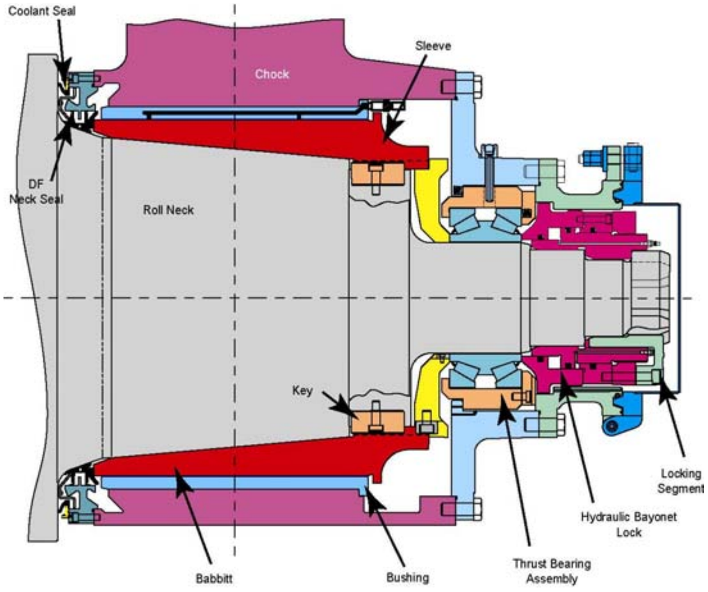

Figure 3: KL type keyless bearing – circa 1980 to 2000

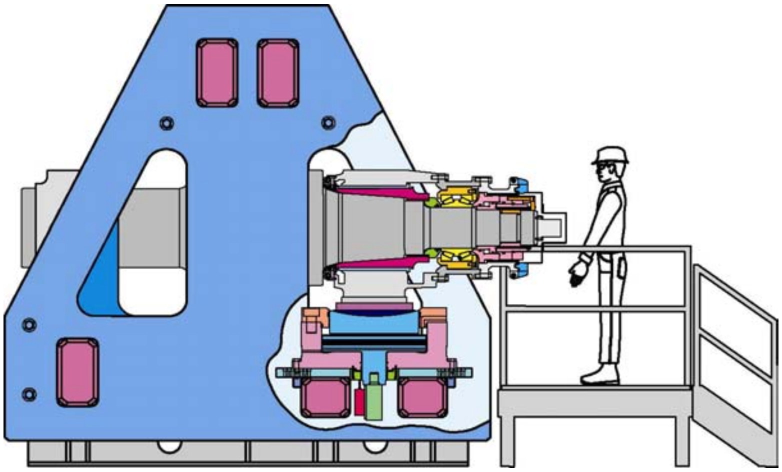

Figure 4: Schematic of MORGOIL Bearing Test Stand built by Morgan Construction Company

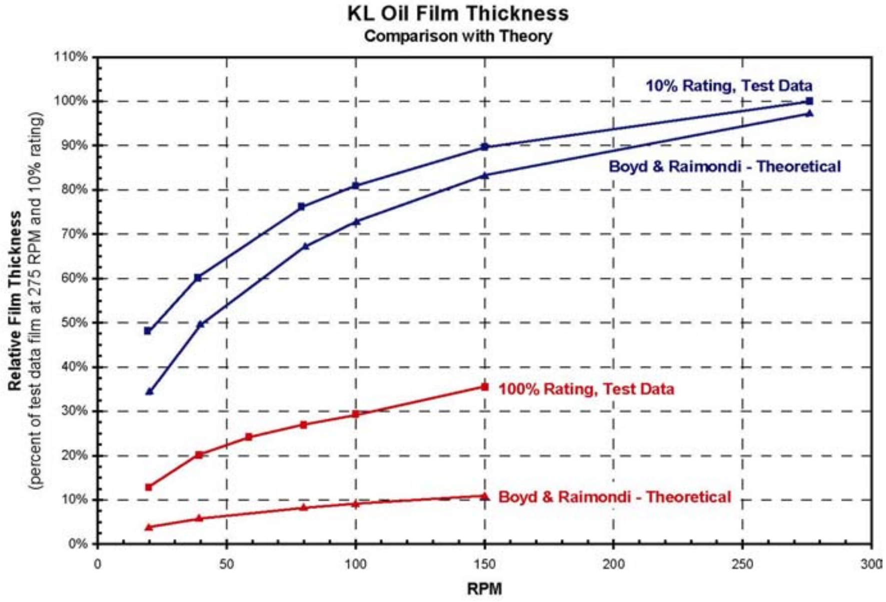

Figure 5: KL Oil Film Thickness – measured compared with theory

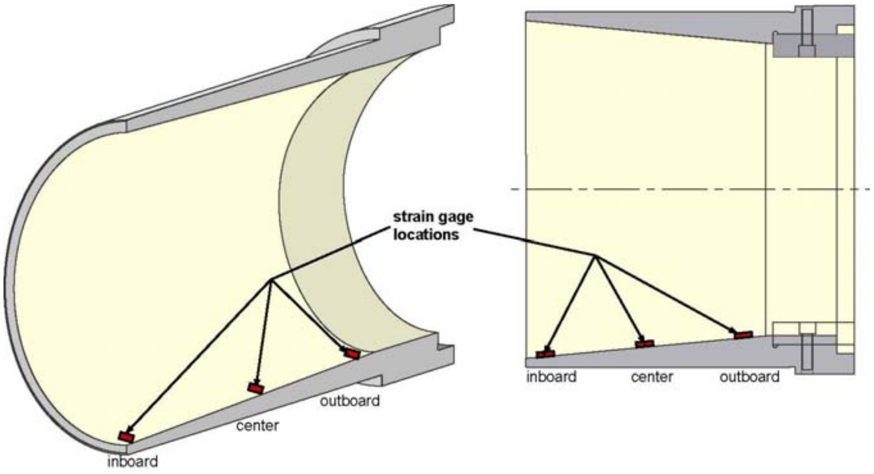

Figure 6: Strain gauge locations on inside of sleeve

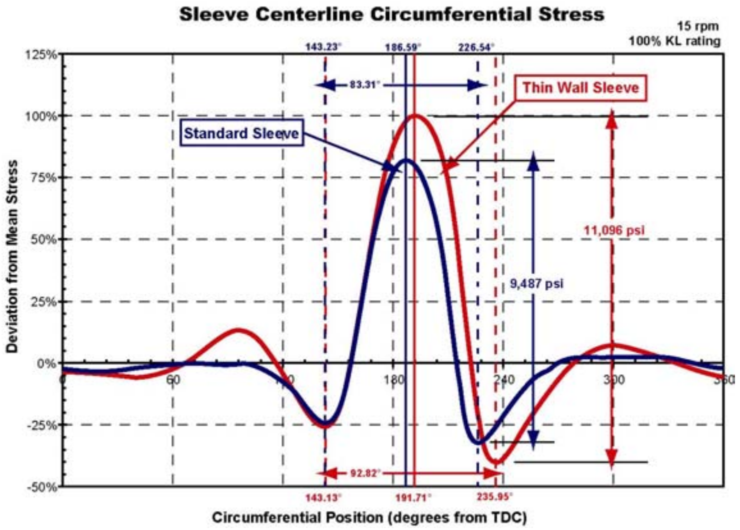

Figure 7: Comparison of standard and thin sleeve deflection

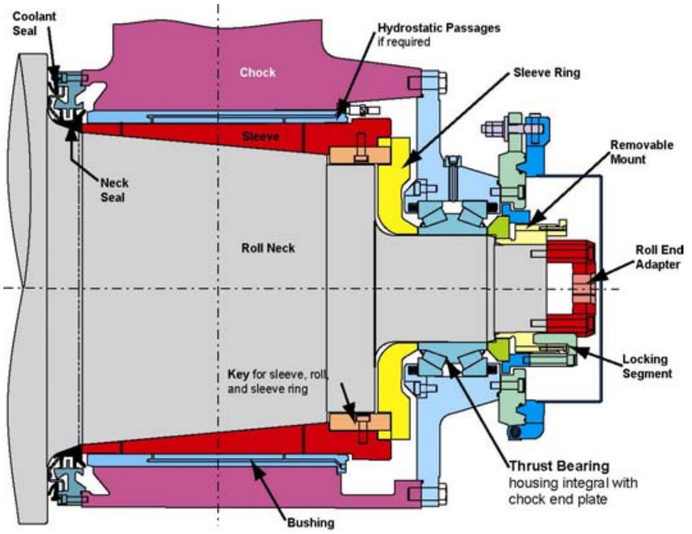

Figure 8: KLX type thin sleeve bearing

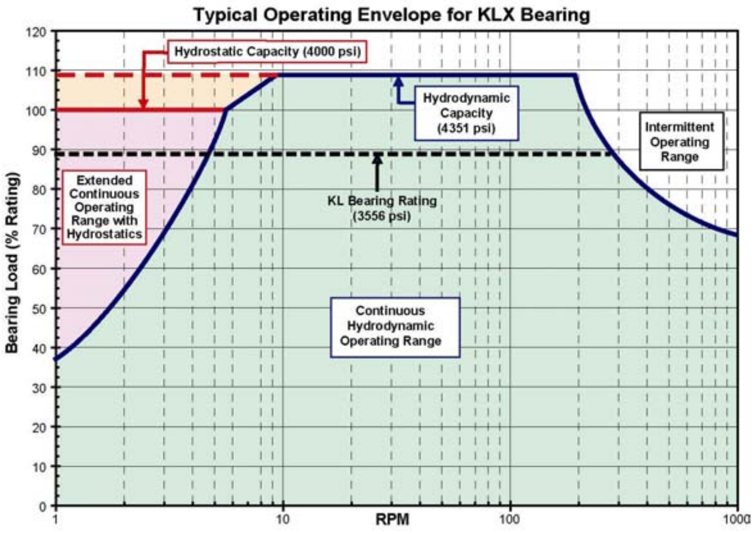

Figure 9: Operating Envelope of KLX bearing compared to KL limit

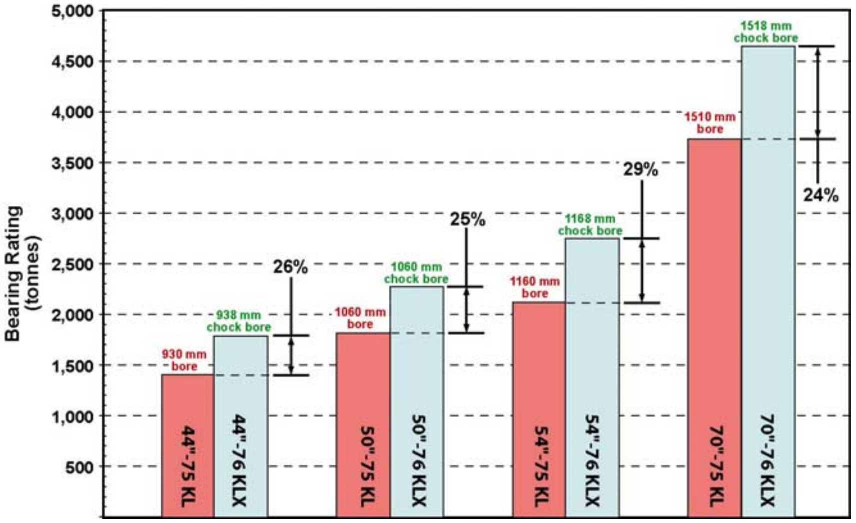

Figure 10: Comparison of KLX and KL Bearing Ratings for bearings of similar sizes

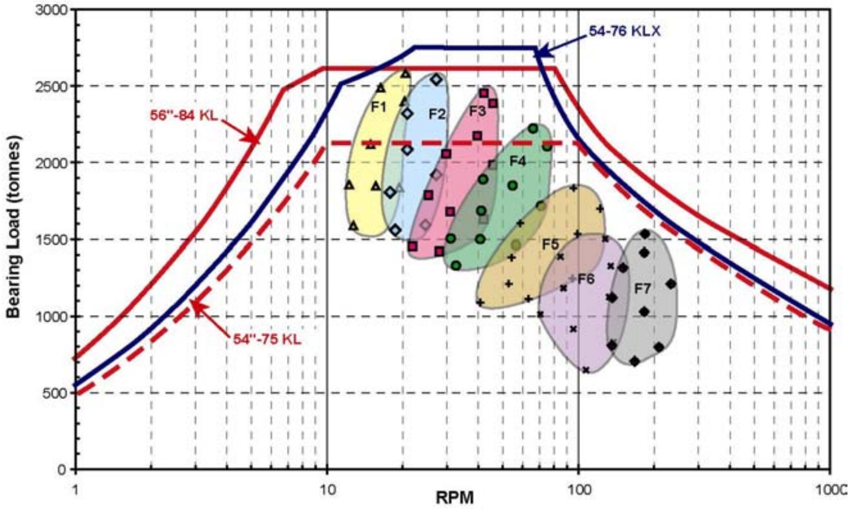

Figure 11: Rolling parameters of example Hot Strip Mill superimposed on operating envelopes of three bearings

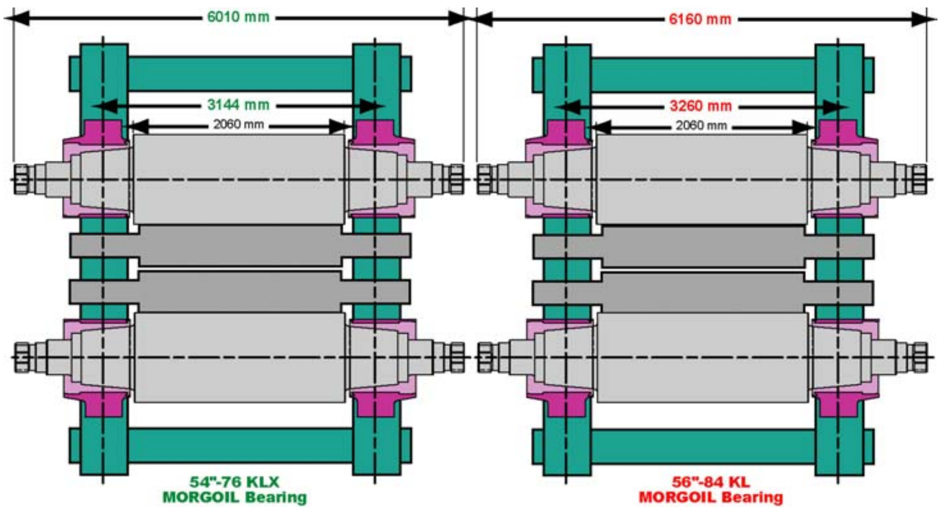

Figure 12: Comparison of roll widths

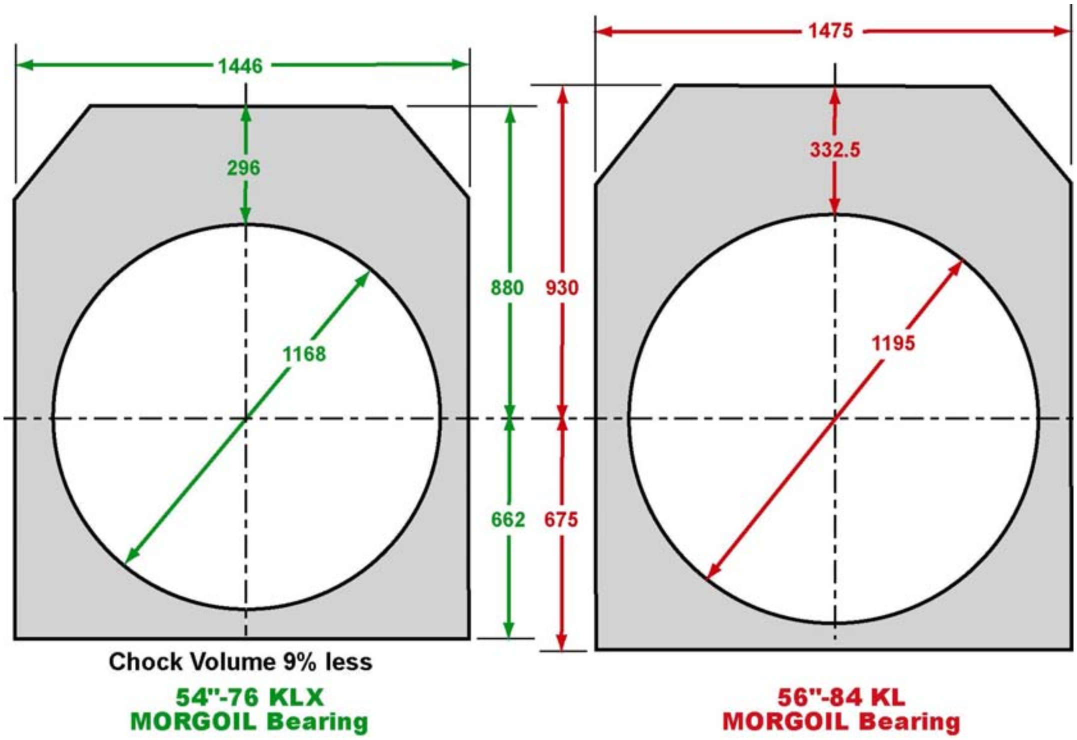

Figure 13: Comparison of chock sized for KLX compared to KL

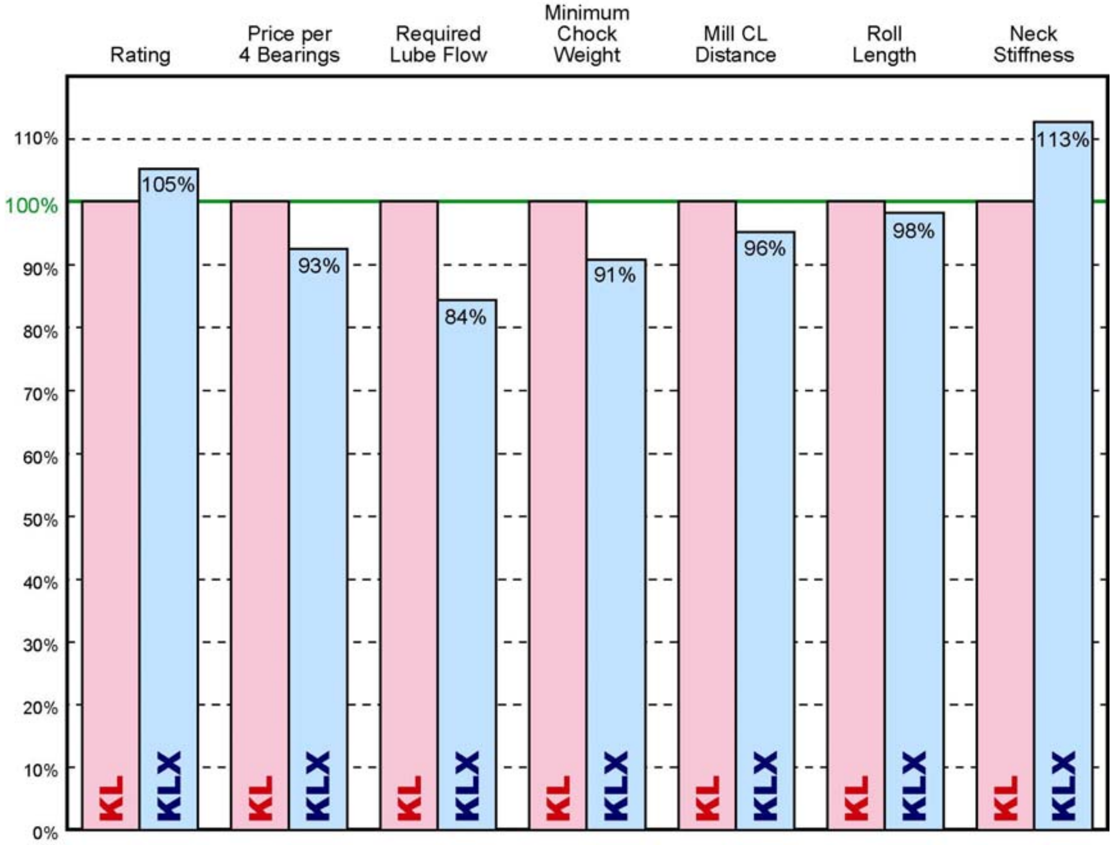

Figure 14: Comparison of KL and KLX for Hot Strip Mill