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# Beyond Catalogue Life calculation in Solving Bearing related Failures in Steel Plant

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***Abstract: This technical paper explains an approach of solving problems related to bearing failures in steel industry by working beyond catalogue calculation using conventional as well as speciality software. Bearing manufacturing companies usually publish a detailed method of L10 life calculation in their catalogue based on international standards as well their own. Whereas they conduct more detailed system level calculations using their own advanced software. But those advance calculation are not easily available to engineers working on design from scratch or solving problem of industrial equipment in-house. So called catalogue method of bearing analysis are mostly done for bearings in isolation without considering the effect of surrounding parts as a system. This paper elaborates a couple of examples of calculation beyond catalogue life of bearing using a commercially available software such as KISSOFT by overcoming some of the constraints in catalogue approach and extends engineers' capability to carry out more realistic analysis of bearing failures and devise a solution with better predictability of success. In this paper two examples one from general steel plant applications and another from gearbox, have been explained to guide design, application and maintenance engineers across industrial domain to critically think beyond hand calculation and bring in more systematic and prediction based approach for bearing related problems***
***Keywords: Rollers, L10 life, Catalogue life, load zone, Dynamic rating, Static Rating***

## I. INTRODUCTION

In steel plant, the single largest failure in terms of number is related to bearings. Some of the prominent failures include that of bearing retainer or cage, sudden cracking of raceway and starvation of lubrication etc. Often the current operating conditions are beyond the original intent of the designer or bearings were originally under selected. Also, it is not always practical that critical equipment in a steel plant is shut-down as soon as initial sign of bearing failure is detected. As a result the equipment continues to run till a proper shutdown logistic is determined and equipment such as gearbox, motor, pulley, conveyors are finally stopped for repair. By that time it may so happen that bearing could completely fail and thereby root-cause analysis becomes extremely difficult as original sign of failures are no more available. Hence it is obvious that steel plant equipment is designed adequately reliable with ample bearing life such that bearings may be replaced only during planned shutdown. Two basics steps are important as far as bearing reliability is concerned, namely

1) Actual Operating conditions with load, speed, and environment. Especially estimating actual load under operating condition requires a great deal of site observation as well theoretical calculation.
2) Particular method used while selecting, analysing and predicting bearing life.

The following example in Figure 1 shows a loading system prevailing in mixing drums, barrel reclaimer , material disposal cylinders etc. The rotating drum vertical load is supported by four support rollers, two each side while the drum is rotated by a ring gear drive.

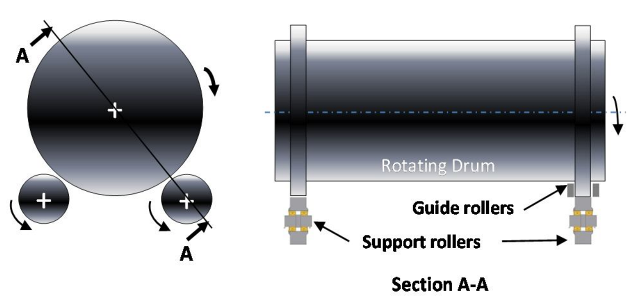



Figure 1: Rotating Drum Layout

There is also a pair of guide rollers at one side of drum for locating the drum in axial direction. We will have a look at one of those support rollers and bearings in detail as shown in Figure 2.

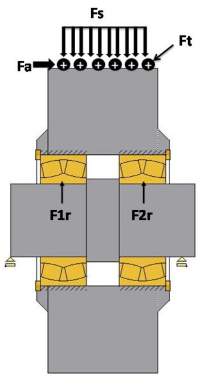



Figure 2: Schematic of support roller

Each of these support rollers is supported by two spherical roller bearings. In an ideal condition the support roller will experience separating force Fs from the weight of the drum, tangential force Ft due to friction agains rotation . The resultant of Fs and Ft will result in radial reactions in bearings A and B as F1r and F2r respectively. Interestingly although guide rollers are provided to locate the drum in axial direction, thereby taking axial load , the drum itself can never remain perfectly horizontal due to uneven wear of the its tyre and supporing rollers. In fact it is also not practically easy to maintain the horizontal alignment of axis of the drum. As a result axial load Fa on the contact point of the support roller is inevitable.

### *A. Case 1: Catalogue Bearing Life Calculation –Spherical Roller Bearing (SRB)*

Let us take following examples.

- Ps = 265 kN, Pt-53 kN, Pa=50 kN
- Bearing A and B: 23224/ 23224
    - Dynamic rating Cr=732 kN,
    - e=0.35, Y1=1.9, Y2=2.9

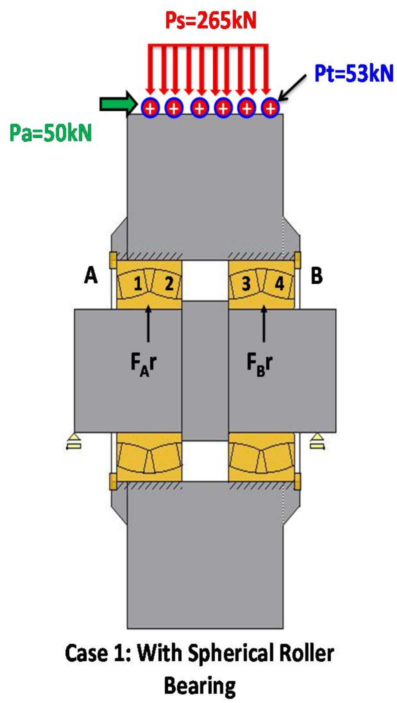



Figure 3: Application schematic with applied loads and Spherical Roller bearing

As per ISO formula for equivalent dynamic load

| Load Ratio | Equivalent Dynamic load |
|---|---|
| $F_a/F_r \leq e$ | $P=F_r+Y_1.Fa$ |
| $F_a/F_r > e$ | $P=0.67*F_r+Y_2.Fa$ |

L10 life is calculated based on following formula,

$$L_{10} = \left(\frac{C}{P}\right)^p$$

The resultant reaction, equivalent dynamic loads are given below.

Table 1

| Bearing | Radial reaction (kN) | Axial Reaction (kN) | Equivalent Dynamic load (kN) | Bearing life Lnh (hrs) |
|---|---|---|---|---|
| A | 45 | 50 | 181 | 5824 |
| B | 232 | 0 | 232 | 4180 |

Note additional axial load Pa=50kN applied on the roller OD created a tilting moment and radial reaction on the bearing B increased significantly while radial reaction on the bearing A is similarly reduced. Induced load due to this axial load on the bearing is directly a function of radius of the roller and bearing spread, i.e. distance between two spherical roller bearings.

### *B. Study Of Load Sharing Pattern Inside Bearing Rolling Elements Ananlysed Throgh Kisssoft For Case 1*

Apparently, the bearings have adequate life even with axial load considered, case 1. At this point of time, perhaps designers would not have any concern about premature failure of the spherical roller bearings used in the roller. However, it should be noted that unlike single row bearings, in this case are total four sets of spherical rollers, two each in the single SRB. While radial load could be shared across these entire four sets, thrust load may transfer only through one set of rollers. To understand more KISSSOFT (software for mechanical design including gears, bearing and other machine elements) was used to model the entire system. The result from KISSSOFT is given in table 4.

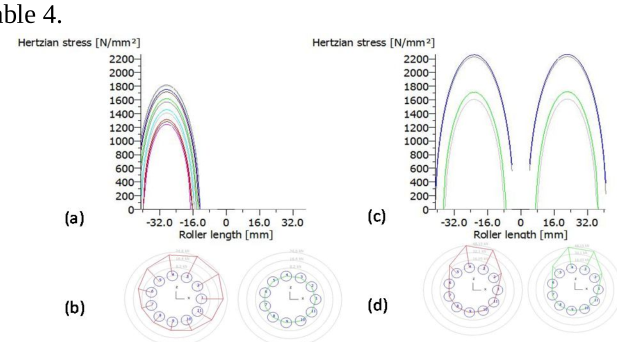



Figure 4: Load distribution inside rolling elements

As shown in figure 4, the inboard row 2 of the left bearing is completely unloaded since the external thrust load Pa is applied toward right. In case it is other way, inboard row 3 of the right bearing will be unloaded and rollers will be sliding. In reality depending on wear pattern of the entire rotating drum and roller, one of these two SRB will be susceptible to premature failure. This situation will lead to cage failure of the bearing.

### *C. Case 2: Study Of Catalogue Bearing Life And Load Distribution With Alternative Rolling Bearing, Tapered Roller Bearings (TRB)*

Let us take the same example with Tapered Roller Bearing.

- Ps = 265 kN, Pt-53 kN, Pa=50 kN
- Bearing A and B: 32228/ 32228
  - Dynamic rating Cr=691 kN,
  - e=0.43, Y=1.4

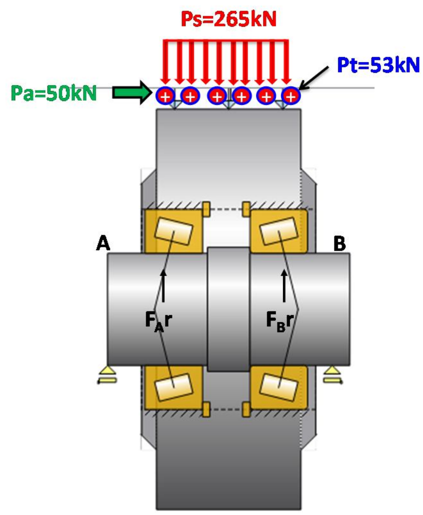



Figure 5: Application schematic with applied loads and Tapered Roller bearing

As per ISO formula for equivalent dynamic load

| Load Ratio | Equivalent Dynamic load |
|---|---|
| $F_a/F_r \leq e$ | $P=F_r$ |
| $F_a/F_r > e$ | $P=0.4*F_r+Y.Fa$ |

Please note when a radial load is applied on to a single row TRB, the applied load is carried from one raceway to the other at an angle to the axis of shaft. As a result an internal load is induced. Hence actual axial load (Fa) being supported by each TRB is not only the external load but also includes this induced force as a vector summation. Detailed calculation may be found in catalogues of reputed bearing manufacturing companies.

Table 2

| Bearing | Radial reaction (kN) | Axial Reaction (kN) | Equivalent Dynamic load (kN) | Bearing life Lnh (hrs) |
|---|---|---|---|---|
| A | 69 | -29 | 69 | 195628 |
| B | 205 | 79 | 205 | 5209 |

Please note that although the bearing B carries the thrust load, because of angularity in tapered roller bearing an axial force 29 kN is also induced at the bearing A and an equal amount is added to the bearing B. Mechanism of this induced force in TRB is not in the scope of this paper.

### *D. Study Of Load Sharing Pattern Inside Bearing Rolling Elements Ananlysed Throgh Kisssoft For Case 2*

The Figure 5 shows load distribtuion on the rolling elements. From this basic graph, it can be inferred that a good number of rolling elements are sharing the loads for bot the TRBs.

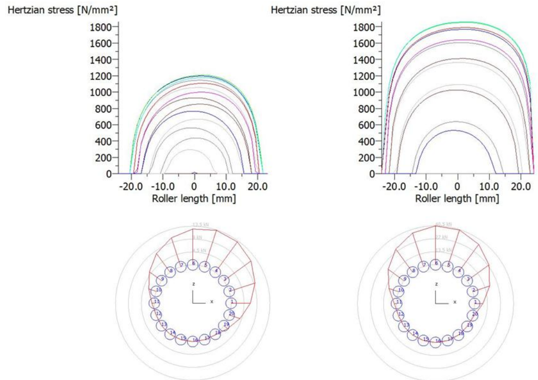



Figure 6: Hertzian stress on rolling elements and load distribution

Let us carefully see the comparative data of case 1 and 2.

Table 3

| Case | Bearing | Dynamic Rationg Cr (kN) | Bearing life Lnh (hrs) | Hertzian Stress (MPa) |
|---|---|---|---|---|
| 1 (SRBs) | A | 732 | 5824 | 1819 |
| | B | 732 | 4180 | 2266 |
| 2 (TRBs) | A | 691 | 195628 | 1207 |
| | B | 691 | 5209 | 1862 |

It is to be noted that inspite of having lower rating, the Case 2 with TRBs produces higher lives than the Case 1 with SRBs because following two reasons.

*a)* The arrangement with TRBs has greater bearing spread than SRB (distance between Bearing A and B) due to its angularity. The reduced resulting reaction of the moment load arising out of the axial load Pa.

*b)* Dynamic equivalent load in case of SRB is higher than the TRB for given set of radial and axial load because of the fact that TRB due to its construction is better cable of taking combined load than the SRB. The ISO euation of dynamic equivalent load for SRB has provided higher X and Y factor to take care of the above.

*c)* Resulting hertzian contact stress on the rolling elements are also lower in TRB than the SRB pairs.

## II. DISCUSSION

KISSSOFT software helps design engineers plot load sharing among the rolling elements (Figure 4b, 4d, 6b, 6d) as well as load distribution across the length of the rollers (Figure 4a, 4c, 6a, 6c). It is not practically possible in SRB to have all the rollers share the radial load unless it also supporting the axial load (Figure 4a). However a large amount of axial load in SRB will necessariliy unseat one row completely in the same bearing leading to sliding of rolling elements. This can not be seen in catalogue analysis. Design engineers needs to do more complex calculation using TS16281 which is a detail….. For the floating SRB, supporting only radial load (Figure 4c and 4d), both the rows share radial load only thereby guaranting rolling among the bearing elements. Usually at least a quarter of the rollers in load zone is desirable. From the graphical representation of load distribution, one can easility get an idea of any problem in particular arrangement of bearing.

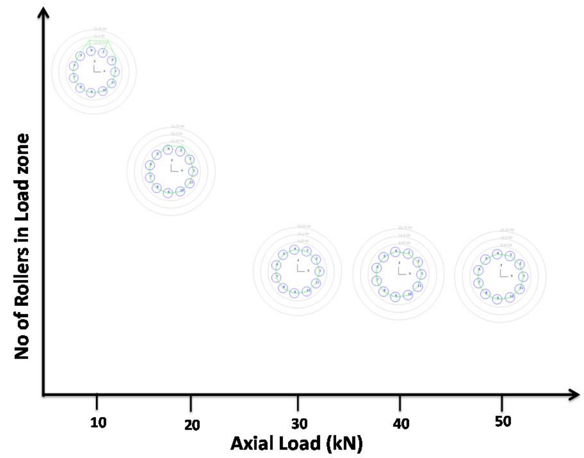



Figure 7: Load sharing of rollers, Row 1, Bearing A as shown in Figure 3

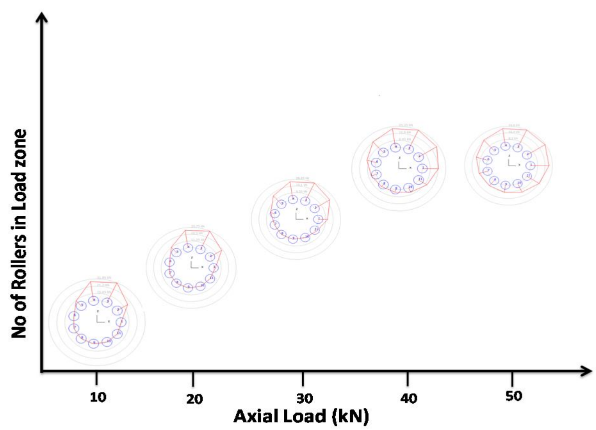



Figure 8: Load sharing of rollers, Row 2, Bearing A as shown in Figure 3

In the Figures 7 and 8 are shown load sharing by the spherical rollers w.r.t. axial load applied. Once the axial load Pa becomes more than 10 kN, the unseating of one row of rollers takes place while the other rows gets loaded more and more. It is obvious that beyond 10kN axial load, usage of spherical roller bearing is not advisable and an alternative bearing arrangement should be designed.

## III. APPLICATION/ LIMITATION

This tool can be used to solve bearing related problems in steel, cement and other similar type of industry. Further this can be used to asses system in totality as KISSSOFT has capability to analyse gears, shafts etc. Results are dependent on user's knowledge about system and data acquisition.

## IV. CONCLUSIONS

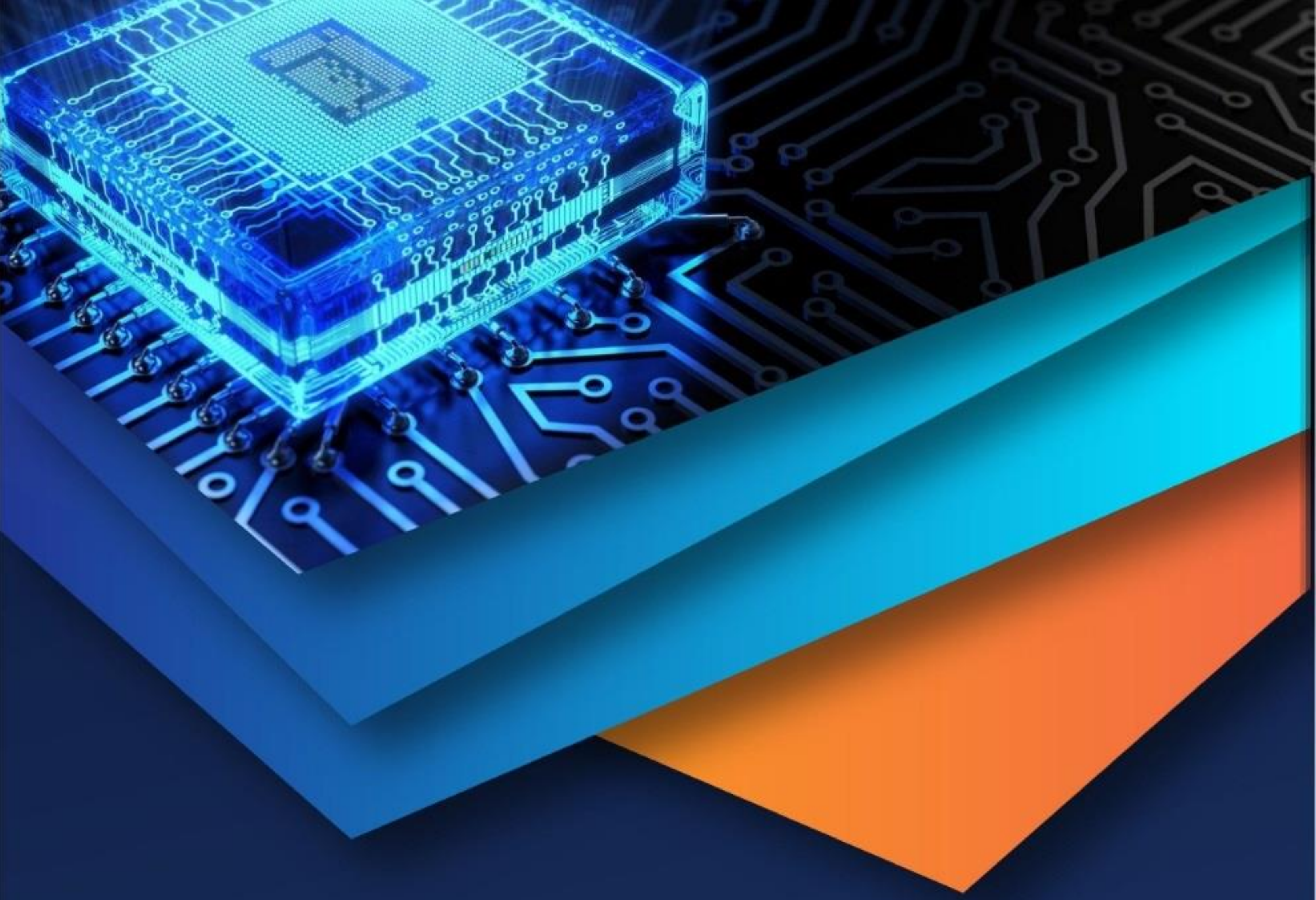
This method can give very close result if proper data is feed judiciously. We can simulate real life scenario to understand reasons of failure. It also helps us in saving time as hand calculations take very long time. One thing we should keep in mind that this method can not be used without basic mechanical engineering knowledge.

## V. ACKNOWLEDGEMENT

We appreciate Kadcraft team.

## REFERENCES

[1] Bearing catalogues by SKF, FAG and Timken.

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