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MISALIGNMENT EFFECT ON CEMENT KILN SUPPORT BEARING

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ABSTRACT

This paper illustrates the effect of misalignment on performance of cement kiln partial journal bearing. The performance parameters include minimum film thickness, load carrying capacity, power loss and dynamic coefficients such as elastic coefficients and damping coefficients. The bearing analyses have been carried out using a commercial rotor dynamics software package.

INTRODUCTION

A rotary kiln is long, tubular and rotating equipment designed for calcining and burning the limestone to clinker. This kiln shell is mounted on tyre/roller assembly at multiple points. The roller shafts are supported by partial journal bearings, as shown in Fig-1. The rotary kiln is supported at two or more stations depending on their length to diameter ratio.

In this kiln shell, the raw material is heated at high temperature (~1400°C) to produce clinker. Due to this high temperature shell undergoes thermal expansion. The rotary kiln shell is a heavily-loaded structure. Consequently the rotary kiln shell takes the final shape as a curved structure at working condition, as shown in Fig-2. Due to this deflection the position of tyre on roller changes as shown in Fig-3. Finally, the position of centre of applied load on support roller also changes and the bearings become prone to misalignment loading conditions.

Due to tilting position of tyre at misaligned condition, the contact area between tyre and roller also reduces and simultaneously increases the contact stress. To accommodate this stress, width of the tyre has to increase. Another alternative solution is to use the flexible support as shown in Fig-4. This flexible support can rotate about two perpendicular axes situated in horizontal plane along kiln axis and perpendicular to this axis. Hence, it provides self-aligning features in the system. The flexible support can offer following advantages over rigid type support.

- This arrangement allows the load to be equally shared by two bearings of each support roller (tilting ability in two planes) and provides self-aligning features to the support roller
- In upset conditions of the shell (thermal distortion / misalignment etc.) the contact area between tyre and roller is not reduced, as shown in Fig-4.

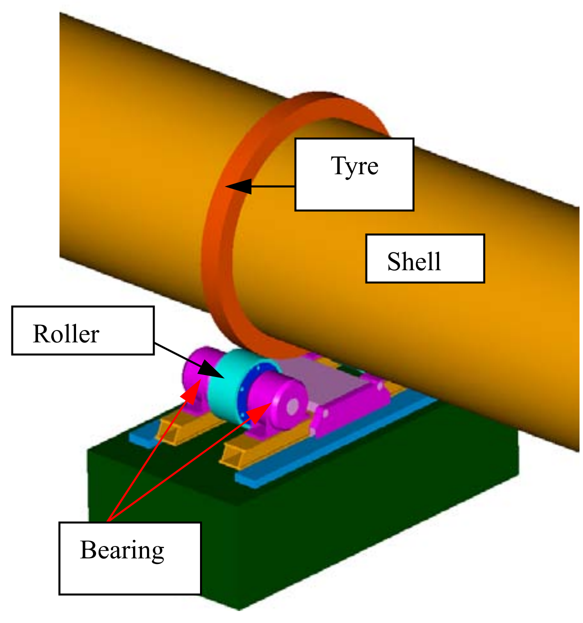

Fig-1 Position of Tyre, Roller and Support Bearing

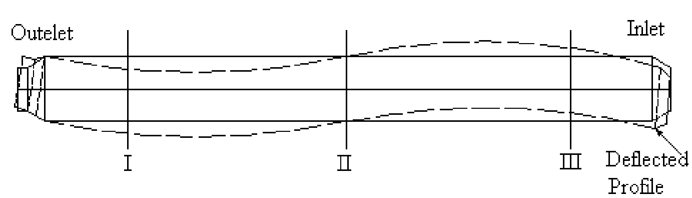

Fig-2 Deflected Profile of Kiln

- Due to higher contact area available (across the full width), the sizes of rollers / tyres can be reduced without increasing the contact stress
- Such an arrangement can be designed for higher specific due to wider contact area available

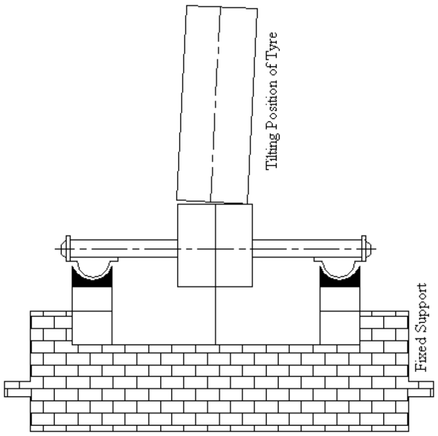

Fig-3 Tilted Position of Tyre on Fixed Support

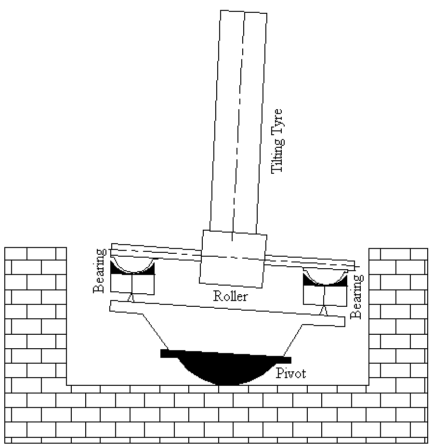

Fig-4 Flexible Support System

Due to two types of support system, bearing operate in two different conditions-aligned and misaligned conditions. The performance analyses of full journal bearing considering misalignment effects are available in literature [1-5]. But limited information [6] is available on partial journal bearings operating at low speeds (15 rpm to 25 rpm) with misalignment. Therefore, analysis of misalignment effect on performance of the partial journal bearing is the main aim of this paper.

BEARING ANALYSIS

The performance analyses of the partial bearing have been carried out using a commercial rotor dynamics software package. Results obtained have been validated with published data [7] as shown in Table-1. The bearing performance parameters include load carrying capacity, minimum film thickness, power loss, attitude angle and dynamic coefficients in terms of stiffness and damping coefficients. All these parameter have been derived at both aligned and misaligned condition.

Table-1 Comparison of Results of Analyses using rotor dynamics software with Published Data

Different Solutions	Eccentricity Ratio	P_{max} (MPa)	h_{min} (mm)	Speed (rpm)	Load (N)
Ferron's Bearing [7]	0.575	1.27	0.06163	2000	4000
Present Work	0.55	1.317	0.06525	2000	4297
Mitsui's Bearing [7]	0.452	1.29	0.04302	2250	3920
Present Work	0.45	1.41	0.0432	2250	3210

Results

Figure 5 shows the variation of minimum film thickness with applied load for both aligned and misaligned conditions. It is seen from the Fig-4 that, at a particular minimum film thickness, the bearing has lower load carrying capacity in misaligned condition than that in aligned condition.

From Fig-6 it is seen that, at lower value of eccentricity ratio, power loss is lower for misaligned bearing than aligned bearing but at higher eccentricity ratio power loss is higher for misaligned bearing as compare to aligned one.

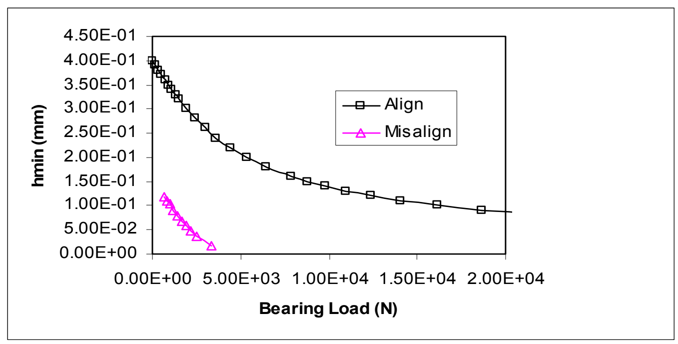

Fig-5 Minimum Film Thickness vs. Bearing Load

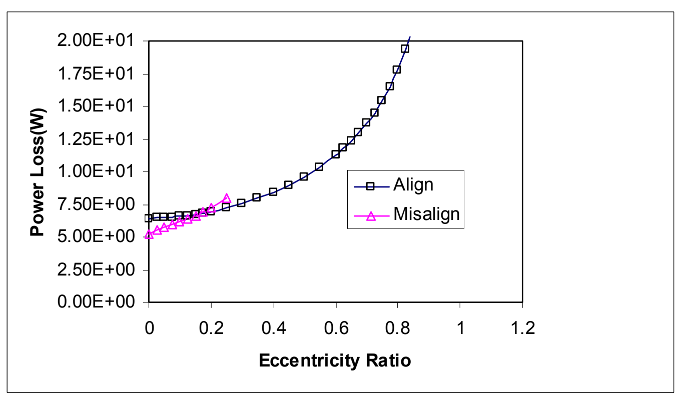

Fig-6 Power Loss vs. Eccentricity Ratio

But in the case of dynamic coefficients such as stiffness and damping, nature of the curve becomes reverse. As shown in Fig-7, it is observed that the misaligned bearing has higher stiffness coefficient than aligned one.

From Fig-8, it is seen that at higher value of eccentricity ratio, misaligned bearing exhibits higher damping coefficient than aligned bearing.

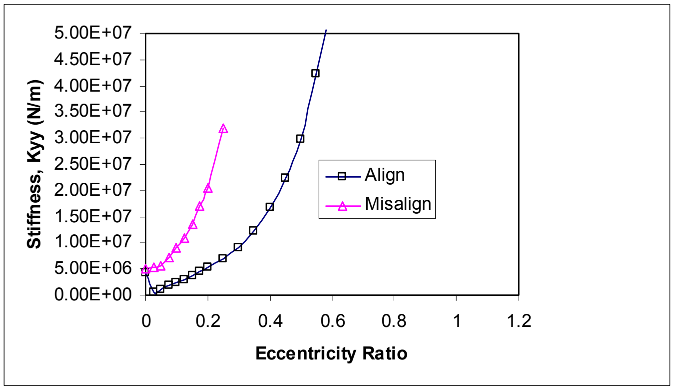

Fig-7 Stiffness Coefficient vs. Eccentricity Ratio

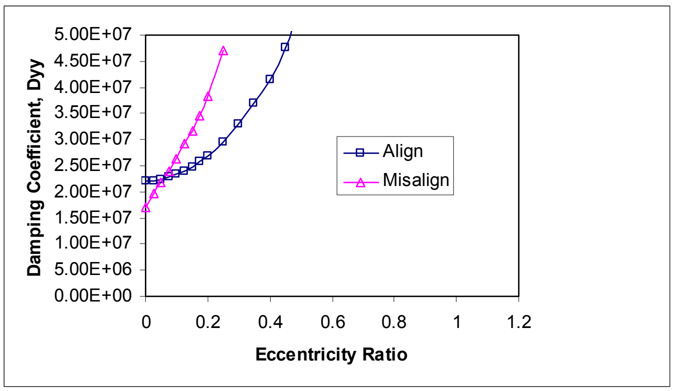

Fig-8 Damping Coefficient vs. Eccentricity Ratio

Figure 9 shows the variation of attitude angle at different loads for both aligned and misaligned condition. It is seen from Fig-9 that for a particular load, misaligned bearing operates at lower eccentricity ratio than aligned one.

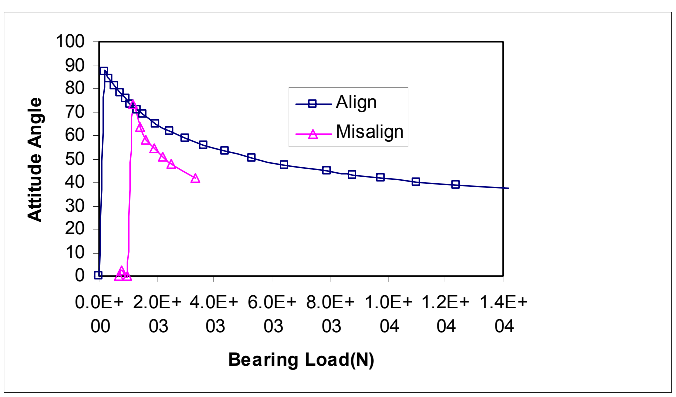

Fig-9 Attitude Angle vs. Bearing Load

Discussion

From aforementioned results, it is cleared that, for a fixed value of minimum film thickness, misalignment substantially reduces the safe load carrying capacity of a bearing as shown in Fig-5. To increase the load carrying capacity of misaligned bearing, the length of the bearing can be increased but it may increase further the probability of edge loading [8].

Since kiln bearings run at very low speeds (~ 15 rpm to 25 rpm) it will be operated at higher eccentricity ratios to accommodate high load of kiln shell. Figure-6 shows that, at higher value of eccentricity ratio, misaligned bearing loses more power, which leads to high temperature of the bearing.

On the other hand, misalignment in the bearing increases dynamic performances in terms of stiffness coefficients and damping coefficients as shown in Figs-7 and 8 respectively. Figure 9 also ensures that misaligned bearing will operate more stably than align one with lower value of attitude angle for a particular load.

But from Fig-5 it is observed that for a particular value of bearing force, misaligned bearing always operates at lower value of minimum film thickness as compared with that of an aligned bearing. This means that a misaligned bearing is more likely to run with metal-to-metal contact between its sliding surfaces. This will greatly reduce the life expectancy of the bearing. To get rid of these problems flexible roller bearing supports have been developed by kiln designers.

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