

Analysis of Failure Modes of Bearing Outer Race Rotation

Salah Alhasia

Lawrence Technological Univ.

Sharif Gindy

Sensor Data Technologies, Inc.

Selin Arslan, Badih Jawad, and Chris Riedel

Lawrence Technological Univ.

ABSTRACT

As the need for super high speed components (pumps, motors, etc) continue to grow rapidly, so does the need to make measurements at speeds higher than ever before. Bearings are a major component in any rotating system. With continually increasing speeds, bearing failure modes take new unconventional forms that often are not understood. Such measurements are impossible if bearings fail to perform.

This paper will address the dynamic modes a bearing passes through and the potential failure modes associated with each. A review of the state of the art of current failure modes will be given, and then a hypothesis on some new failure modes associated with particular speeds will be discussed. The paper will also describe an apparatus that was designed especially to study these phenomena. Range of speed studied is 0- 60,000 rpm.

Preliminary measurements indicated that this range breaks into three different zones: low (0-15,000 rpm), moderate (15,000-25,000 rpm) and high (25,000- 60,000 rpm). Each zone has its own unique possible failure characteristics. More emphasis will be given to the middle zone where natural frequencies of bearing outer race play a major role.

CITATION: Alhasia, S., Gindy, S., Arslan, S., Jawad, B. et al., "Analysis of Failure Modes of Bearing Outer Race Rotation," *SAE Int. J. Passeng. Cars – Electron. Electr. Syst.* 8(2):2015, doi:10.4271/2015-01-0146.

INTRODUCTION

Recent high pace improvements in computers, automobiles and industrial machinery, have pushed the demand for superfast bearings. A common problem that is becoming more prominent in high speed bearing applications is the rotation of bearing outer races. Once the outer race starts to creep; failure of the application is eminent.

While the problem of bearing outer race rotation is often discussed by technical groups, it is seldom studied scientifically.

Tsuyoshi Niwa[1] reviewed two mechanisms for bearing outer race rotation suggested by Soda[2] and Ten et.al[3] Tsuyoshi also presented a travelling wave theory to explain outer ring rotation. He ascribed the traveling wave in bearings to the strain resulting from the force applied

by the rolling element on the ring where it is in solid contact with the housing underneath. Although these efforts discussed the phenomena of both the forward and the reverse rotation of the bearing outer race, they continue to leave serious questions unanswered.

Primarily, they conventionally consider bearing rotating load as the primary cause of outer race rotation. The load on the bearing's being fixed possibility has not been discussed.

Additionally; the effects of a negligible load on the bearing on the rotation mechanism for the outer race has not been studied.

Furthermore; the question of the repeated reverse and then forward rotation, remains unanswered.

The research carried out by the authors' showed that bearing outer race would rotate both in the forward and the reverse directions, with very minimal fixed direction bearing load. Besides, J. Murata [4] used FEM to generate a mechanism of inner ring creep.

While there is consensus between bearing manufacturers that vibration is a very important factor in bearing proper operation, only NSK [5] had the most research in this area, especially that of bearing outer race rotation

This paper is an attempt to characterize outer race creeping phenomena, understand its causes, and suggest some solutions.

PROPOSED HYPOTHESIS

The experimental work showed that, as the speed is increased, the outer race passes through three unique zones. In the first zone, the outer race is stationary till a certain speed is attained. As the speed is carefully ramped up, three more phenomena are observed;

- Outer race starts to hesitatingly creep in the reverse direction of bearing rotation,
- Outer race starts to hesitatingly creep in the same direction as the bearing rotation,
- Outer race takes off at increasingly higher speeds in the direction of rotation.

While it may be easy to justify moving from (b) to (c), (a) remains inexplicable.

POSTULATE

Treating the outer race as a vibration problem suggests two different mechanisms of ring rotation cause.

In (a) & (b) the natural frequency of the ring can explain its hesitation to rotate. As the forced vibration caused by bearing rotating speed approaches the natural frequency of the outer ring it starts to rotate. It was further observed that touching the outer race with some tool would immediately stop its rotation and associated noise subsides.

In zone (c), it is a condition of forced damped vibration that both the centrifugal force and gyroscopic moments of the rolling element dominate ring rotation phenomenon.

The authors believe that the natural frequency of the bearing outer ring may well not only explain ring wandering in zones (a) and (b), but also may shed some light on the reverse in direction and its sequence.

MODELING

Consider the thin ring of Fig.1, as analogous to the bearing outer race. This ring may vibrate in a radial (bending) mode as shown in Fig. 2a, or an axial (shear) mode as shown in Fig.2b. These modes are known as the elastic modes of vibration. In addition, there exist also rigid body modes which are of no interest to this study.

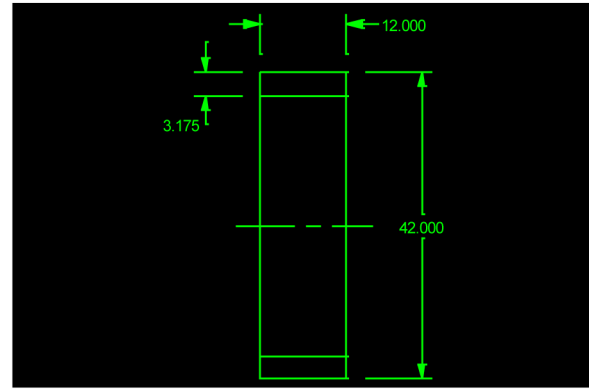


Fig. 1. Modeling Bearing Outer Ring

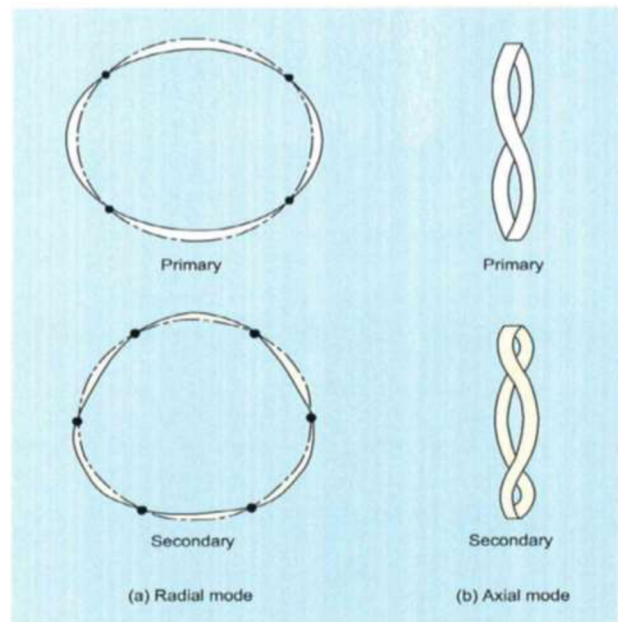


Fig 2a & b. Radial and Axial Elastic Modes of Vibration

For the radial natural frequency of the outer ring, NSK [5] proposed the following equation based on the theory of thin circular arc rod;

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{Eg}{\gamma}} \frac{I_x}{AR^4} \frac{n(n^2-1)}{\sqrt{(n^2-1)}} \quad (1)$$

Where

f_0 : The natural frequency of individual bearing ring in the radial direction

E: Yong's modules (Mpa) (kg/mm^2)

γ : specific weight (N/mm^3) (kgf/mm^3)

g: gravity of acceleration (mm/sec^2)

n: number of deformation waves in each mode (i+1)

I: area moment of inertia at the natural axis of the bearing ring (mm^4)