Examine Bearings Before Class

not time in class for everyone to see when discussing see comments on sheets beside the bearings

- Bearing A-frosted band in raceway is normal pattern
- Bearing B-spall in raceway, detect with vibration
- Bearing C1-self aligning
- Bearing C2-spalls 180°, marks 180°, fretting on bore
- Bearing D-photo, melt/bent shaft, inner ring blue & dented by balls, balls blue, outer ring straw color
- Bearing E-shaft spun in bearing
- Bearings F1 & F2-pillow block,
  - spherical seat brg. in housing, eccentric lock to shaft, F1 “clicks” as rotates
- Notice surface finish on misc. balls & cutaway ring

Background W. B. Fagerstrom PE PhD

- worked on process machinery to improve
  - reliability (health) of process equipment
  - quality of product produced by process equip.
- did computer modeling & made measurements
- measurements reveal behavior/phenomena
  what & how much; values for computer modeling
- learned bearing’s physical behavior as problem solver, I’m not bearing expert
- Besides machinery: buildings, ship, helicopter, distillation column, piping, customers facilities

Agenda

- Introduction
  - Bearing Function
  - Bearing Parts & Types
  - Mounting on Shaft & in Housing
  - Physical Behavior of a Rotating Bearing
- Design & Engineering
  - Tolerances, Fits & Clearances
  - Forces & Life
  - Lubrication
  - Selection/Calculations: Textbook vs. Catalogs
- Case Histories-CSI Forensics (Post Mortems)
  - Illustrate Bearing Behavior, Design & Engineering
- Introduction-Function, Parts, Types, Mounting, & Behavior

  - Function-are joints between rolling & stationary
  - most machines have multiple bearings
  - #rolling element brgs.>>#journal brgs. (oil film)
  - Fascinating Physical Behavior
    - clearances about 0.0001 inch for typical bearing
    - hydroplaning on thin oil film, millionths of inch
    - illustrate bearing defect frequencies
  - Bearing Parts in textbook plus seals & shields
  - Bearing Types & Ratings
  - Mounting of Bearing on Shaft & in Housing

April 16, 2008
Questions - Oil Film Thickness

- Why is an oil film beneficial for a brg.?
  - avoid metal to metal contact, asperities touching, high stress
- Is there an oil film at zero rpm (speed)?
  - no
- How is oil film thickness created?
  - hydrodynamic action, rolling action oil is squeezed out
- What happens if the oil film is too thin?
  - asperity contact $\Rightarrow$ high stresses $\Rightarrow$ surface/bearing failure
- If brg. rpm increases, oil thickness inc/dec?
- If oil viscosity increases, oil thickness inc/dec?
- If bearing temp. rises, oil thickness inc/dec?

Shields & Seals
not shown in textbook, see backside of handout

SF One Shield  
SZ One Seal  
SFF Two Shields  
SZZ Two Seals

Types & Ratings
on backside of handout

<table>
<thead>
<tr>
<th>Type</th>
<th>Radial Load</th>
<th>Average</th>
<th>Relative Ratings</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1.00</td>
<td>1.00</td>
<td>±0° - 2°</td>
</tr>
<tr>
<td>DEEP GROOVE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANGULAR</td>
<td>1.00</td>
<td>1.00</td>
<td>±4°</td>
</tr>
<tr>
<td>CONTACT 40°</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SELF-</td>
<td>0.70</td>
<td>0.20</td>
<td>±0° - 5°</td>
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<tr>
<td>CYLINDRICAL</td>
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<td>0.00</td>
<td>±1°</td>
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<tr>
<td>ROLLER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPHERICAL</td>
<td>6.00</td>
<td>1.70</td>
<td>±1°</td>
</tr>
<tr>
<td>ROLLER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEEDLE</td>
<td>2.60</td>
<td>0.60</td>
<td>±0° - 2°</td>
</tr>
</tbody>
</table>
Pillow Block Housing w/Bearing
common in air handlers (fans) & pumps

Mounting-on Shaft, in Housing

Shoulder on Shaft in Housing (best)

Set Screw
Eccentric Collar

Nut

Taper Lock

Tightening Taper Lock with Spanner Wrench & feeler gage to expand inner ring (reduces internal clearance)

Typical Bearing
- rotating inner ring, stationary outer ring
- load-radial only, stationary, on inner ring, often vertical
- horizontal shaft

Load distribution within a bearing.

April 16, 2008
Intro-Bearing Defect Frequencies

3 Defects (spalls)
• Outer ring
• Inner ring
• Ball

Calculating Bearing Defect Frequencies

If a bearing with 10 balls has dimensions so that the separator rotates 40% in 1 shaft revolution, how many balls pass the outer ring (green spot) in one shaft revolution? If 3600 rpm the outer ring defect frequency is 10x0.4x3600=14,400 cpm=240 Hz
ditto pass the inner ring (yellow spot) in 1 rev?
inner ring defect freq. is 10x0.6x3600=21,600 cpm=360 Hz

Design & Engineering-1
Tolerances, Fits & Clearances

these 3 are mutually exclusive

• Tolerances of components, 5 ABEC grades, for 2”brg.
  grade 1~0.0005", 3~0.0004, 5~0.0003, 7~0.0002, 9~0.0001
• Fits bearing to shaft & bearing to housing
  fits per tables, vary with loading condition & bearing size
• Clearances (internal, radial)
  • 50mm bore brg. clearance ≈ 0.00055 inch
  • mounting (interference fit) & running removes ~80% clearance
  • clearance shifts to unloaded side (top)
  • changes in fit, load & thermal growth alter clearance

Design & Engineering-2
Forces & Life

• Forces
  – Typically used: static wt., drive forces, dynamic forces
  – Often overlooked: misalignment, restrain thermal growth

• Life
  – Life based on fatigue failure using contact stresses
  – Fatigue Life=Constants x (brg. rating/applied load)^3
  – If radial & axial loads, applied load=X x radial + Y x axial
  – Factors Limiting Life & % of bearings in that factor
    • Reach Fatigue Life (8%)
    • Poor Fabrication (8%)
    • Under Designed (16%)
    • Poor Handling & Install (33-%)
    • Poor Lubrication (33+%)
Design & Engineering-3
Lubrication & Selection/Calculation

- **Lubrication**
  - **Purpose**
    - film between ball & raceway so no contact
    - lubricate sliding between separator & balls
    - protect surfaces from rusting/corrosion
    - carry away heat
  - **Oil vs. Grease**
    - oil is ideal,
    - grease is oil in a carrier/thickener
  - **Systems**
    - grease, oil reservoir, re-circulating oil
    - increasing cost, complexity & performance

- **Selection/Calculation-Textbooks vs. Catalogs**
  - Textbooks limited data, only a few bearing sizes & types
  - Bearing catalogs have full range sizes/types & recommended fits
  - Catalogs in pdf at skf.com mrcbearings.com ntnamerica.com

Case Histories with Forensics
Illustrate Behavior, Design & Engr.

- **Bearing “Wear” Pattern-Good**
  - Brg-A; frosted band in center of inner raceway

- **Defect Frequency** *so detect faults before failure*
  - Brg-B; spall on outer raceway
  - Brg-C; spalls 180°, marks 180°, oval ring, hsg. ecc.

- **Brg-D** photo melted/bent shaft; taper lock not tight
  - **Brg-E** shaft spinning in brg.; hi temp environment; designed for thermal growth of shaft but not for brg.

Thick-Thin Coating Bands on Sheet

Sheet (Web) Coating Process

- Sheet movement thru coating process
- Coating Applied
- Roll
- Roll
- Roll
Marks on Bearing C

Inner Surface of Outer Ring

2 rows of fading spall marks, repeat in 180°

Outer Surface of Outer Ring

2 frosted lines 180° apart, begin with inner spall marks

If Outer Ring of Bearing is Distorted, Oval Shape

Then potential negative clearance (interference) in bearing at 2 points 180° apart

If Top of Bearing Housing is Reversed

Distorts Outer Ring

zero clearance in bearing at 2 points 180° apart will give us the wear pattern seen

If Top of Housing is Reversed

Distorts Outer Ring

smaller diameter

Inner Surface of Outer Ring

180°

Outer Surface of Outer Ring
Sheet (Web) Coating Process

Bad Bearing Caused Thick-Thin Bands

Bearing D
Bearing Failure Wrecks Motor-Fan

left to right Brg. Hsg. (outboard brg., near motor), Shaft, failed Brg. (inboard brg. near fan)
They had tightened bearing on shaft, didn’t realize needed expand inner ring using a spanner wrench & feeler gage to check clearance, so bearing became loose & shaft was rotating faster than bearing (rub-heat)

Recap

- Introduction
  - Bearing-Parts, Types & Mounting on Shaft, in Hsg.
  - Physical Behavior millionths, hydroplaning, def. freq.
- Design & Engineering
  - Tolerances, Fits & Clearances mutually exclusive
  - Forces & Life most bearings don’t fail from fatigue
  - Lubrication oil best, grease easiest
  - Need catalogs not texts to select/calculate brgs.
- Case Histories with Forensics Illustrate
  - Clearances-tight & critical
  - Mounting-good/bad shaft/housing
  - Defect Frequencies-catch early avoid catastrophic
  - Thermal Growth can be tricky in bearing
  - Forensics can find cause (CSI), save corpse
  - Imply-surface finish & tolerances are very good

Brg.-E high temp. environment

- Bearing bore polished, looked like shaft spinning in bearing
- Used in a very hot process @low rpm
- How much a 1” shaft grow if 400°F rise? \( \alpha = 6 \times 10^{-6} \text{ in/in } ^\circ \text{F} \)
- Client started with recommended shaft-bearing fits to size shaft then re-sized shaft to allow for its thermal growth of 0.0024”
- Your thoughts on their procedure?
- So problem and correction were?
- Shaft & Bearing both rise about 400°F so both grow about the same & no re-sizing needed for shaft
- 2nd problem-rusting, using special aerospace hi temp grease, I brought in engr. from grease mfg., him recommended anti-rust inhibitor (option with this special grease) & rec. buying a cheaper (5x?) non-pedigree version of the grease, message-suppliers can help you
Summary-Questions

- Name the major parts of a bearing
- Types-most common, good axial, very good radial
- Best way to mount a brg. to shaft, 1 other way
- Difference-Tolerances, Fits, & Clearances
- Forces-name 1 recognized, 1 unrecognized
- Life-relationship to load, what if axial & radial load, name 2 reasons brgs. don’t reach rated life
- Lubrication-2 purposes, merits of oil vs. grease
- How did a case history illustrate brg. fundamental
- Discuss physical action between ball & raceway
- How solve problems with forensics or brg. freq.

Introduction-Function, Parts, Types, Mounting, & Behavior

- **Function**-are joints between rolling & stationary
  - most machines have multiple bearings
  - rolling element brgs.>>#journal brgs. (oil film)

- **Fascinating Physical Behavior**
  - clearances about 0.0001 inch for typical bearing
  - hydroplaning on thin oil film, millionths of inch
  - illustrate bearing defect frequencies

- **Parts**  Textbook Figs. 11-1 & 13, seals & shields*
- **Types & Ratings**  Text Figs. 11-2 & 3
- **Mounting**  Text Figs. 11-8, 19, 20, 21, 22, & 23
  + pillow block* & mounting*
  *shown on the reverse side of handout