The Value of Inspection and Testing on Global Bearing Sourcing & Bearing Qualification Strategy

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President and Chief Engineer of Napoleon Engineering Services
Global Bearing Industry Facts

• Global Bearing Industry 50.5 Billion Dollars Annually

• Global Bearing Demand to increase 8.5% through 2014

Top Bearing Manufacturers:
- Europe
- Asia Pacific
- United States

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The Global Bearing Market

Risk

- Quality/Counterfeit issues
- Reduction in performance from current supplier
- Inadequate engineering support
- Variations in performance between plants from same company

Reward

- Establish New Sources of Credible Supply
- Reduce Bearing Costs
- Reduce Lead Times/Improved Production Supply

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Poll Question

Please Indicate Your Job Title:

- Supply Planning
- Research/Development
- Design/Application Engineer
- Quality Engineer
- Test Engineer
- Other
What Has Changed?

- Large bearing manufacturers are buying plants around the world and establishing global sources.
- Available sources of US made bearings has dwindled.
- Smaller bearing manufacturers from remote regions of the world now have access to you, creating apparent opportunities for additional sources.
- Divergence of bearing quality
- Bearing engineering support has changed with influx of off-shore suppliers.
- Low Risk Switch & Go is no longer true
- OEM responsibility for bearing design has increased significantly
Key Sourcing Strategy Steps for Risk Mitigation

• Accept and acknowledge:
  – Bearings are not a commodity
  – Resources are required to achieve a positive outcome
    • time, staff development, financial resources, management support.

• Determine possible sources who appear to meet commercial needs:
  – Bearing type
  – Manufacturing Capacity
  – Quality Systems
  – Cost

• Determine Supplier Type
  – Defines contractual agreements, expectations, communication chain, test requirements that are required.
  – Distributor, Broker, Off-Shore Manufacturer, US Sales unit of foreign manufacturer, Manufacturers Rep
Key Sourcing Strategy Steps for Risk Mitigation

- Determine Bearing Types and Sizes
- Establish plant and manufacturing line
  - Qualification is ONLY for specific product and manufacturing line
- Determine available application engineering support, failure analysis and testing capability
  - It is relative to the criticality of the bearing in the application
- Understand Application Conditions – Criticality of the Application
- Quality Systems Audit – Plant or Distribution Facility
  - Audit by Quality Department
- Evaluate Bearing Failure Modes and Warranty Data for existing supplier

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Key Sourcing Strategy Steps for Risk Mitigation

• **Perform Bearing Manufacturing Plant Audit**
  – Design, Material, Turning, Heat Treatment, Grinding, NDT, Inspection, Assembly, Mark/Wash/Preserve/Package

• **Develop Product Qualification Plan and Capability:**
  – Inspection
  – Modeling
  – Testing
    • Lab
    • Application/Field

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Poll Question

What current method of bearing sourcing do you use? (can indicate more than one):

• Bearing Lab Testing
• Bearing Field Testing
• Bearing Inspection
• Bearing Modeling
• No Sourcing Strategy
Old Philosophy

• Testing via Lab and/or Field Test

Issue

• Results provide no explanation for why bearing passed or failed the test
• Offers no long term benefit to future bearing qualifications
• Provides no assignable cause for failures
• Can Increases cost and qualification time
**Bearing Inspection Program**

*First Step in Product Qualification Program*

- **Goals:**
  - Design Intentions
  - Manufacturing Capability
  - Quality of Workmanship

- **Consists of:**
  - Detailed Dimensional Analysis of Internal Geometries
  - Visual Inspection
  - Noise Testing
  - Seal Dimensional Evaluation
  - Material Chemistry, Microstructure, Grain Size, Cleanliness, and Hardness

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Ball Bearing Critical Characteristics

- RC/EP/Contact Angle
- Face offset – Preload or Endplay
- Raceway Curvature
  - Deviation of True Form
  - Hertzian Stress
- Surface Finish
- Roundness, Waviness, Harmonic Analysis
- Capacity
- Cage clearances and quality of workmanship
- Noise
- Seal torque and contact interference
- Grain size, retained austenite, carbide banding, cleanliness

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Roller Bearing Critical Characteristics

• Roller Bearings:
  – RC/Contact Angle/EP
  – Raceway and Roller Contour Geometry
  – Roll to Ring End Clearance
  – Raceway flange angles
  – Surface Finishes
  – Raceways, flanges, roller OD/flanges
  – Roller end/raceway flange contour
  – Roundness, waviness, harmonic analysis
  – Cage design-diametral clearance, axial/circumferential pocket clearance
  – Capacity calculation – Effective Length
  – Grain size, retained austenite, carbide banding, cleanliness
Power of Inspection

Allows OEM’s to:

- Understand why the baseline is effective
- Determine why suppliers perform differently
- Openly communicate design issues with bearing manufacturer
- Control the bearing design to ensure success in the global supply chain
- Reduce both time and cost in any future qualification undertakings
- Enhance the technical aspect of requirement drawings
- Accurately model bearing performance characteristics through software programs such as Romax, Shaberth, Cobra, etc.
Computer Modeling

Raceway-Roller Stress Profile

<table>
<thead>
<tr>
<th>AZIMUTH</th>
<th>NORMAL FORCES (POUNDS)</th>
<th>HZ STRESS (LB/IN**2)</th>
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Testing Programs

- Test Types:
  - Environmental
  - Dynamic
  - Impact or Static Load
Environmental Testing

- Mud Slurry
- Dust Box
- Salt Spray
- Humidity

- Evaluates Seal Effectiveness, wear resistance and corrosion resistance of coatings, platings or materials

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Dynamic Testing

- Performed to confirm effectiveness of
  - Materials
  - Product Design
  - Manufacturing process
- Performed at accelerated conditions to reduce test time
- Adds to knowledge database for risk reduction
Output From Dynamic Testing

- Life Adjustment Factors (LAF)
- Load Rating Validation
- Fast Track Qualification - Temp/Torque Testing
- Weakest Link Failure Mode
- Material/Process Validation Endurance Testing
Dynamic Testing

- Establish Life Adjustment Factors (LAF)
Life adjustment Factors

Knowing the normalized life, the OEM can now establish bearing life enhancement or reduction value relative to the application for the new supplier.

Normalized Life

- Theoretical
- Supp A
- Supp B

Diagram showing normalized life for theoretical and two suppliers (A and B).
**Dynamic Testing**

- Load Rating Validation - Bayesian Testing

### Bearing Reliability Life Predictions - Assuming No Failures - Bayesian Testing

<table>
<thead>
<tr>
<th>Sample Weibull Shape Size</th>
<th>Parameter</th>
<th>L10 Life Time</th>
<th>Test Duration</th>
<th>Confidence Level</th>
<th>Test Duration</th>
<th>Confidence Level</th>
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<td>2) Six (6) Groups of Four (4)</td>
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<td>69.0%</td>
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<td>64.0%</td>
<td>100</td>
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<td>300</td>
<td>99.4%</td>
<td>200</td>
<td>99.8%</td>
<td>100</td>
</tr>
</tbody>
</table>

**Assumptions:**
1. The Weibull shape parameter equals 1.5
2. The L10 life is 300 hours
3. Tests are run for the listed duration and no failures occur
4. Weibull distribution assumed as base distribution
5. If the Weibull distribution is known and at tests are run until at least 3 failures are identified, a more accurate comparison of the reliability could be derived
Dynamic Testing

- Roller Bearing Fast Track Qualification
  - Temperature/Torque Testing
    - 28 hour test for determining product acceptability based on break-in and stabilized operating temperature and bearing torque.

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Dynamic Testing

- Weakest Link Failure Mode
  - Dynamic testing can highlight design or manufacturing deficiencies that can result in surface or subsurface initiated failures. It also provides validation of knowledge gained through inspection process.
    - High Operating Temps
    - Cage Issues
    - Surface Finish Issues
    - Poor Contact Load Profile
Dynamic Testing

- Material or Process Validation Testing
  - Foundation Testing of Manufacturing Lots
    - Ball testing
  - Material Design Change
    - Cage

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Impact or Static Load Testing
Static/Impact Rig

- TRB Static axial load test
  - Evaluates cone rib
    strengths and undercut
    design

- Impact testing
  - Material choice vs. true
    brinelling

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Bearing Qualification Advantage

- Reduce risk and qualification time
  - Inspection provides a link between the baseline and the application.
  - Comparing inspection and test results link alternate supplier performance capability to the application
  - Inspection and testing performed within 4-6 month window

- Make informed decisions
  - Plan provides technical information about:
    - Design
    - Manufacturing capability
    - Workmanship quality
    - OEM’s can gain more knowledge about how the product will perform in their applications

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Recap

- Acknowledge Risks & Responsibilities
- Determine Supplier Sources & Structure
- Define Bearing Types & Sizes
- Establish Production Plants Sites & Manufacturing Lines
- Evaluate Engineering Support Capability
- Define Application Conditions & Criticality of Bearing In Application
- Conduct Quality Systems Audit
- Conduct Manufacturing Audit
- Develop Capability/Resources for:
  - Inspection
  - Modeling
  - Testing - Lab and Application
- Develop Mitigation Plan Meeting Risk, Time & Budget Constraints
Further Information

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  - 877-870-3200

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