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Wind Turbine Drive Train Inspection Technology Comparison

Portable Vibration Analysis vs. Borescope Inspections

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Borescope vs. Vibration

- Some wind farm owners are still skeptical about vibration analysis.
  - What is the reason for this?
    - Bad experience in the past?
- Wind farm owners may not know the limitations of borescope inspections.
- This presentation will discuss the advantages and disadvantages of each inspection type.

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Borescope Inspections, Pros and Cons

Pros

- Offers indisputable evidence of bearing or gear damage.
- Analysis of findings are not always required.

Cons

- Inspection labor cost is high.
- Inspection typically limited only to gearbox. Main bearing(s) and generator bearings are usually inaccessible.
- Portions of gearbox bearings or sometimes entire bearings are inaccessible to the camera.
- Thoroughness of the inspection is mainly dependent on the experience/skills of the camera operator.

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Portable Vibration Analysis, Pros and Cons

Pros

- The labor cost for gathering vibration data is low.
- Measurements can be recorded from all gears and bearings in the gearbox.
- The condition of generator bearings and main bearing(s) can be established.
- Can find mechanical and electrical problems not visible to the borescope camera (i.e. misalignment, unbalance, electrical defects, etc.)

Cons

- Data needs to be analyzed from a certified and experienced analyst.
- Sometimes vibration analysis results are not accepted by companies as definitive evidence of damage.

Labor Cost Comparison

- Borescope inspection
  - Requires 6-8 hours with 2 technicians to complete 1 inspection.
  - 12-16 man hours per inspection.

- Portable Vibration Analysis
  - Requires 2 hours with 2 technicians to complete 1 tower.
  - 4 man hours per inspection.
  - Allows multiple inspections to be completed per day.

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Gearbox Component Accessibility

- During a borescope inspection the camera has limited access to gearbox components.
- Depending on the gearbox type generally:
  - 90% of the gear teeth are accessible.
  - 30-40% of the bearing races and rollers are accessible.
- Some reasons for the restricted access to gearbox bearings include:
  - An oil dam plate could be installed in front of a bearing.
  - A bearing's cage is too close to the bearing race to allow camera access.
  - The bearing rollers are small and too close together for the camera to fit in-between.
  - The bearing is completely sealed off.
  - Large gears sit in front of the bearing, making it difficult to access.
- **Due to this, it is possible the inspector may fail to see damage in the gearbox**

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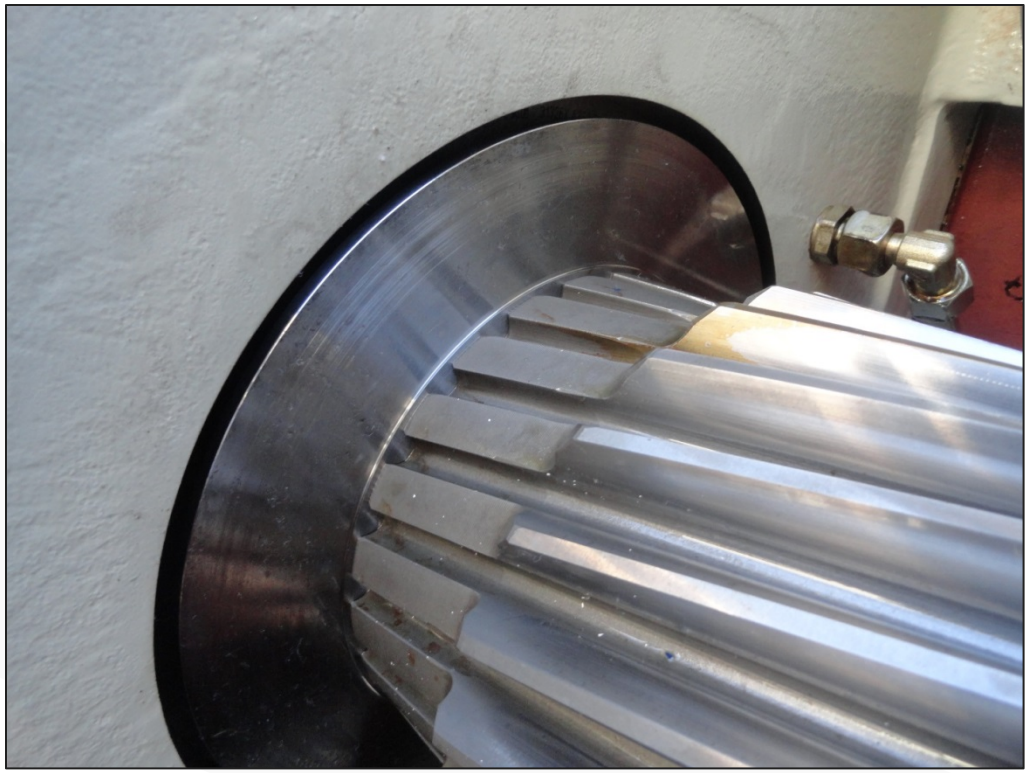

Gearbox Component Accessibility

An example of a bearing with an oil dam plate blocking borescope camera access.

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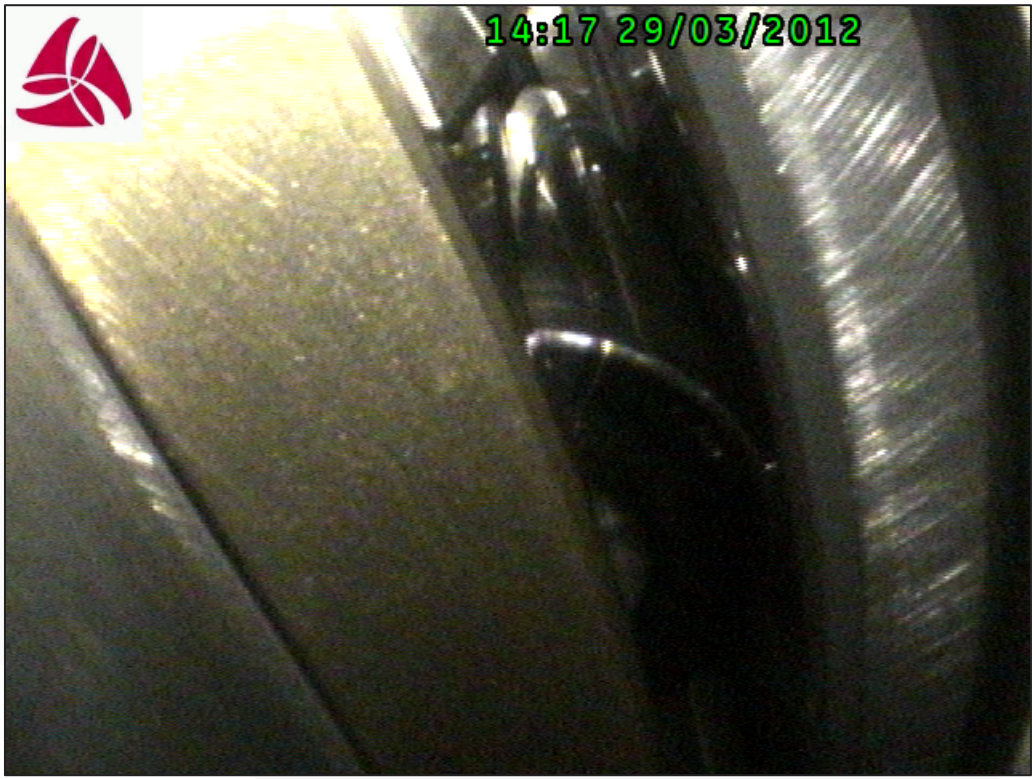

Gearbox Component Accessibility

The bearing's cage prevents access to the inner race of this bearing.

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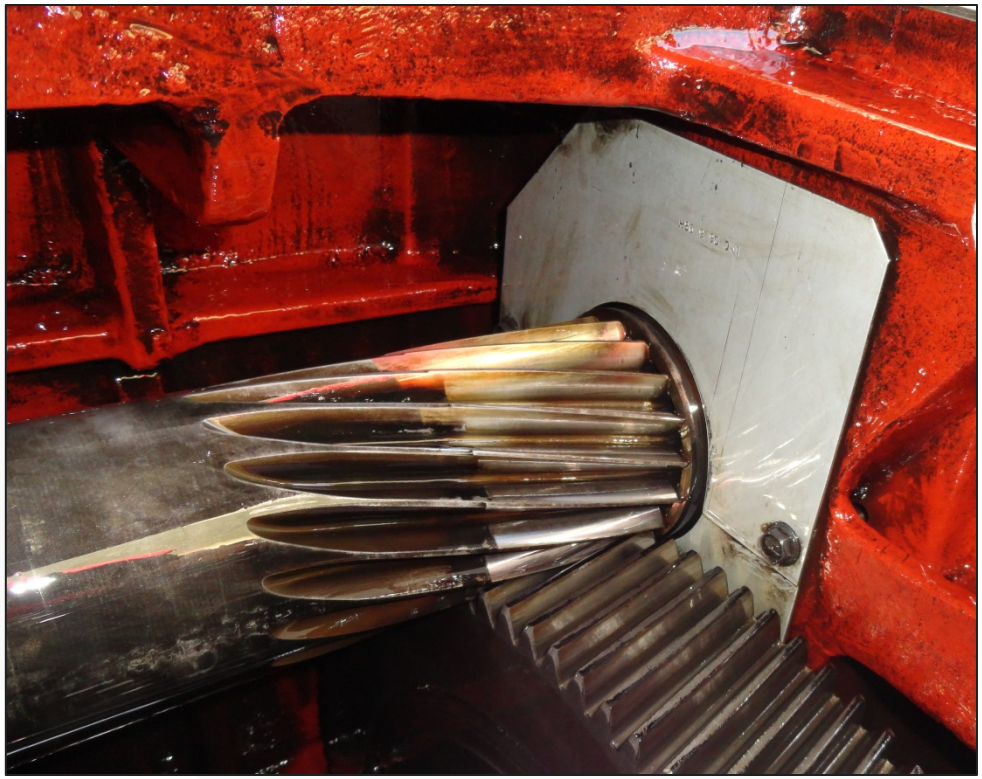

Gearbox Component Accessibility

This bearing is completely sealed off.

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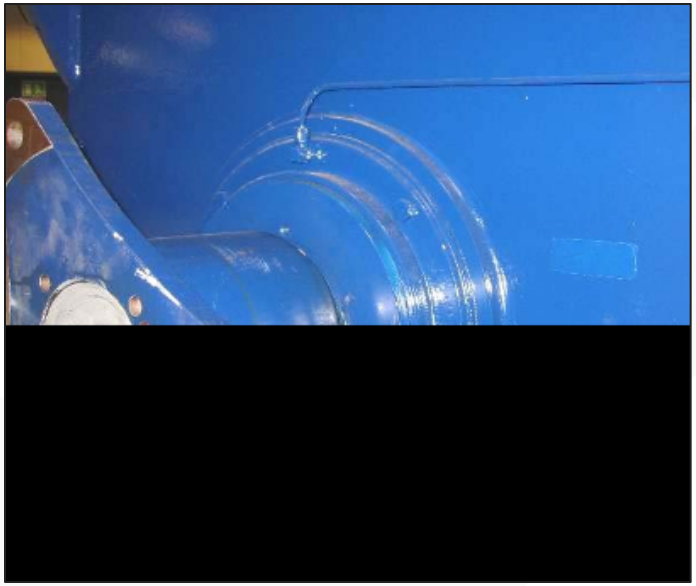
Gearbox Component Accessibility

The space between these bearing rollers is too small to allow enough room for the borescope camera.

Generator Accessibility

- Borescope cameras are usually not able to access generator bearings.
- These bearings are typically packed with grease. The grease covers all the surfaces of the rollers and races making it impossible to find damage.
- Vibration analysis is very sensitive to generator bearing defects.
- Most generator bearings are standard bearings which have all their defect frequencies available to the public. This makes defending the generator bearing vibration analysis results easy.



Main Bearing Accessibility

- Borescope cameras are also typically not able to access main rotor bearings.
- These bearings are almost always grease lubricated. The grease covers all the surfaces of the rollers and races making it impossible to find damage.
- Using low frequency accelerometers, vibration analysis can detect main rotor bearing defects.
- These main bearings are also usually standard bearings which has all defect frequencies published to the public.

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Detecting Other Mechanical & Electrical Problems

- Portable vibration analysis can also detect other mechanical and electrical defects which a visual inspection cannot.
- Some examples of these problems include:
  - Generator/gearbox misalignment
  - Shaft or rotor unbalance
  - Bearing looseness
  - Generator looseness
  - Generator frame damage
  - Generator stator/rotor electrical problems
  - Mechanical pump wear
  - Pump cavitation

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Properly Utilizing Each Inspection Technique

- Possible situations where portable vibration analysis or borescope inspections could be used:
  - End of warranty inspections.
  - Finding metal flakes in gearbox oil filter.
  - Overheating faults occurring during operation.

- However, when should each inspection technique be used?
  - These two techniques should be used together to get the most effective and economical inspection.
  - Using vibration analysis first, especially when inspecting multiple turbines, will reveal the exact location of all possible defects.
  - Then, a borescope team can be dispatched to inspect the locations identified by the vibration analysis results.
  - This process utilizes the quick and accurate detection of defects by the vibration measurement equipment and the undeniable proof of component damage offered by the borescope pictures.

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Summary

- Both inspection techniques offer their own advantages and disadvantages.
- Portable vibration analysis can be used to quickly and cheaply identify component defects.
- A borescope inspection can offer indisputable evidence of damage, but can be unreliable and labor intensive unless coupled with vibration analysis results.
- The best solution is to make use of the advantages of both techniques and use them together to get the most thorough and economical inspection.