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Wind Gearbox Workscope Optimization

PHM Society
2013 Wind Energy Workshop
October 16th, 2013

Introduction

Today's presentation is based on the following proposition:

- The most sophisticated sensors & predictive / diagnostic software in the world won't help equipment stay in service and control Life Cycle Costs if asset owners / maintainers don't make smart decisions during maintenance events

A Prime Example:

- Wind industry doesn't agree on optimum strategy for bearing replacement during heavy maintenance events, opting to:
  - Only replace damaged bearings (to keep shop visit $ low), or
  - Replace all bearings regardless of their condition or time in service to avoid unplanned events
- Neither approach is optimal
  - The "Best" option is somewhere in-between

Introduction (con't)

StandardAero has developed new reliability-based methods & tools to enable smarter maintenance decision-making

- Goal: Work with asset owners to improve revenue generating capability and minimize long term costs due to off-tower maintenance
- Created several workscoping and fleet modeling tools for multiple customers / applications
- Jet Engines: 10-20% improvement in Cost / Reliability

Undertook engineering study to investigate wind gearbox workscope question (as it applies to bearings)

The Maintainer's Dilemma

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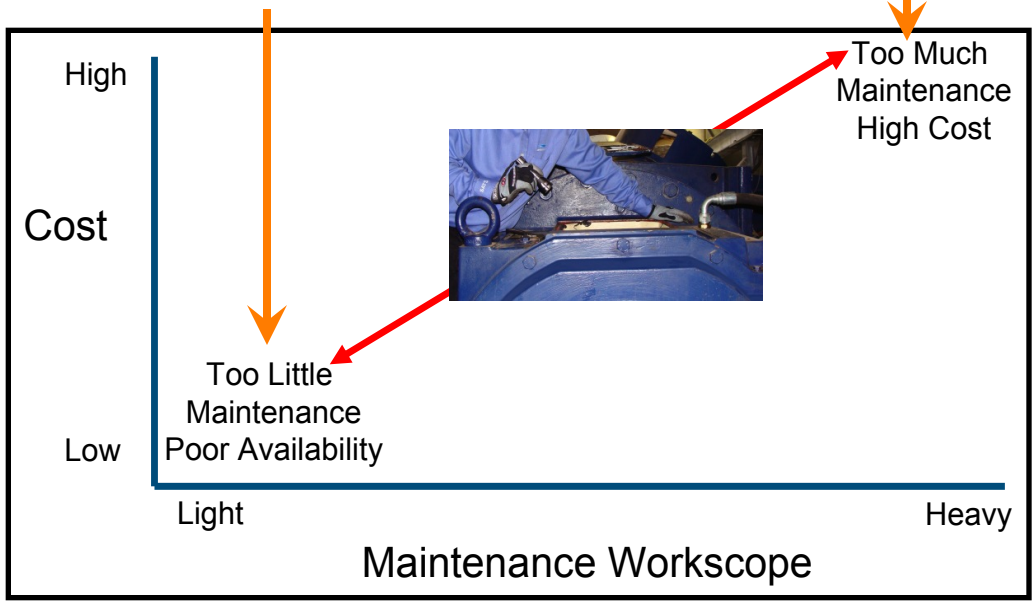
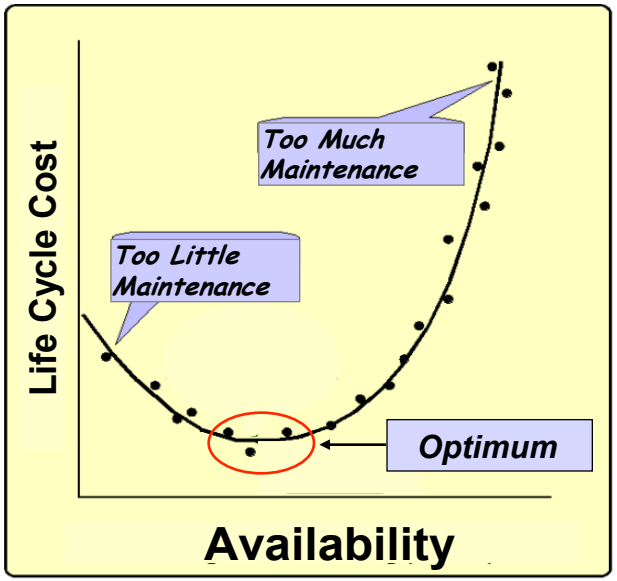
Workscoping question is common to many industries

- Often referred to as the "Maintainer's Dilemma"

Repair only what is broken (OCM strategy) & potentially live w/shorter time in service or unexpected times to next failure

Perform extensive overhaul / replacement at this event & potentially incur costs without extending time in service





How can you optimize maintenance to maximize revenue & minimize life-cycle costs?

- ***Plot amortized cost per operating hour (shop visit cost / life expectancy) vs. life expectancy for each possible workscope to identify the best choice***

Creating the Reliability Tools

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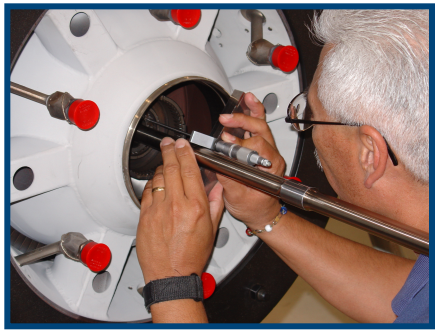
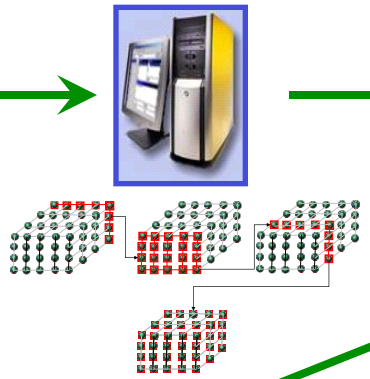
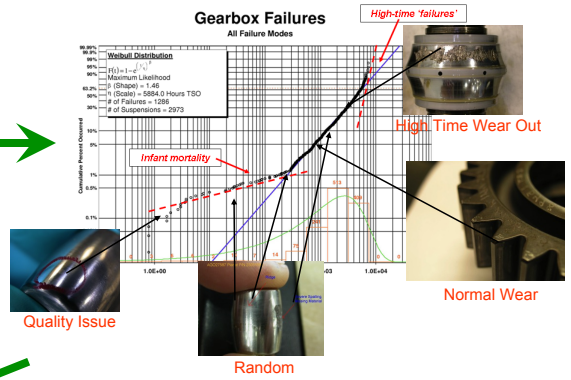
Data Collection/Mining



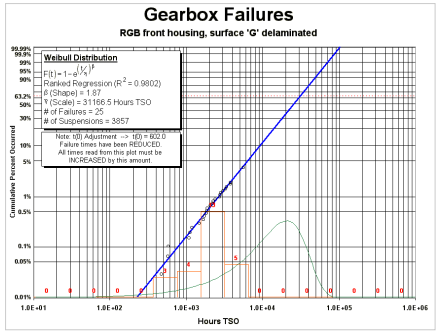
Data Analysis & Management



Failure Analyses

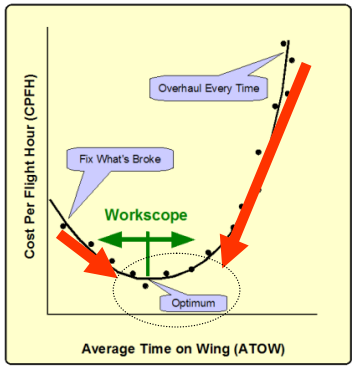


Reliability Analyses



Reliability Models

Practical Cost Based Models & Tools



Study Methodology

Built reliability/cost models for generic gearbox

- Min (L10) lives AGMA spec. 6006-A03

Three (3) workscope approaches analyzed

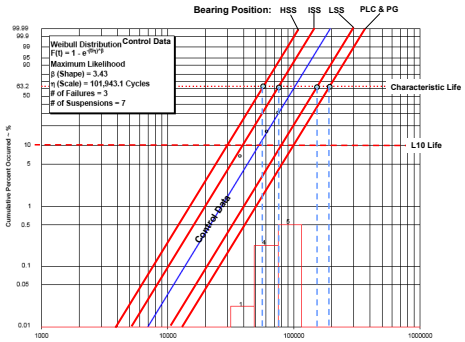
- OCM (replace only failed bearings)
- Replace 100% (replace all bearings)
- Dynamic Strategy: Bearings replaced based on individual ages (& time remaining until unit is retired) to optimize LCC @ Shop Visit

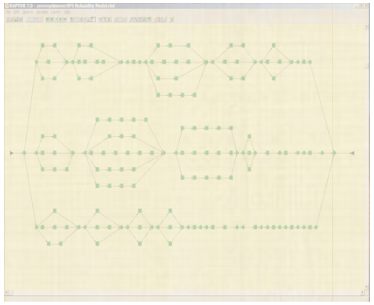
Calculate MTBF & cost of each workscope

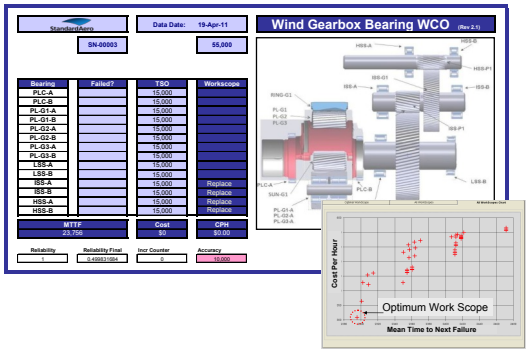
- MTBF based on the combination of items / ages
- Cost: Unit repair cost + next event cost
  - Crane, lost revenue, shipping, labor RR Gbx

Determined $/Hr of each possible workscope

AGMA Specification



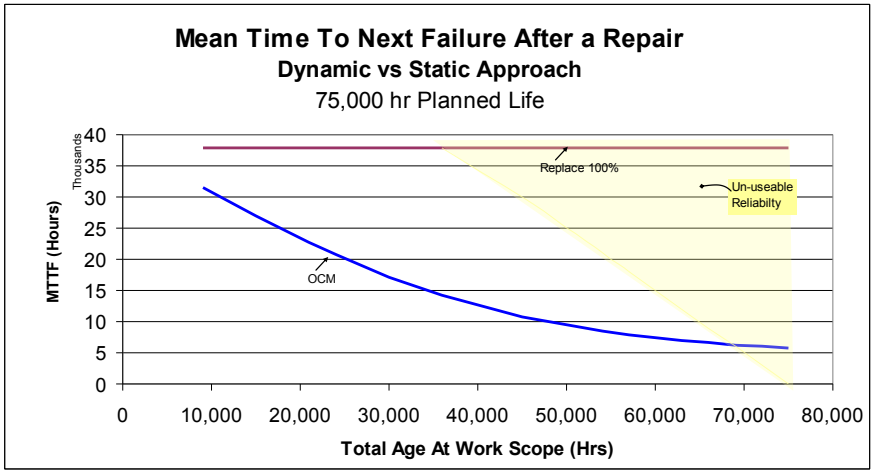




Results: OCM vs Replace 100%

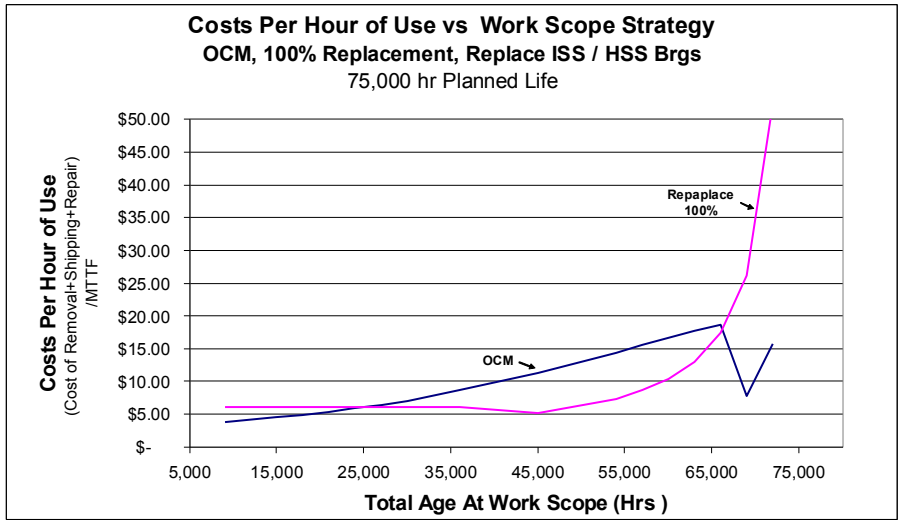
Reliability Impact:

- OCM:
  - MTBF after repair continually decreases as unit ages
- Replace 100%:
  - Buys reliability that can't be used



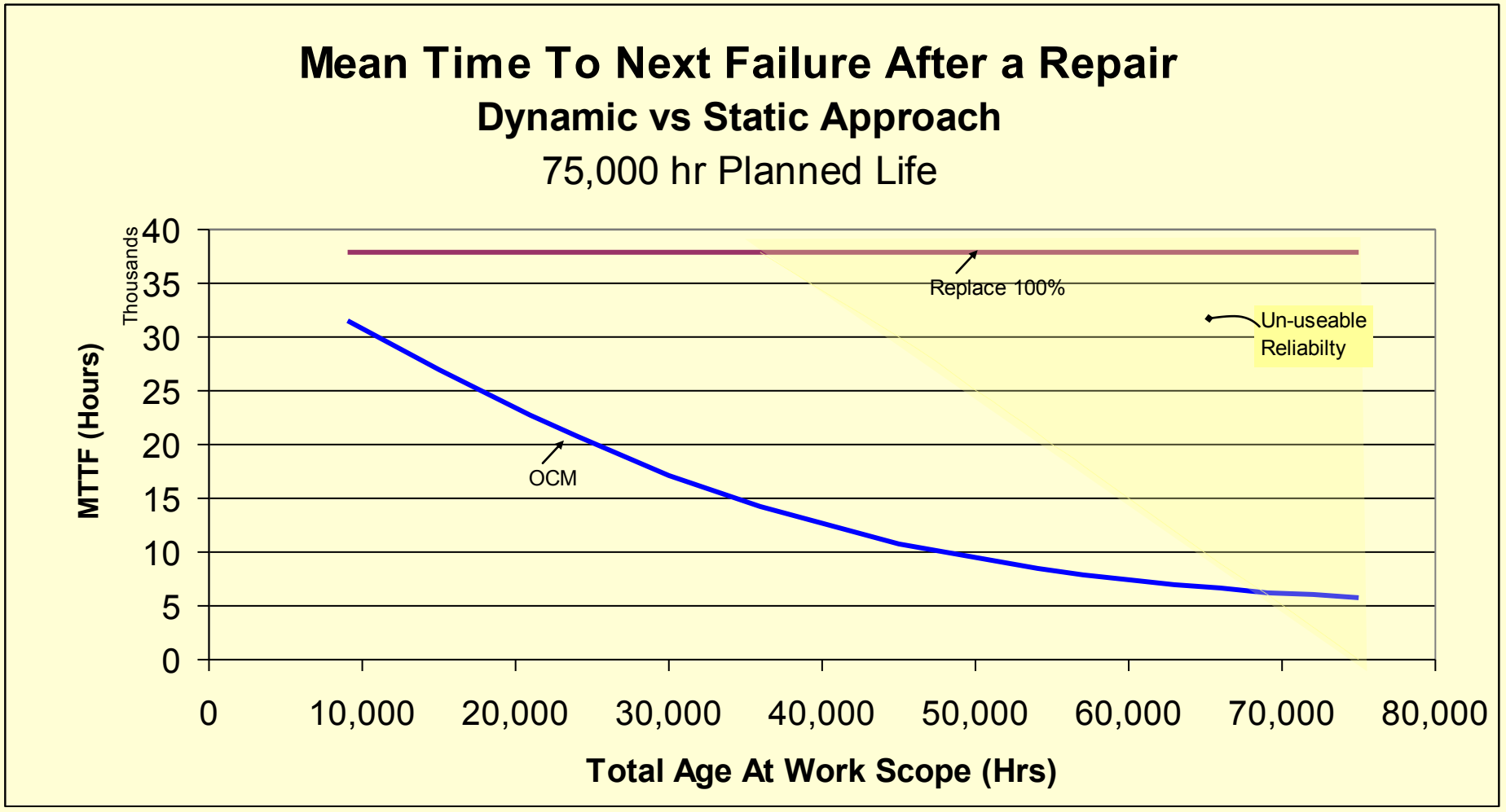
Cost / Hr Impact:

- OCM:
  - Typically more expensive
  - Trends upward until MTBF exceeds planned life
- Replace 100%:
  - Generally better than OCM
  - Buys reliability that can't be used



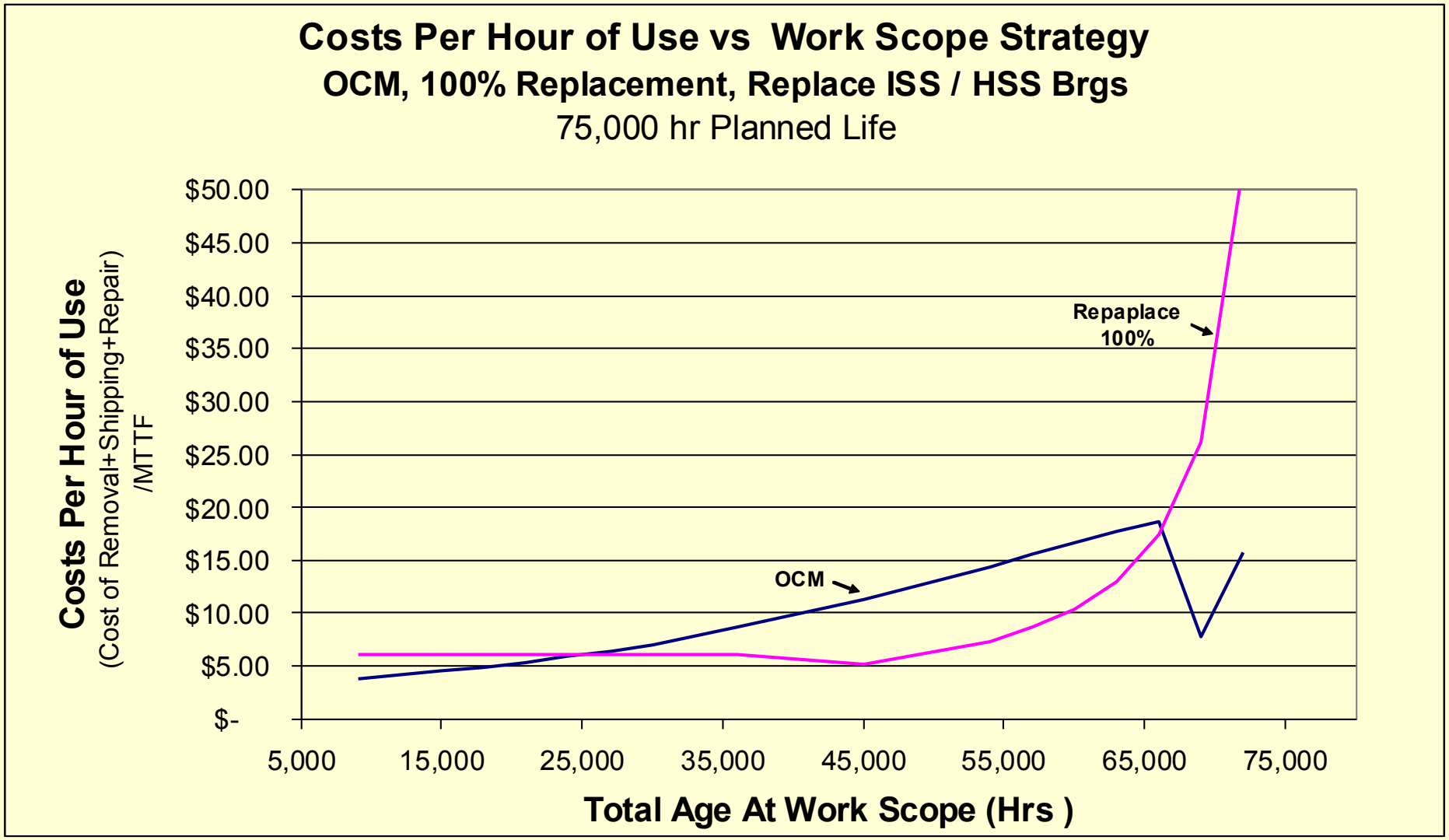
Avg Total O-M Costs: $10/MWH (Wind Energy Update)

Results: OCM vs Replace 100%



Avg Total O-M Costs: $10/MWH (Wind Energy Update)

Results: OCM vs Replace 100%



Avg Total O-M Costs: $10/MWH (Wind Energy Update)

Results: Dynamic vs Static Strategy

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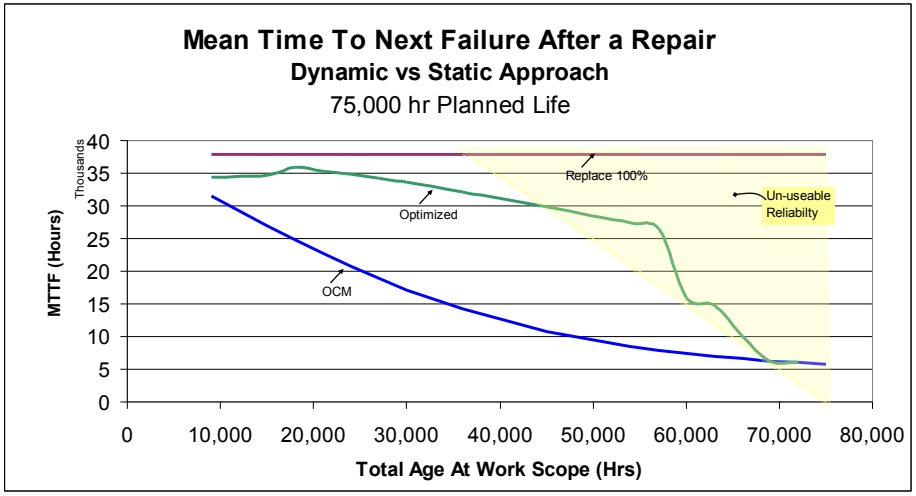
Reliability Impact:

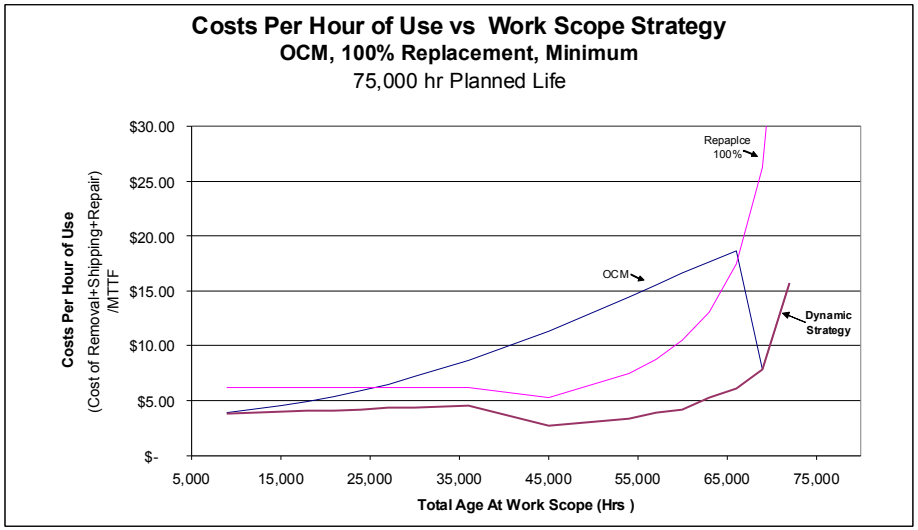
- Dynamic strategy is less than 100% replacement, but more than OCM
- Much less unused reliability

Cost / Hr Impact:

- Dynamic always Lowest
- Equivalent to “OCM” very young and very old lives

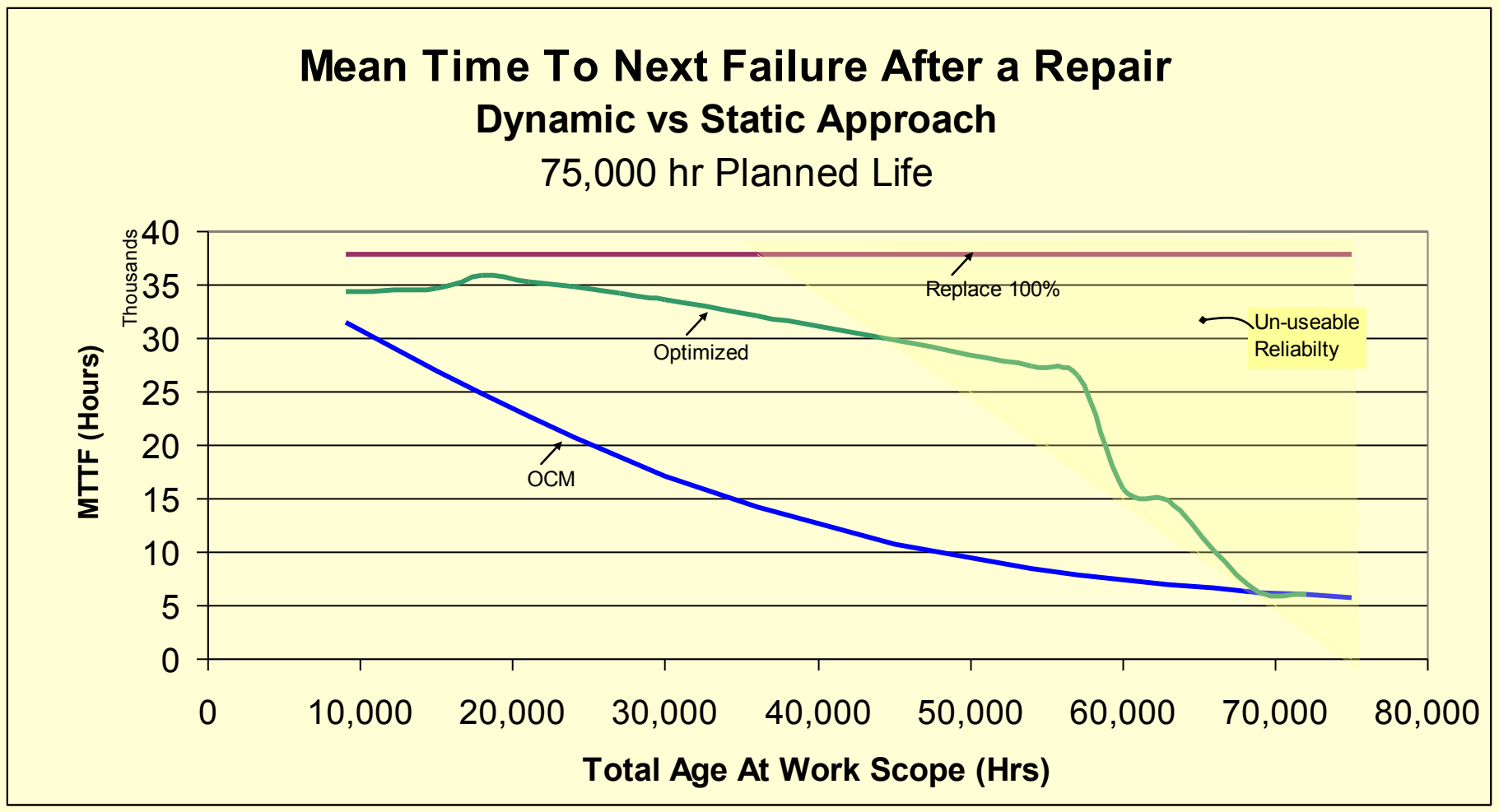


Workscope Occures Between	Avg Cost Delta ($/Hr)	$/KWH
21-30,000 Hours	$ 2.22	$ 0.0015
30-45,000 Hours	$ 5.19	$ 0.0035
45-63,000 Hours	$ 11.24	$ 0.0075
63-72,000 Hours	$ 14.41	$ 0.0097
72-75,000 Hours	$ 36.67	$ 0.0246



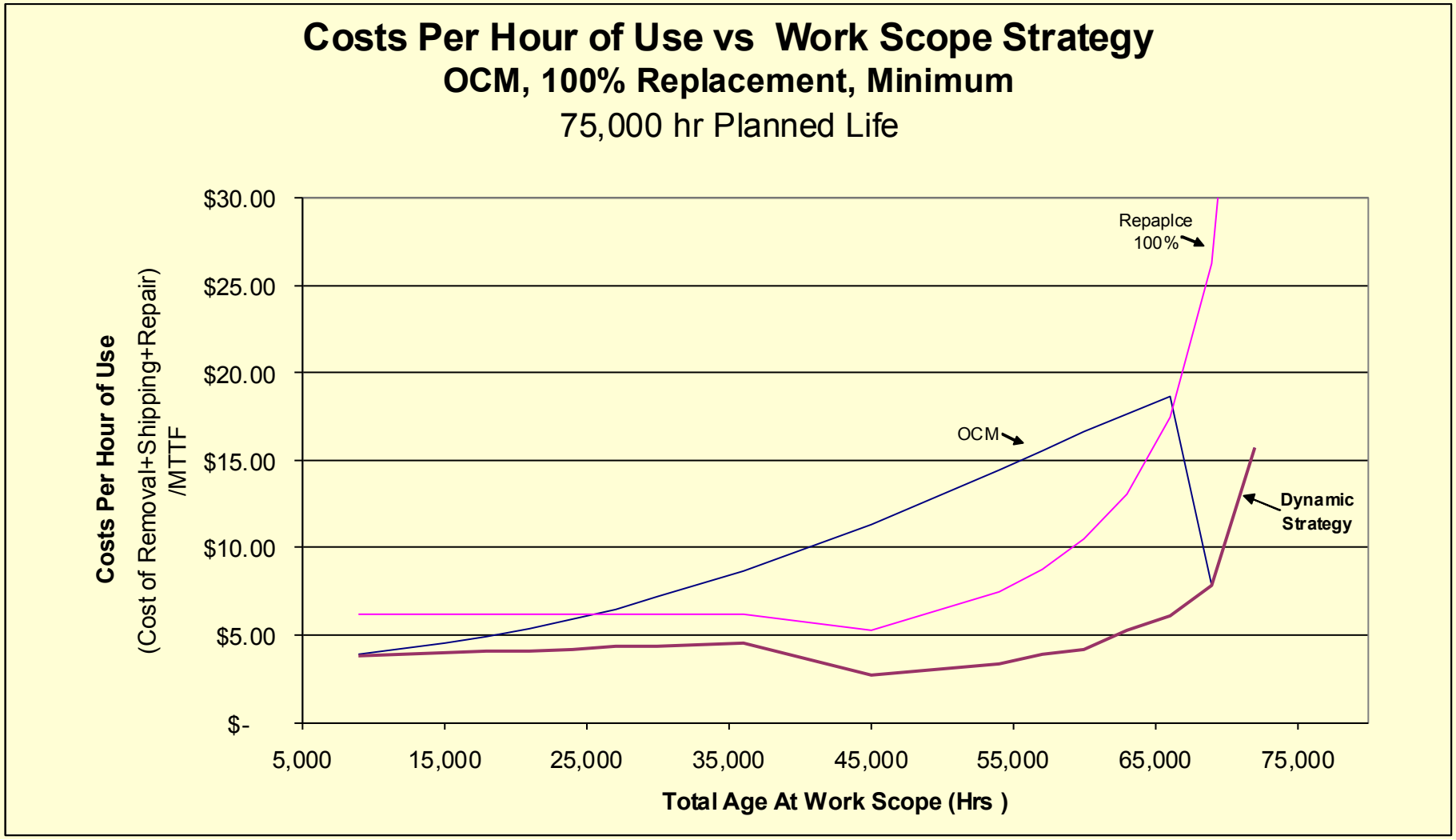
Avg Total O-M Costs: $.01/MWH (Wind Energy Update)

Results: Dynamic vs Static Strategy



Avg Total O-M Costs: $.01/MWH (Wind Energy Update)

Results: Dynamic vs Static Strategy



Avg Total O-M Costs: $.01/MWH (Wind Energy Update)

Conclusions

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The main points to take away from this study:

- MTBF of OCM workscopes degrade significantly w/age
- MTBFs for different workscopes are dictated by which components are replaced or not, their ages, & inherent reliability of components
- Optimum workscope is affected by several factors including:
  - Age of other bearings, and planned retirement age of the unit
- "Static" workscope strategy tends to result in highest LCC
  - Doing the same thing for the entire service life of the unit
- A "Dynamic" strategy is best
  - Determining an "Optimum" build at each point in the unit's life
- Cost impacts from "Worst" to "Best" workscopes vary widely
  - $2.00/Hr ($.00149/kWH) early in unit's life
  - Over $14.00/Hr ($.0096/kWH) late in unit's life
- Wind turbine asset owners need a repair source that can:
  - Quantify reliability & costs of different workscopes (thru gbx life)
  - AND can act on the data such that it minimizes Life Cycle Costs

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