Vibration Fatigue Analysis of a Cooling Fan Mount

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Bobcat Company
Boring? Blame the medium, not the messenger

- Not every presentation translates well to PowerPoint

Gettysburg Cemetery Dedication
Abraham Lincoln

Agenda
- Met on battlefield (great)
- Dedicate portion of field - fitting!
- Unfinished work (great tasks)

Not on Agenda!
- Dedicate
- Consecrate
- Hallow
  (in narrow sense)
- Add or detract
- Note or remember what we say

Review of Key Objectives & Critical Success Factors
- What makes nation unique
  - Conceived in Liberty
  - Men are equal
- Shared vision
  - New birth of freedom
  - Gov’t of/for/by the people

The Gettysburg PowerPoint Presentation: http://norvig.com/Gettysburg/
By: Peter Norvig
Challenge/Project Scope

- Unexpected field failures during validation testing (Proving Grounds)
- Limited analysis history on previous component
- No field failures on previous component
- No well defined FEA load cases
- Strain gauge testing predicted high life – failure was unexpected
Using GlyphWorks and Design Life

- GlyphWorks useful for analyzing field and lab test data
  - Provides insight into the loading and duty cycle of the component
- Design Life helps bridge the gap between simulation and test
  - Allows for application of duty cycle loading to the FE model
  - Helps put the FE results into context (for example – convert stress to fatigue)
Using GlyphWorks and Design Life

- Combining both tools allows for an effective relationship between simulation and test
  - Analyzed test data improves the FE model
  - A useful FE model creates an effective test (what, where to measure, what to expect)
- Simulation tools are effective when solving known failures
  - The failure limits the scope of the model
  - The failure provides a target and reality check for simulation results
- The challenge is to move simulation from reactive to proactive
Fan Mount
Initial Analysis – before Proving Ground Evaluation

Analysis 1a – used static g loading to simulate impact load case. Stress results high, but below ultimate strength. Is this acceptable?

Analysis 1b – 1st mode in operating range (track frequency) Is this acceptable?
Analysis of field data

- After failures at the proving grounds, strain gauge data was collected
- Fatigue life based on Customer Usage Profile (CUP)
- CUP is made of individual duty cycles
- Some of the duty cycles are fatigue type loading (high hour life criteria)
- Some of the duty cycles are extreme type loading (low hour life criteria)

<table>
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<th>Duty Cycle</th>
<th>Life (Hours)</th>
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<tr>
<td>GN 3</td>
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<tr>
<td>Duty Cycle 1</td>
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Composite Acceptable May 14-15, 2014

Livonia, MI (USA)
Analysis of field data

Cross plot of two active gauges

Low pass filter

FFT

High pass filter
Analysis indicated two different load cases

1. LC 1: frame twisting
   - Poor correlation between accelerometer and strain gauges (stress not due to vibration or movement of the fan motor)
   - Stress due to frame twisting during extreme loading
   - This load produced relatively high stress, but low cycle counts
   - Low hour life prediction, but not a significant part of the customer profile

2. LC 2: vibration
   - Good correlation between accelerometer and strain gauges
   - Stress due to track vibration
   - Low stress, but high cycle count
   - Large portion of customer profile, but not very damaging

Strain gauge data did not predict the failure occurring on proving ground machines
Refining the FE model: Frame Twist Load Case

Design Life matches reasonably well with some strain gauges, but did not predict the crack initiation locations.

Upon further review of proving ground data, decide this load case was not the root cause.
Refining the FE model: model setup

- The model setup is reviewed.
- The fan assembly has a rubber gasket between the motor and mount. This is to prevent motor vibration from generating noise.
- In order to decouple the motor from the mount, the motor is connected with two bolts, torqued to 7.5 ft-lbs.

![Rubber gasket](image1.jpg) ![Steel gasket](image2.jpg)
Vibration Fatigue: Mean stress

The assembly stress from the bolt pretension was not considered. It is proposed this mean stress significantly increases the damage of the vibration load case. A vibration lab test is created to verify this assumption and to validate the new design.

No mean stress

With mean stress correction
Lab Validation
Lab Validation
Lab Validation

Lab run time: 6 hours

Red contour: 2 hours
Lab Validation: Bolt Preload
Lab Validation: New Design

New design tested to 40 hours without failure.
Old design went 6 hours to failure.
Thank you!