Fatigue Damage Spectrum Analysis of Vibration Data for Ranking Durability Schedules

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The Electric Drive Component Development & Validation group is dedicated to supporting vehicle launch excellence. As a team, we apply accelerated testing techniques for robust product development and validation of high-voltage power electronics. All testing is customer damage-based, mathematically modeled, and empirically supported.
Road Load Data Acquisition (RLDA) was performed on a test vehicle instrumented with accelerometers. The vehicle was exposed to various road surface inputs to measure vibrational input into a transmission-mounted motor.

Need to reproduce component failure by repeating drive schedules.

Use accelerometer time history data from vibrational input into the motor to determine which drive schedules inflict the most potential damage in the shortest amount of time to reproduce this failure.

What metrics can be used to compare the potential fatigue damage severity due to vibration for these durability drive schedules?
Metrics for Comparing Durability Drive Schedule Severity

- **RMS acceleration from time series data (gRMS)**
  - Single, calculated **absolute** value
    - 1 gRMS vs. 8 gRMS
  - Not directly related to fatigue damage content
    - gRMS calculated directly from acceleration time history

- **Damage sum across Fatigue Damage Spectrum (ΣFDS) *Smithson**
  - Single, calculated **relative** value
    - 1.0 x $10^{-5}$ vs. 1.0 x $10^{-14}$
  - More directly related to fatigue damage content
    - Fatigue Damage Spectrum calculated using double integral of acceleration (displacement)
    - Presents a worst-case scenario by assuming natural frequencies at all frequencies of interest (e.g. 10-2000 Hz) and adding up the points along this curve
Using nCode GlyphWorks for RMS Acceleration

1. All acceleration time histories are input into the flow.
2. The RMS acceleration is calculated for each signal using the Statistics glyph.
The calculated RMS acceleration for each drive schedule was normalized to the maximum value.

Drive schedule 26 had the highest gRMS level.

Based on this metric, we would select and repeat drive schedule 26.
Using nCode GlyphWorks for Fatigue Damage Spectrum

1. All acceleration time histories are input into the flow.
2. The Fatigue Damage Spectrum is calculated using the Shock Response Spectrum glyph (assuming material property coefficients).
3. The damage sum is calculated after exporting FDS from nCode.
The calculated damage sums for each drive schedule were normalized to the maximum value.

In this case, drive schedule 30 had the greatest damage sum.

All other drive schedules had significantly lower damage sums (≤ 50%)

Based on this metric, we would select and repeat drive schedule 30.
Both methods distinguish two different drive schedules with the “highest severity.”

Why do these methods produce different results?

Diagram: Normalized RMS Acceleration and Damage Sum in Vertical Axis

- Drive Schedule
- Normalized RMS Acceleration
- Normalized Damage Sum

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Comparing Methods with Normalized Results

- Schedule 26 has low-frequency FDS content several orders of magnitude higher than Schedule 30.
- Schedule 30 has more high-frequency PSD content than Schedule 26.
- Since we are more interested in the fatigue damage content, we would select and repeat Schedule 26.
References

*Steve Smithson
President-Smithson & Associates since 1983
BSME-University of Michigan
MBA-Arizona State University
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Representing:
  • Vibration Research
  • ETS Solutions
  • Vibration & Shock Technologies
  • TUV SUD Equipment Solutions
  • Instrumented Sensor Technologies