Analysis of Passive Vibration Measurement and Data Interrogation Issues in Health Monitoring of a HMMWV Using a Dynamic Simulation Model

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Report Documentation Page

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Motivation

HMMWV comes in over a dozen variants:

- Some heavier than others;
- Variation in loading;
  - Durability of suspension,
  - Frame and cross members.

- A method is desirable through which passive vibration response is used to detect faults.
Issues

Issues with using vibration for fault detection:

- Which frequency range?
- Sensors, how many and where to place?
- Damage variety (suspension, frame, etc.).
- Non-stationary excitation due to terrain:
  - L/R wheels in phase,
  - L/R wheels out of phase,
  - Must identify operating regime first.
- Variability from vehicle-to-vehicle.
Approach

87 degree of freedom dynamic model:

\[
[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{f\}
\]

- x and z forcing functions;
- Free response analysis:
  \[
  [M]^{-1}[K]\{X\} = \lambda \{X\}
  \]
- Force response analysis:
  \[
  \frac{d}{dt}\begin{bmatrix} \{x\} \\ \{\dot{x}\} \end{bmatrix} =\begin{bmatrix} 0 & I \\ -[M]^{-1}[K] & -[M]^{-1}[C] \end{bmatrix}\begin{bmatrix} \{x\} \\ \{\dot{x}\} \end{bmatrix} + \begin{bmatrix} 0 \\ [M]^{-1} \end{bmatrix}\{f\}
  \]
  \[
  = [A]\begin{bmatrix} \{x\} \\ \{\dot{x}\} \end{bmatrix} + [B]\{u\}
  \]
Results (Free Response)

Suspension, cross member, and frame damage:

- Low, high, and broad frequency changes,
- 40-50% damage results in 10% variation.
Results (Free Response)

Modal deflection shapes show that:
- Sensors on F/R cross members are optimal,
- Sensors on wheel are suboptimal (filtering).
Results (Force response)

Faults in suspension, frame, cross members are:

• detected in different frequency ranges;
• best detected for certain terrains (modes).
Technical Barrier

HMMWV forced response varies significantly:

- Without regime recognition, fault detection is difficult using conventional methods.

Excessive variation!
Proposed Approach

Method to control vibration input for diagnosis:

• Timing, and
• diagnostic cleats.

• “Weigh station” approach will target certain faults.
Experimental Setup

Pickup truck with 2 vertical accelerometers:
• F/R control arm and F/R frame.
Experimental Results

Sway bar link loosened to 400, 200, 0 lb-in:

• Low freq insensitive to fault;
• Both sensors sensitive from 2.6-3.9 kHz.
Conclusions

Fault detection using vibration data is feasible:

• Free response (modal) changes depend on frequency range;
• Forced response changes depend on regime;
• To control variability in fault indicators, diagnostic cleat approach is proposed;
• Experiments indicate fault in stabilizer bar link can be detected amidst variability in data.