Tools for Integration of Analysis and Testing

SAE 2003-01-1606

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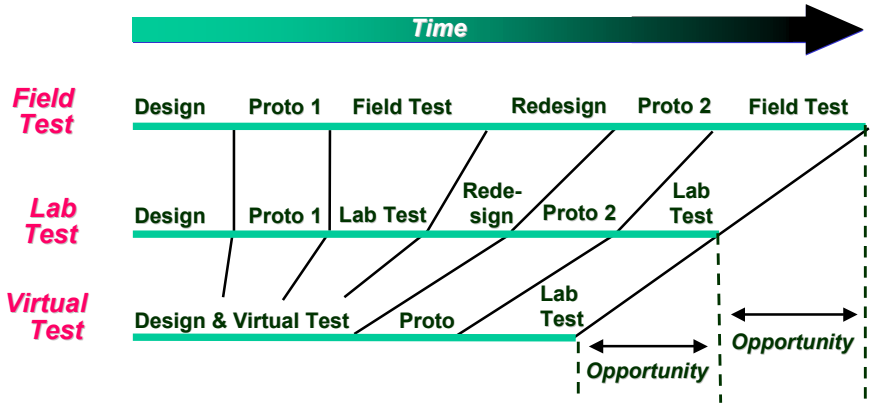
SAE Traverse City, May 5-8, 2003

Product Development Cycle



Opportunity = Lower Development Cost = Shorter Development Time

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Virtual Component Test to Obtain Loads

Collect data on physical prototype or a similar product and perform Virtual Test (simulate the durability test) that can be validated with Physical Test

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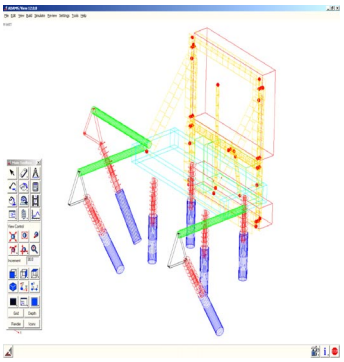
Virtual Component Test

Advantages

- Can Be Conducted at Very Early Design Stage, Including Design Iterations
- Can Determine Loads and Boundary Conditions
- Allows to Optimize Subsequent Physical Test Program Prior to Start of Tests



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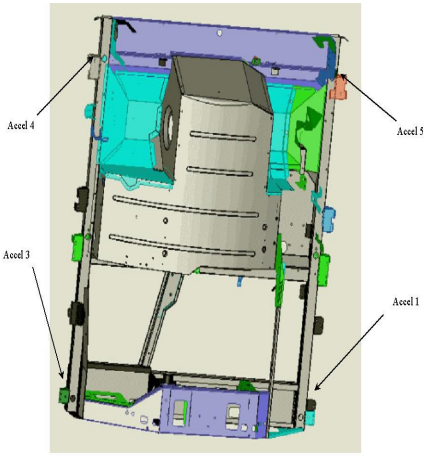
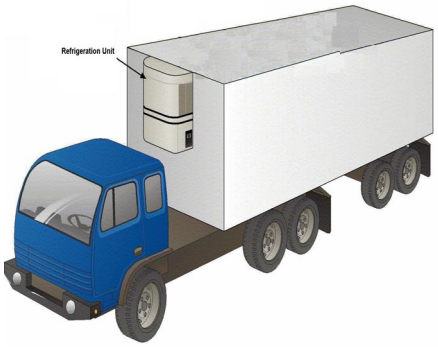
Road "Load" Data Acquisition





Instrumentation: four tri-axial accelerometers

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Road "Load" Data Acquisition

- Five road surfaces with loaded and un-loaded conditions
- A combination of the road surfaces formed a test block which corresponds to certain kilometers of real usage
- Lab test simply repeats the test block
- The durability test simulates 3,000,000 kilometers of real usage

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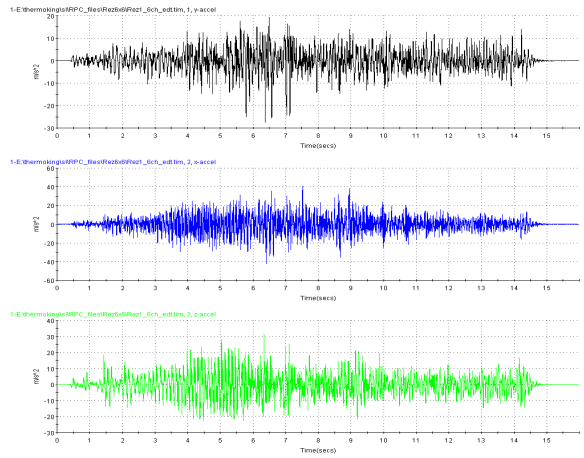
Road "Load" Data Acquisition



Acceleration signal of number 1 accelerometer of one surface.
Top chart: Lateral Direction
Middle Chart: Longitudinal Direction
Bottom Chart: Vertical Direction

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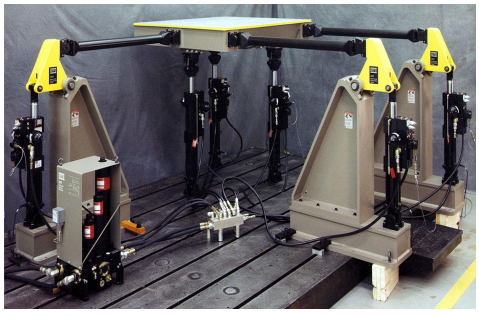
Physical Test

1. **Multi axis shaker table was employed**
2. **Iterative approach was used to reproduce the measured acceleration**



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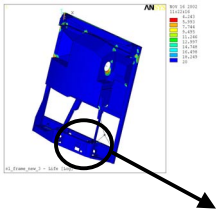
Snubber Mount Failure



Picture taken at about 10,070 test blocks

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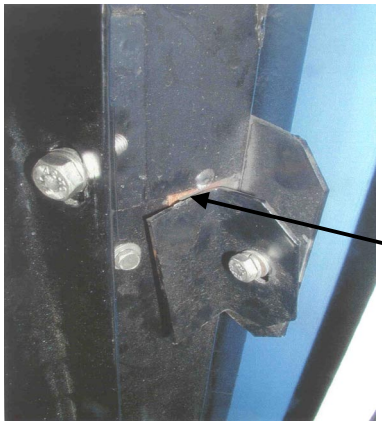
Front Right Bracket Failure



Picture taken at about 10,070 test blocks

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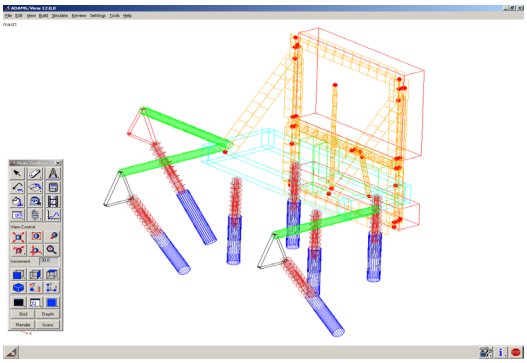
Test Rig Model

1. **The ADAMS model was a direct representation of the physical testing system**
2. **Flexibility of the specimen and the fixture was modeled by beam elements**



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Road "Load" Simulation Test

- Reproduction of measured events
- Industry standard process
- Iterative approach due to non-linear response
- Virtual Test Rig Is MAST Table With 6 DOF
- 6 Drive Channels As Actuator Displacements
- 6 Accelerometer Measurements as Desired

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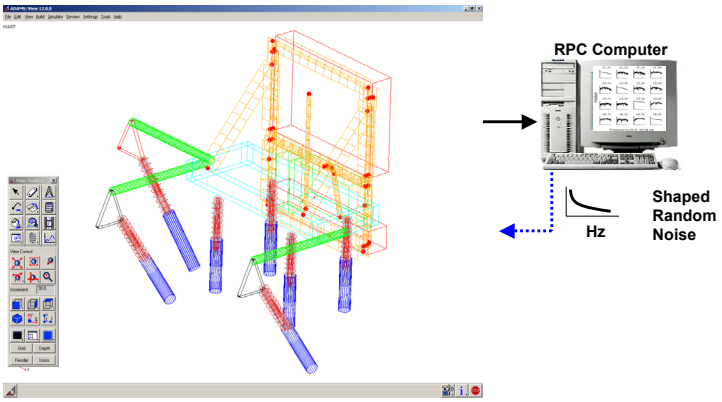
FRF Calculation of RPC



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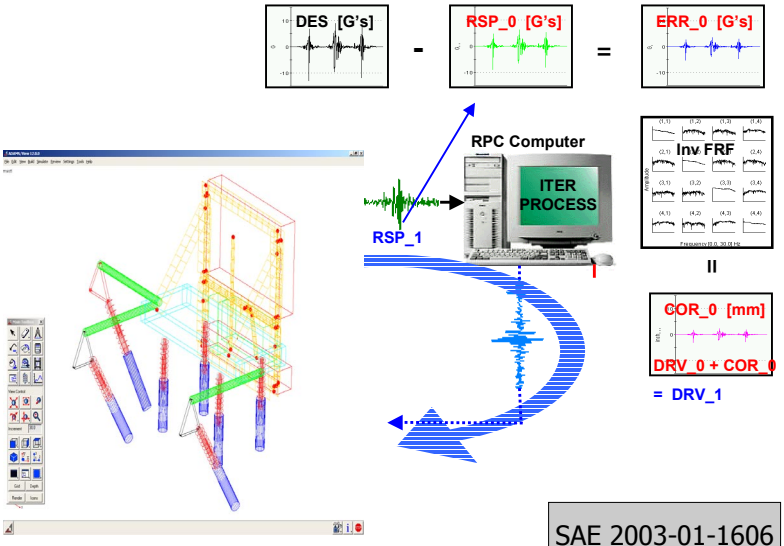
Iterations within RPC



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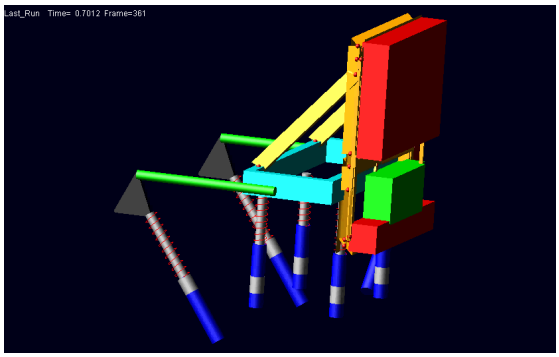
Drive File Generation

- Two Iterations Were Conducted
- Close Agreement Between Desired and Achieved Acceleration Signals Was Achieved



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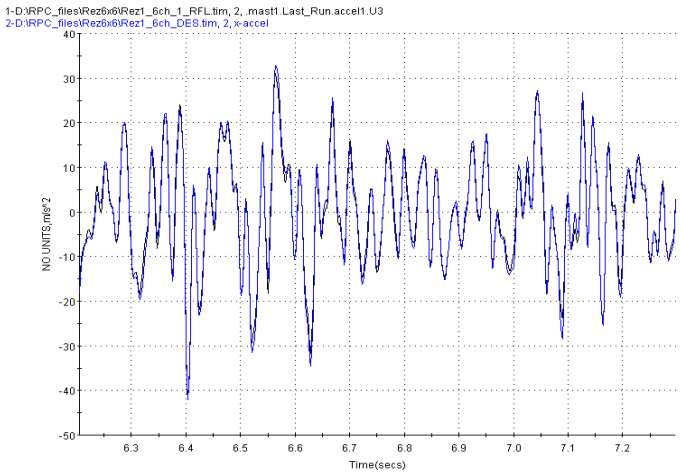
Iteration Result



Desired vs. achieved acceleration signals of number 1 accelerometer in longitudinal direction of one event

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Load Output

- After successful reproduction of acceleration profiles, resulting loads onto the frame were exported
- There were a total of 63 output load channels (10 points with 6 DOF, 3 points with 1 DOF).

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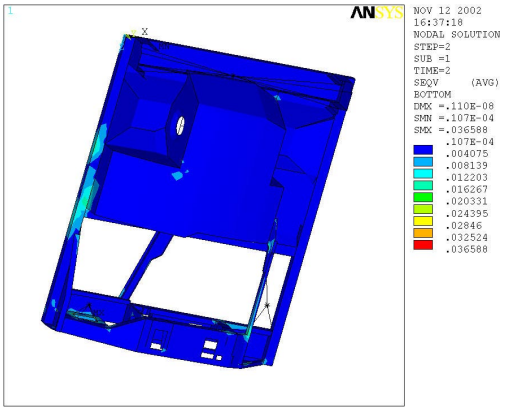
Stress Analysis for Subsequent Fatigue Analysis

- 63 load cases corresponding to 63 load components
- Unit load in each load case
- Inertial relief calculations was conducted
- 63 sets of stress distribution result obtained



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Life Prediction

- Fatigue software was used
- Strain life prediction method was conducted
- Material was assigned

Sixty-three loads from multi-body dynamic model

Combined with

Sixty-three sets of stress distributions from FE model

→ **Fatigue Analysis Software** → **Fatigue life plot**

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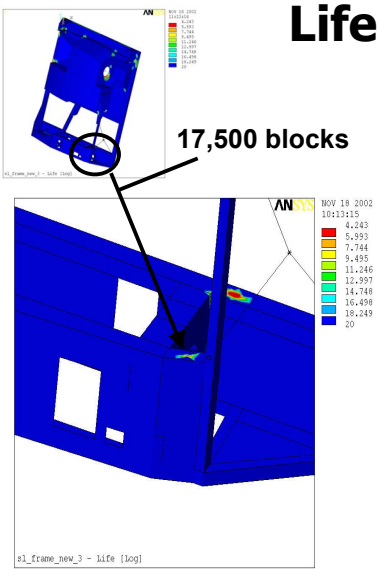
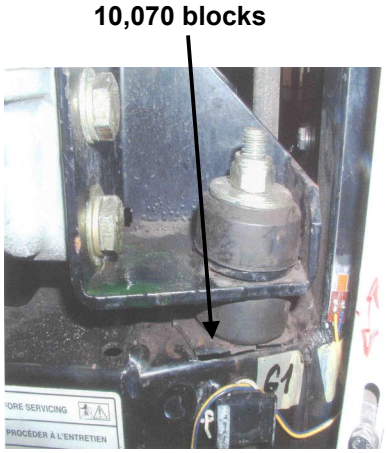
Life Prediction





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Conclusion

- Predicted failure location matches the lab test observation.
- Fatigue life of virtual test = 17,500 blocks
- Fatigue life of lab test = 10,070 blocks
- Ratio between virtual and physical fatigue life is 1.74, which is an excellent match
- The front right bracket were not predicted because the component was not modeled.
- Virtual test cannot replace physical test.

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Possible NVH Applications

- Prediction, and comparison to measured results, of sound power emitted from the structure.
  - Excellent fatigue prediction validates the models
  - The FE model provides input for acoustic model
  - Sound power emission of the refrigeration unit can be predicted by the acoustic analysis
  - Subsequent analysis can predict sound characteristics
  - What if type of analysis can be conducted to evaluate options to insulate the system.

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Summary

- Virtual testing is capable of predicting fatigue life and failure mode
- Virtual testing can evaluate the design early in development
- Virtual component tests can simplify the modeling process significantly
- Component loads can be obtained by virtual tests
- Virtual test should be validated by physical test

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