Strategic Smart Testing for NVH Development on the CNH Quadtrac Tractor

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Breaking New Ground
Innovation Sustainability Productivity

KEY FIGURES

1
COMPANY

9
BRANDS

$19.8B
CONSOLIDATED REVENUES

35,000+
FULL-TIME EMPLOYEES

40
PLANTS

49
R&D CENTERS

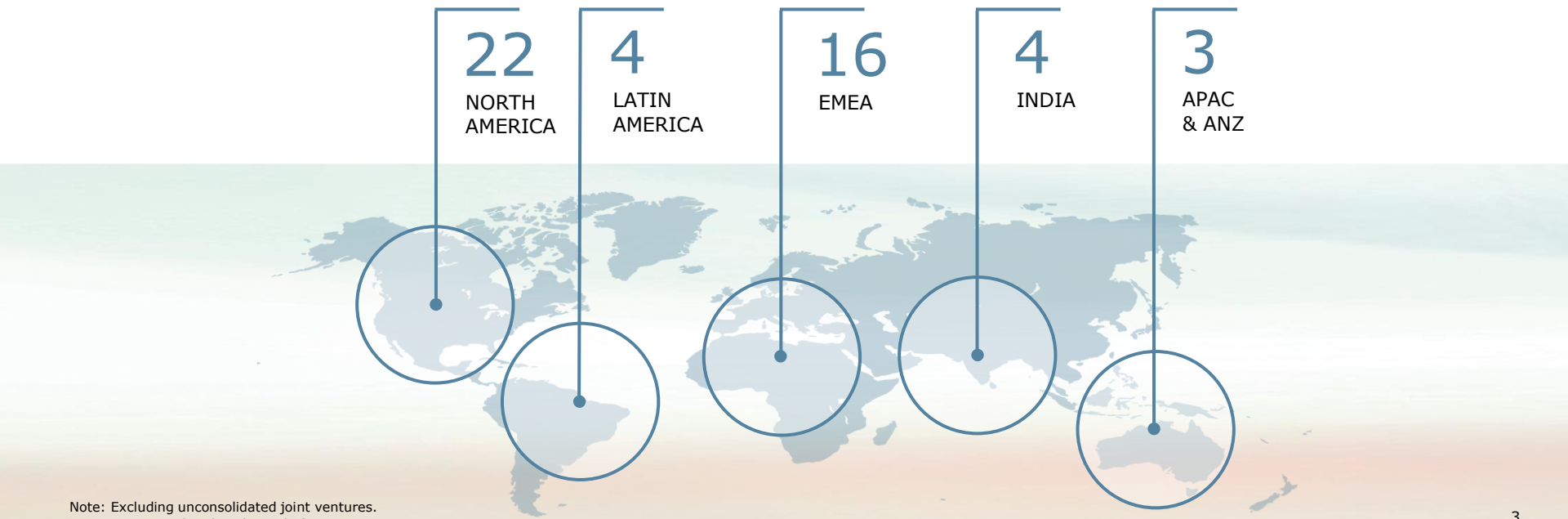
~11,000
REGISTERED PATENTS

~170
COUNTRIES WITH OUR COMMERCIAL PRESENCE

Note: figures are on a US GAAP $ basis and updated at the end of 2024 as per Company's 10-K Report.

INDUSTRIAL **FOOTPRINT**

49
R&D FACILITIES



Note: Excluding unconsolidated joint ventures.
Locations are updated at the end of 2024.

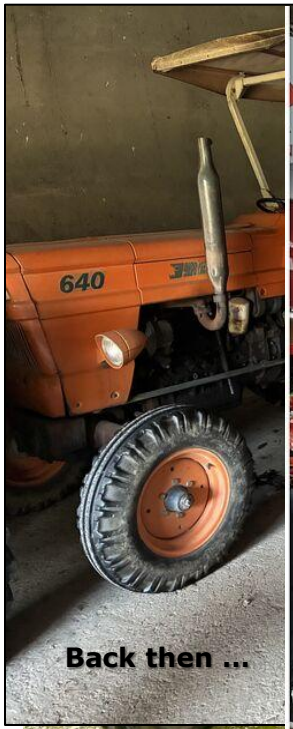
Abstract

- This presentation shows how physical testing and simulation can be strategically combined to support NVH development across the product lifecycle. Several cases of smart applications will be presented

- Focusing on a project dedicated to the CNH Quadtrac tractor vehicle; it highlights how TPA and related test methods can identify key contributing paths, support countermeasure development, guide target setting, and provide evidence for design changes.

- The work demonstrates a practical Smart Testing approach in which physical data and simulator-based evaluation are used together to improve engineering decisions and accelerate development.

AG Machines overview

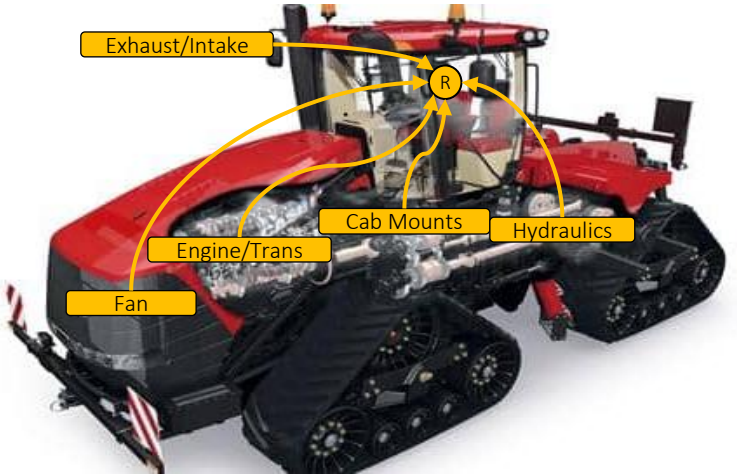


Background & Motivations

- Facing similar challenges as other industries with the reduction of development cycle durations and minimization of prototypes.
- Historically, noise and vibration have been largely managed via evaluation of physical prototypes, with resulting development of countermeasures to achieve program targets.
  - Strong push recently for proactive performance achievement via analytical models, both physical and virtual based.
- In collaboration with HBK, a full noise and vibration path contribution study was performed to develop a simulation model to aid product development activities.
  - Airborne and structure-borne paths
  - Focused on key sub-systems: hydraulic systems, powertrain components, cab connection, etc.

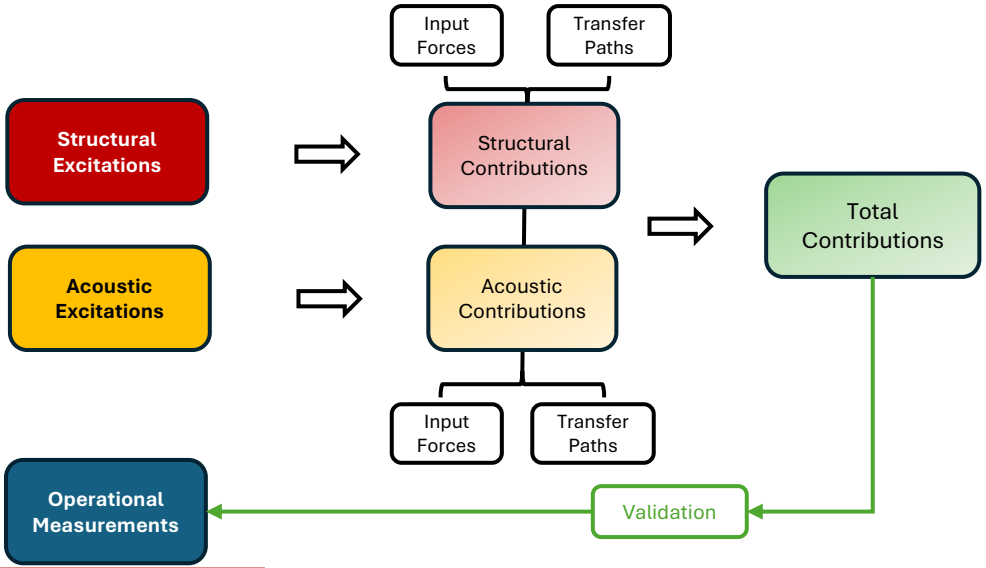
What was done: TPA

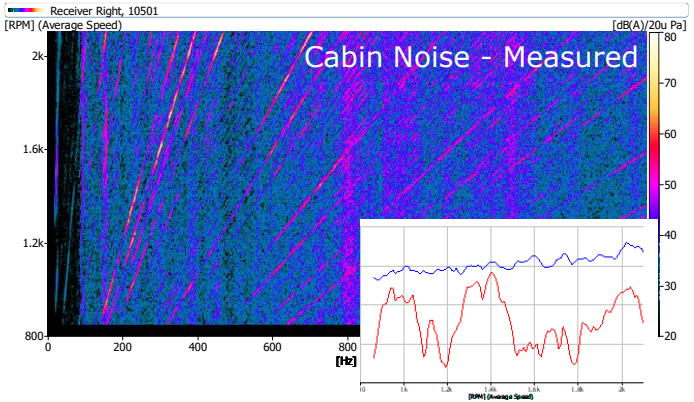
- Development program chosen that historically had noise levels that required troubleshooting and countermeasures.
- To develop the analytical model, a transfer path analysis study was conducted
  - Included key airborne systems:
    - Pumps, hydraulic components, powertrain
  - Included structure-borne paths, in two ways:
    - ~10 structural inputs into the cab
    - ~20 structural inputs into the frame from hydraulic and other systems
- Considering structural forces both into the frame and into the cab provides unique insights into development opportunities:
  - Related to the system sources (hydraulic connections, etc.).
  - Related to the cab suspension and mounting system

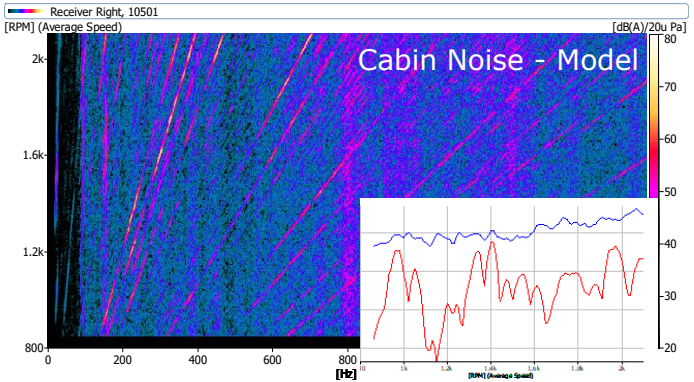


The results

- Correlated model providing insight into the key sources and paths of structure-borne and airborne energy affecting the customer.
  - Input forces at each source location
  - Transfer functions from each source to the operator
  - Contribution shares between structure-borne and airborne

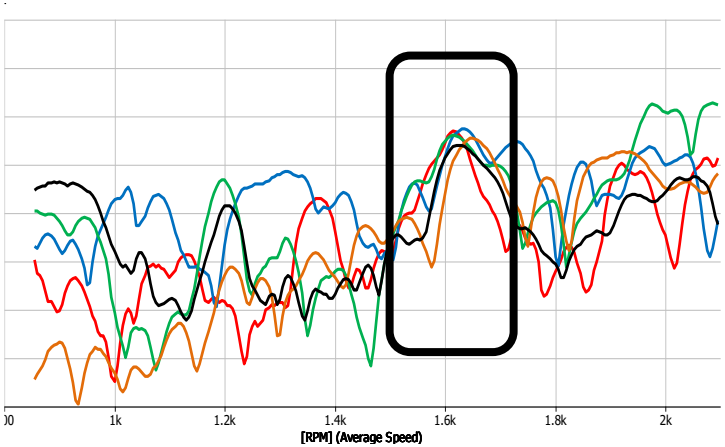


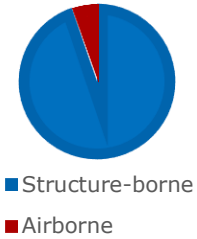


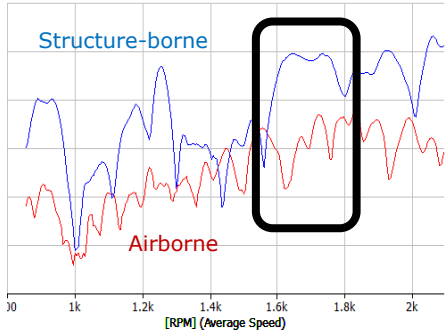


How it was utilized – Focused Development Efforts

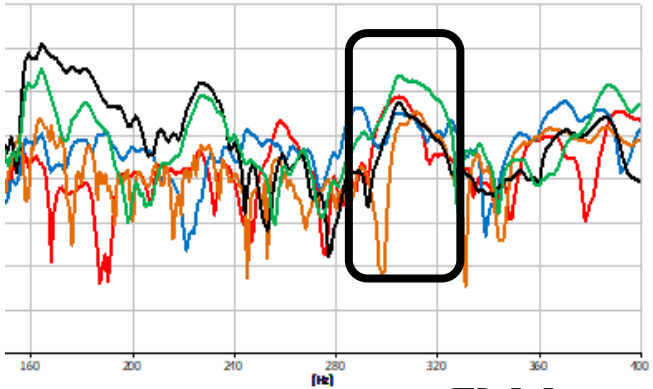
We were able to confirm structure-borne vs. airborne contributions







Identified key contributing energy paths through the frame

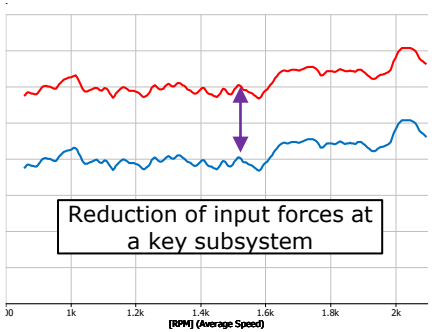


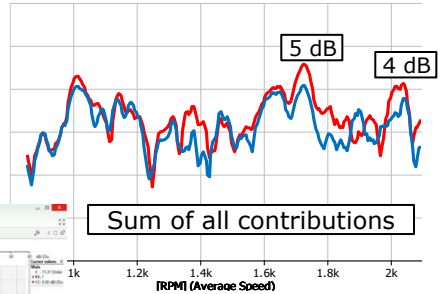
Acknowledge a resonance contributing to cabin noise.

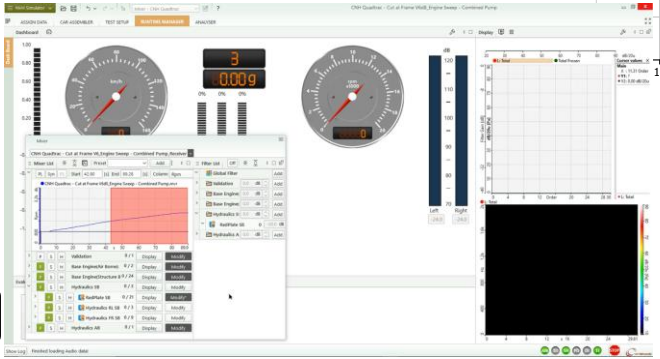
Insight = Focused Development Efforts

How it was utilized – What-if-studies

- Utilize the model to determine effects at the operator position due to the addition of **an isolation layer for a key subsystem**.
- Input forces into the frame were modified virtually.
- Able to understand the effects to the total sum of contributions.
- NVH Simulator was utilized for back-to-back playback and listening studies.
- Determine if the changes would affect the subjective operator experience.



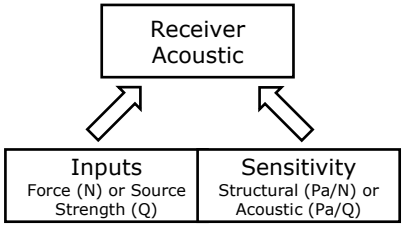


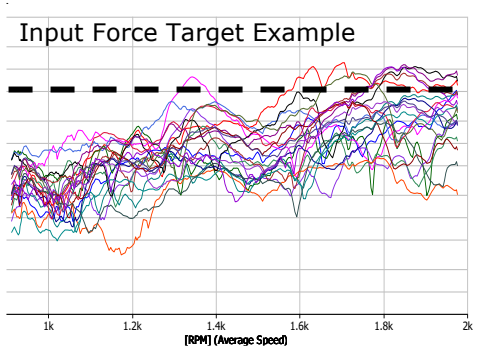


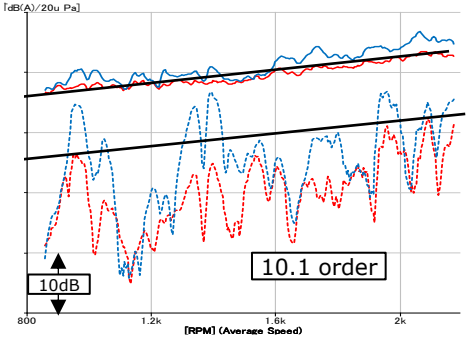
Justify engineering efforts with data

How it was utilized – Target Setting

- Cascade operator acoustic targets down to key components and systems utilizing the NVH Simulator model.
- Consider targets for both input forces and path sensitivities.
  - What are the most efficient ways to make improvements?
- Utilize NVH Simulator software
  - Create digital filters (force and transfer functions)
  - Assess objective data
  - Perform listening studies to confirm



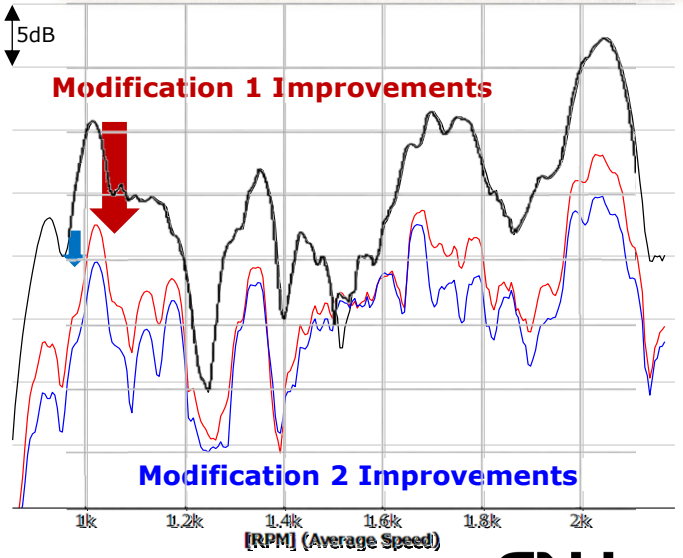




Data-based recommendations for component and system targets

How it was utilized – Suspension Design Direction Study

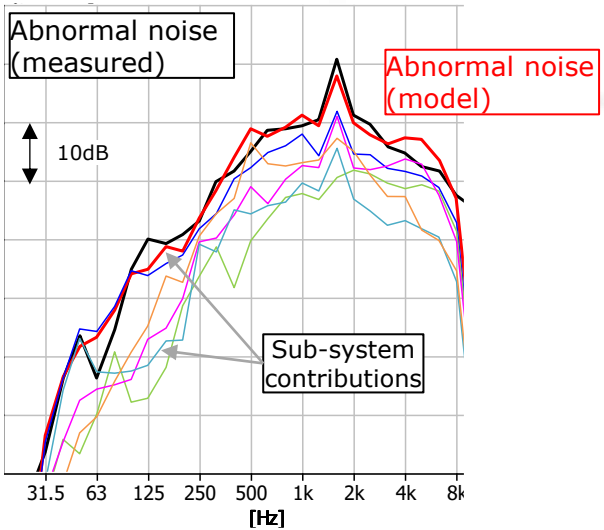
- NVH Simulator model to determine improvements from various cab suspension isolation designs.
- Modifications to forces into the cab to simulate various isolation strategies.
- Quantified improvements at the operator position for Modification 1. Able to confirm via listening studies.
- Minimal improvements with Modification 2.
  - Focus elsewhere if additional improvements are needed.



Identified point of diminishing returns for modifications to this system

How it was utilized – Pass-by Source Identification

- Troubleshooting an exterior abnormal noise
- Performed a path analysis study to identify the key contributions
  - Input forces
  - Transfer functions to exterior
- Identified the key sub-system contributing to the exterior noise.
  - Able to determined the improvements necessary to resolve the issue.



Identify root cause and target levels for acceptable performance.

Overview Summary

How did CNH benefit from, or utilize, physical testing alongside analytical predictions?

- CNH has successfully used targets recommended from HBK test-based analytical models in the design and virtual validation processes to improve chances of success when confirming the improvements on the full vehicle.

In what ways has the cooperation with HBK helped?

- Biggest benefits realized with clear recommendations of sources or paths in need of further investigation or improvements.
- HBK modeling and what-if analysis has driven the NVH improvement roadmap strategy
- Sensitivity studies provide clear indications of improvement ideas and expected outcomes which help secure project funding by improving management's confidence in investment outcomes.

What is the direction CNH is heading with development? Reliance on analytical models for development and physical testing for validation (the ideal case)? Or a different split in this balance?

- CNH is currently evolving from reactive to reliance on test-based analytical models with further evolution into simulation based analytical models correlated with physical testing.

Many thanks for your attention!