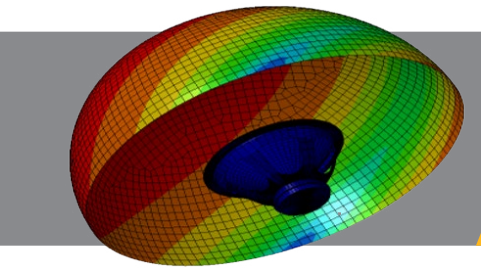
Engineering the Future of NVH: *Driving Innovation with Ansys Solutions*

Content

The Journey of NVH: From Afterthought to Key Focus

In an era defined by fierce market competition, Noise, Vibration, and Harshness (NVH) has evolved from a secondary concern into a defining factor in product quality across industries like automotive, aerospace, heavy machinery and consumer electronics. The push for smoother operation, improved comfort and increasingly stringent environmental regulations has made NVH a crucial focus for engineers and manufacturers alike.

Once overshadowed by factors such as performance and durability, NVH is now considered integral to superior engineering. A quiet, refined experience is regarded as a hallmark of high-quality design, directly enhancing brand perception and building consumer trust. Manufacturers, particularly in the luxury segment, leverage superior NVH performance as a key differentiator to stand out in the market.[1]



79% ***of consumers cite product quality as critical to trust in a brand.[2]***

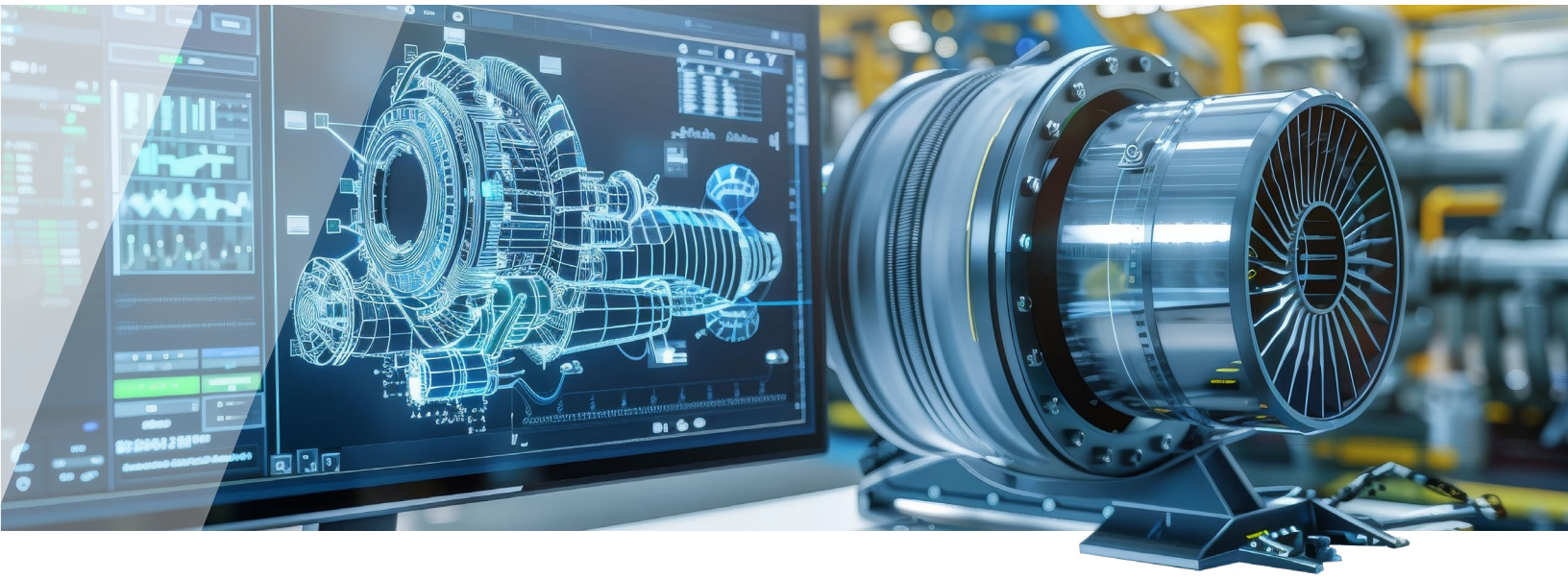
A prime example of how NVH performance reshaped an industry is Bose's introduction of noise-cancelling technology, which revolutionized the headphone market. In 1978, during a flight to Switzerland, Dr. Amar Bose, frustrated by the engine noise overpowering his music, began sketching designs for noise-canceling headphones on a napkin.[3] This breakthrough would become a defining feature for Bose and reshape the entire audio industry as competitors followed suit. Today, noise cancellation is a key selling point in premium headphones, much like NVH performance in other sectors.

As consumers increasingly prioritize sustainability, durability and repairability have become major factors in purchasing decisions.[4] This reflects the growing preference for long-lasting products that reduce waste.

Quiet, seamless operation not only enhances perceptions of reliability and quality but also reduces wear and tear, directly contributing to longer product lifespans.

As consumers increasingly expect high performance to go hand in hand with sustainability, these factors have become essential for brand success.

This e-book explores the current landscape of NVH engineering, diving into the latest practices and emerging trends, as well as outlining the critical factors that define superior NVH performance. From the role of physical testing to the integration advanced simulation tools, each section offers key insights to help engineers navigate the growing complexity of NVH challenges while delivering innovative, high-quality solutions.



Current Approaches to NVH: Progress and Practices

In the past, NVH testing was reactive, performed late in development and heavily reliant on physical prototypes. These prototypes[5], which were costly and time-intensive to produce, underwent extensive testing to detect noise, vibration, and harshness issues. However, problems often surfaced too late in the product lifecycle, leading to expensive redesigns, delays and limited capacity for broad testing under varied conditions.

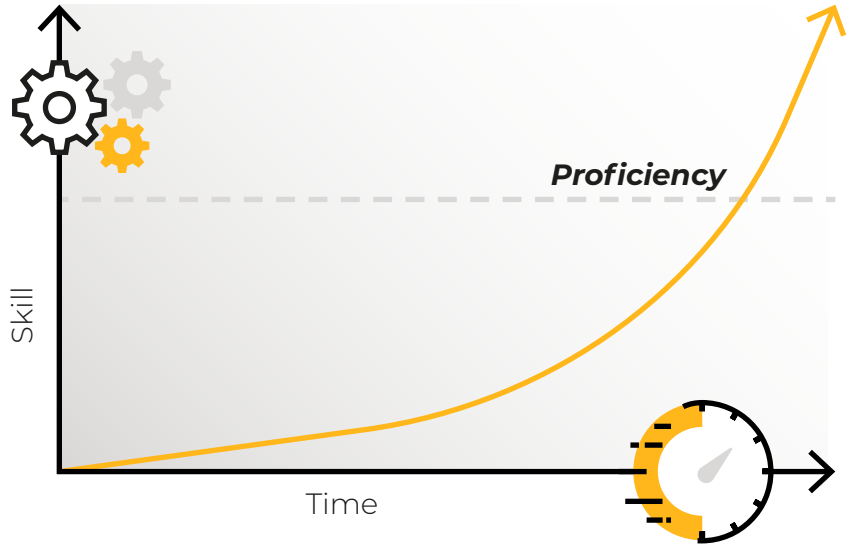
Today, simulation software, predictive modeling, and data analytics are central to NVH assessment, enabling engineers to address noise and vibration concerns early in the design phase, long before physical prototypes are created. This proactive approach reduces the need for late-stage testing and lowers development costs. Yet, despite these digital advancements, integrating multiple platforms across engineering teams remains challenging. Different tools often lack compatibility and standardization, creating isolated data that prevents collaboration and underscores the need for unified platforms to centralize NVH data.

Simulation models provide valuable insights during the early design stages – however, real-world validation remains essential to ensure accuracy. Physical testing is needed to align virtual predictions with actual performance, delivering a reliable NVH assessment. This hybrid approach, merging virtual modeling with real-world testing, requires efficient data management as physical tests produce large volumes of data that are challenging to analyze.

Resource demands add further complexity to NVH testing, requiring expensive equipment, precise procedures and iterative analyses, making it both time and budget-intensive. While early-stage NVH integration has improved issue detection, some challenges persist, often emerging late in development and triggering costly redesigns. Engineers are frequently forced to balance quality with production timelines, underscoring the need for efficient, integrated tools.

Figure 1

State of Simulation Today:
High Barrier of Entry for New Users

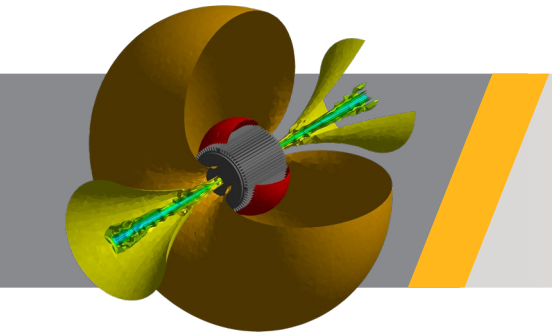


To address these challenges, NVH engineers are turning to sophisticated digital solutions and centralized data-sharing platforms that streamline workflows and support cross-functional collaboration. Advanced tools designed for compatibility and standardization help eliminate data silos, unifying NVH insights across teams. By combining powerful simulation with selective physical testing, these solutions allow for agile adjustments, reduce late-stage redesigns and optimize resources across the development process.

Emerging Industry Trends and Their Impact on NVH

As industries increasingly shift toward sustainable technologies, electrification is reshaping NVH engineering by introducing new and complex challenges. This transition requires a fresh approach to NVH strategies, demanding innovation to ensure comfort, safety and performance in systems that are quieter yet more intricate.

Electric vehicles (EVs) exemplify these changes. The absence of traditional engine noise creates a quieter cabin but amplifies other sounds, such as high-frequency motor whine and cooling system noise, particularly noticeable at low speeds. Additionally, the weight of lithium-ion batteries affects weight distribution and NVH dynamics. To balance this, engineers often use lightweight materials, which can introduce structural vibrations, adding further complexity to NVH management.



Beyond the automotive sector, electrification is impacting aerospace, railways, renewable energy, home appliances and industrial machinery.

The integration of electric motors and embedded systems in these industries leads to intricate interactions with mechanical assembly imperfections, rotor aerodynamics, and electromagnetic forces contributing to increased vibration and noise. These interactions, governed by nonlinear coupled physics regulating the magnetic and structural behavior of these systems, require multiphysics simulations and robust testing to accurately predict and control acoustic behavior.

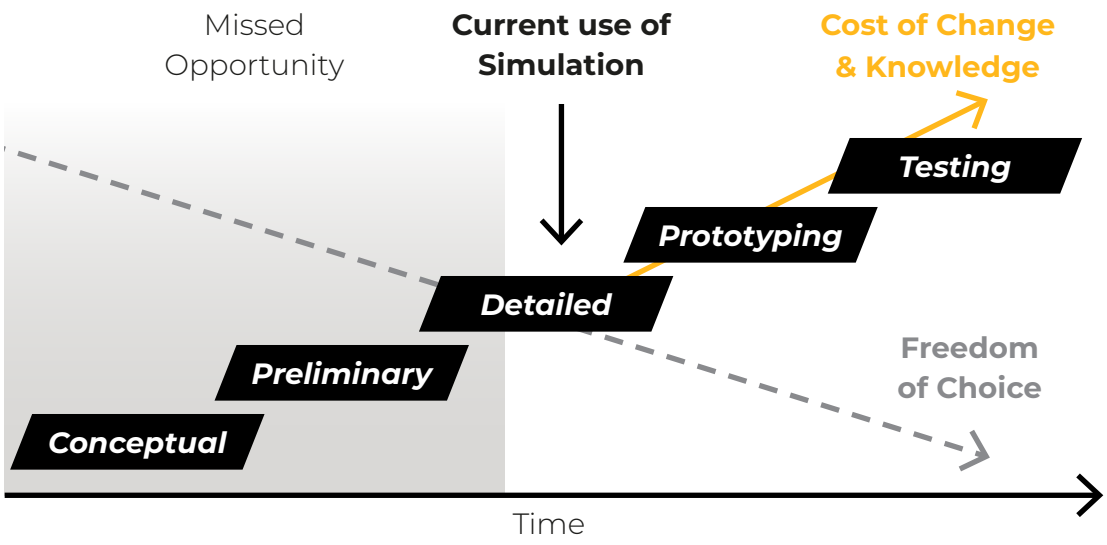
In parallel, regulatory demands across industries are driving thorough NVH testing to ensure products meet stringent safety, environmental and performance standards. Compliance with noise and vibration regulations is essential for market access and avoiding penalties. In sectors like construction and manufacturing, where equipment noise impacts worker safety and public health, meeting NVH standards is vital. Many countries enforce industrial noise regulations to mitigate its harmful effects on hearing and well-being. For example, the European Union's noise emission limits underscore the importance of environmental noise management for public health and market viability.

Incorporating these evolving priorities and using specialized NVH tools and simulations empowers engineers to address NVH challenges with greater precision. As electrification, regulatory demands and innovation reshape industry expectations, a comprehensive approach with advanced NVH solutions ensures that products meet performance goals while delivering optimal comfort, safety and compliance across increasingly complex systems.

Product Development Priorities for Superior NVH Performance

As the importance of NVH in product design grows, engineers face new challenges in analysis and testing. To achieve superior NVH performance, it's critical to integrate key priorities into the product development process.

Figure 2
State of Simulation Today



The key priorities driving superior NVH performance include:

Early Integration of NVH Analysis[5]

Integrating NVH considerations at the start of the design process is crucial for minimizing costly redesigns. By identifying these potential problems early, engineers can implement solutions proactively, streamlining the development process and enhancing overall product performance.[6]

Advanced Simulation and Testing

Simulation tools are essential for creating virtual prototypes that enable comprehensive NVH analysis. This reduces reliance on physical models and allows engineers to optimize performance across different domains, including acoustics, aerodynamics and structural dynamics.[7]

Holistic Design Approach

Collaboration across engineering, design and testing teams is crucial to ensure NVH performance at every level. By aligning NVH targets with overall design goals, engineers can establish that changes in one area don't negatively impact NVH in another.

Material Selection and Optimization

The rise of electrification has introduced new challenges related to lightweight materials and unwanted vibrations. Innovative damping techniques and smart materials are vital for managing these issues.

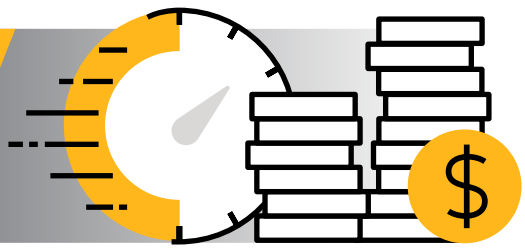
User-Centric NVH Solutions

By combining objective measurements with subjective evaluations, engineers can design personalized sound environments, such as adaptive noise cancellation systems to meet consumer preferences.[8]

Advantages of Simulation in NVH Analysis

Simulation technology has become essential in NVH analysis, providing engineers with efficient ways to address noise, vibration, and harshness challenges that can be costly to handle through traditional testing alone. By incorporating simulation early in the design process, teams can proactively identify and address NVH issues before physical prototypes are needed, leading to faster development and more precise designs.

One key advantage of simulation is its ability to reduce costs and shorten project timelines.



By virtually evaluating essential components, simulation can limit the need for multiple physical prototypes, helping to conserve resources and stay within budget. This approach also supports ongoing NVH refinement, allowing projects to progress without the resource-intensive adjustments that might otherwise be necessary.

Simulation provides a more comprehensive view of NVH performance by combining mechanical, electromagnetic and acoustic factors within a single model. This integrated approach helps prevent noise or vibration sources from being overlooked, supporting compliance with performance and regulatory standards. Engineers can therefore simulate different scenarios to identify potential issues that could remain unnoticed until physical testing, adding confidence to the process.

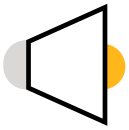
The flexibility of simulation further benefits engineers by enabling them to quickly test various materials, configurations and designs. This adaptability supports optimization efforts that balance NVH goals with other design requirements, making it easier to improve both functionality and user experience. Virtual testing also helps speed up the development of innovative solutions, allowing engineers to achieve optimal designs efficiently.

Key Features of Effective NVH Software Solutions

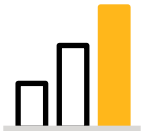
Effective NVH software solutions are essential for engineers addressing noise, vibration, and harshness challenges across diverse industries, supporting innovation and quality assurance throughout the entire product lifecycle. These tools improve performance, enhance user experience and ensure compliance with regulatory standards while keeping pace with technological advances. Key features include:

Multiphysics Integration
Robust NVH solutions integrate multiple domains—electromagnetic, mechanical and acoustic—necessary for accurate analysis in complex systems where noise and vibration stem from various factors, such as in electric vehicles or high-performance machinery.

Scalable Workflows
Scalable workflows tailored to each stage of product development are crucial. Early design phases benefit from fast, low-fidelity checks that help identify potential NVH issues efficiently. Cloud computing enables engineers to scale capacity during high-demand periods and facilitates seamless collaboration, accelerating complex analyses without delays.



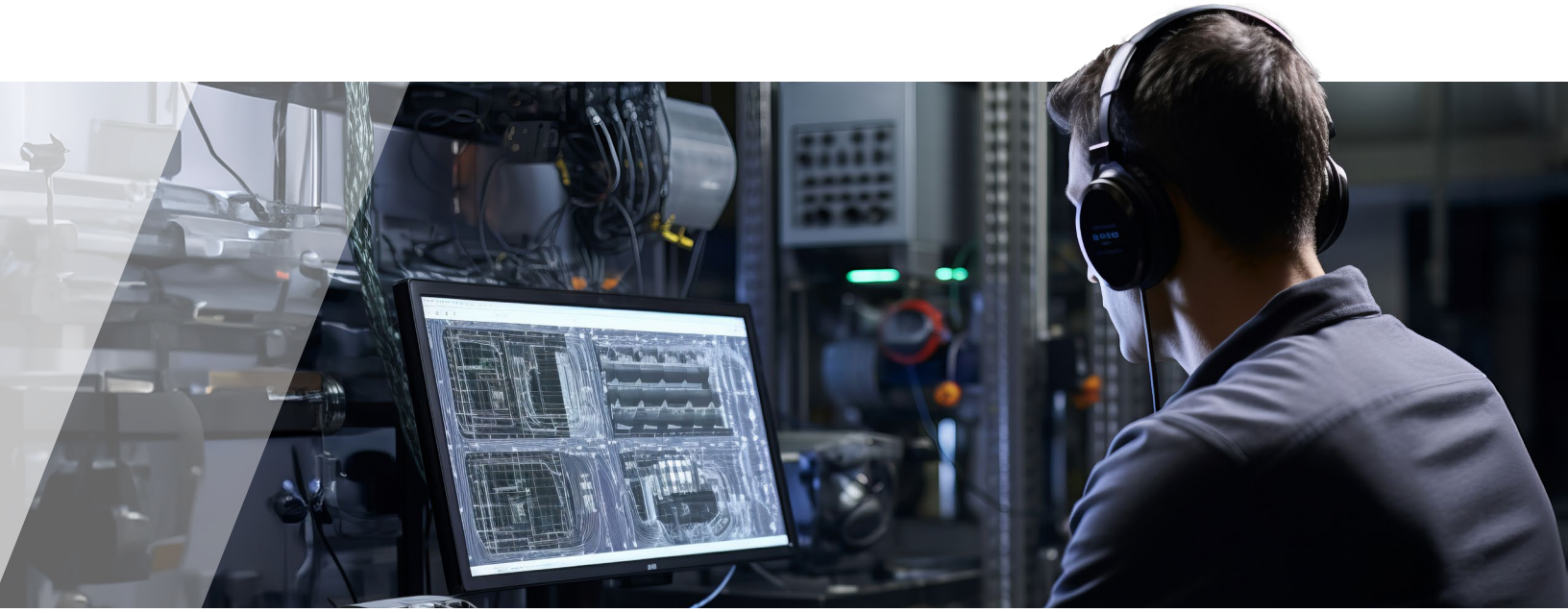
Comprehensive Modeling Capabilities
Advanced modeling tools simulate noise sources across systems—from electric motors to drivetrains—allowing for accurate analysis of electromagnetic, mechanical and aerodynamic noise. This helps engineers detect and mitigate issues early in the development cycle, ensuring refined performance.



Integration with Testing
Effective NVH solutions seamlessly integrate virtual simulations with real-world test data. Importing experimental data and aligning it with simulations enables accurate validation, improving reliability and allowing engineers to make informed design decisions based on comprehensive insights. Leveraging GPU-powered tools accelerates simulations[9], enabling efficient, detailed analysis and significantly reducing time for complex scenarios.

User-Friendly Interface
A streamlined, intuitive platform simplifies complex NVH analyses. Automated workflows reduce setup time and simplify processes, allowing engineers to focus on design rather than troubleshooting, ultimately enhancing productivity.

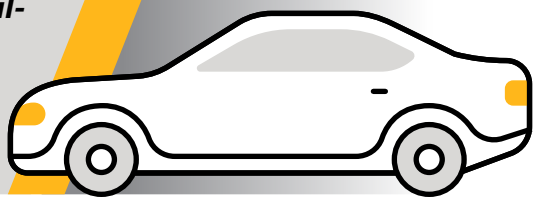
Optimization with AI and ML
AI and ML equip NVH tools with predictive insights, rapid testing, and optimized parameters, reducing simulation times and accelerating design iterations. By automating adjustments and analyzing past data, they provide accurate predictions, enabling engineers to explore broader design possibilities.



Integrating Physical Testing and Simulation for NVH Excellence

In NVH analysis, integrating physical testing with simulation has become essential for achieving accurate, reliable, and efficient assessments. While simulation offers early insights and reduces dependence on physical prototypes, physical testing is vital for validating these predictions under real-world conditions, providing a balanced and comprehensive approach.

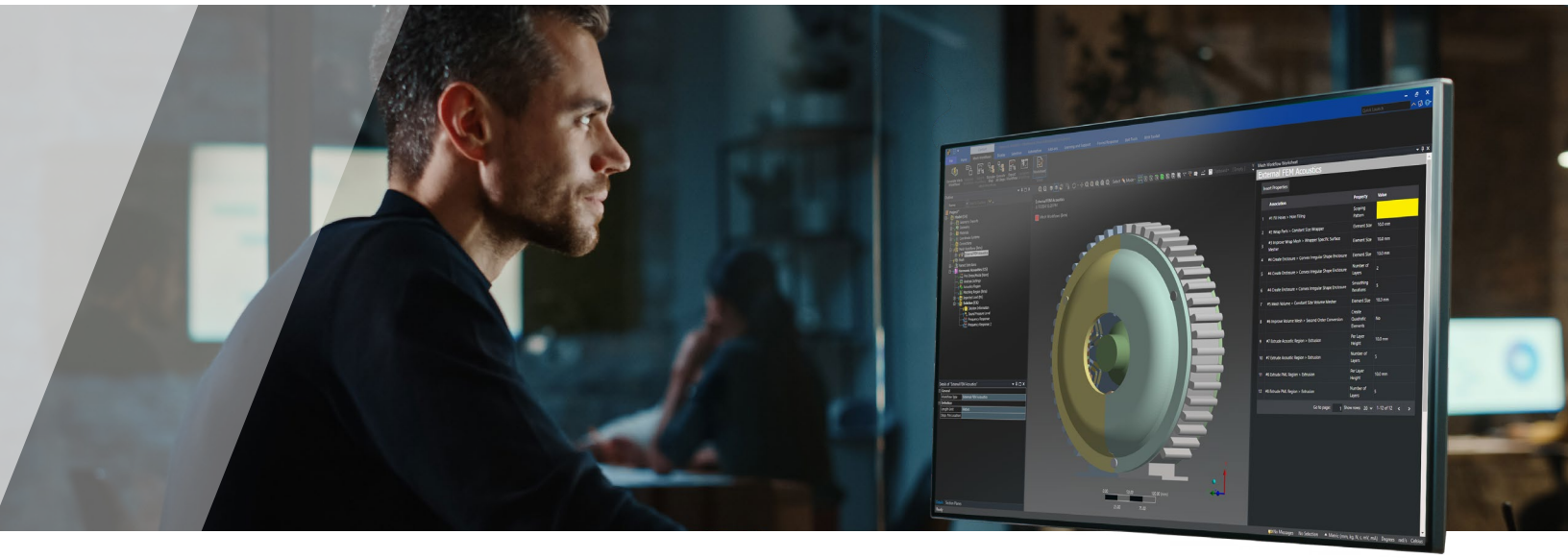
Physical testing provides indispensable real-world data to validate simulation models, allowing engineers to compare predictions with actual measurements.



This verification process identifies discrepancies, improves future simulations and leads to more reliable outcomes. Real-world tests, such as road trials across varied environments and speeds, reveal NVH characteristics often missed in virtual or lab settings, particularly important in electric vehicles where the lack of engine noise makes NVH issues more pronounced.

In addition to quantitative data, physical testing captures subjective feedback from users, helping engineers assess human perception of noise and vibration. These insights are critical for aligning NVH performance with customer comfort expectations. Physical tests can also uncover unforeseen issues, such as resonances or noises resulting from part interactions, which may not appear in simulation alone. Detecting these problems early helps reduce costly, late-stage adjustments, and supports compliance with regulatory noise and vibration standards, ensuring vehicles are certified for market entry.

Simulation complements physical testing by enabling detailed analysis of components like electric motors and vehicle structures in a virtual environment, minimizing reliance on physical prototypes and speeding up the development cycle. This reduces costs while allowing engineers to refine designs and address NVH concerns earlier. By integrating simulation with physical testing, engineers can fine-tune models to better reflect actual product behavior, creating an efficient and accurate NVH development process. Simulation guides early design decisions, while physical testing provides final validation, ensuring the product meets performance goals.



Optimizing NVH with Ansys: Solutions and Strategies

Ansys offers an end-to-end multiphysics simulation platform that allows engineers to optimize NVH performance with precision and efficiency. By connecting people, processes and data through an integrated digital thread, Ansys enables seamless simulation throughout the product testing process, identifying and resolving NVH issues early to reduce costly late-stage changes and speed up time to market.

With its comprehensive solutions, Ansys helps companies develop quieter, more efficient and sustainable products. It reduces development time and cuts validation efforts, all while ensuring product quality and regulatory compliance.

Ansys can help you achieve:

9×
reduction in development time

1,000×
faster validation

20%
reduction in operational costs

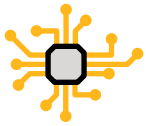
Key Features

Advanced & Automated Acoustics Meshing
Ansys Meshing offers automated meshing from structural geometry or mesh, creating acoustics mesh with minimal manual intervention.

Comprehensive Sound Analysis
Ansys Sound offers advanced post-processing, enabling engineers to visualize, analyze, and modify sound outputs for precise acoustic tuning.

Physical Test-Simulation Integration
By merging real-world test data with simulations, Ansys delivers highly accurate and reliable NVH results.

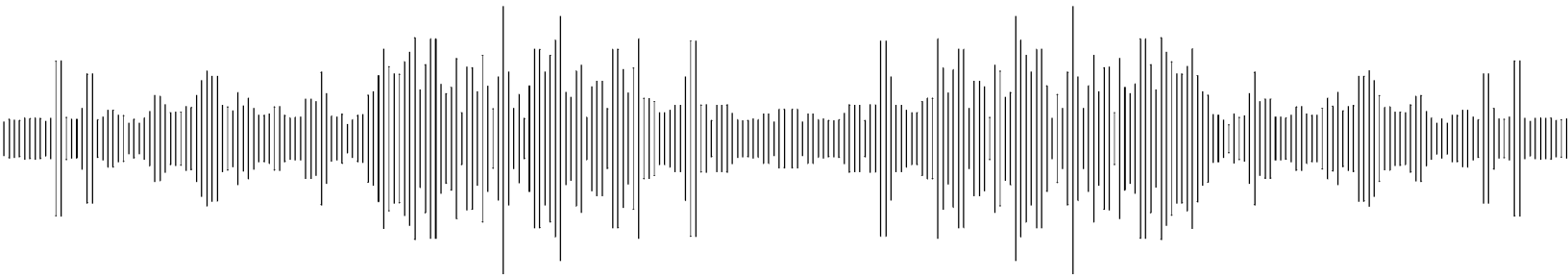
Multiphysics Capabilities
Ansys excels in simulating coupled phenomena, such as electromagnetic-induced vibrations, providing critical insights for early design optimization.



AI/ML Integration[10]
Ansys optiSLang optimizes NVH performance through AI/ML techniques, while Ansys Mechanical includes AI capabilities to determine computational requirements, streamline simulations and enhance efficiency.

Case Study: Leveraging Simulation to Meet Electric Motor NVH Requirements

Ansys offers an end-to-end NVH solution for electric machines. The solution includes a fast NVH workflow and a high-fidelity NVH workflow for calculating acoustic noise of electromagnetic and mechanical origins. Aerodynamic origin acoustic noise can also be calculated using Ansys Fluent.

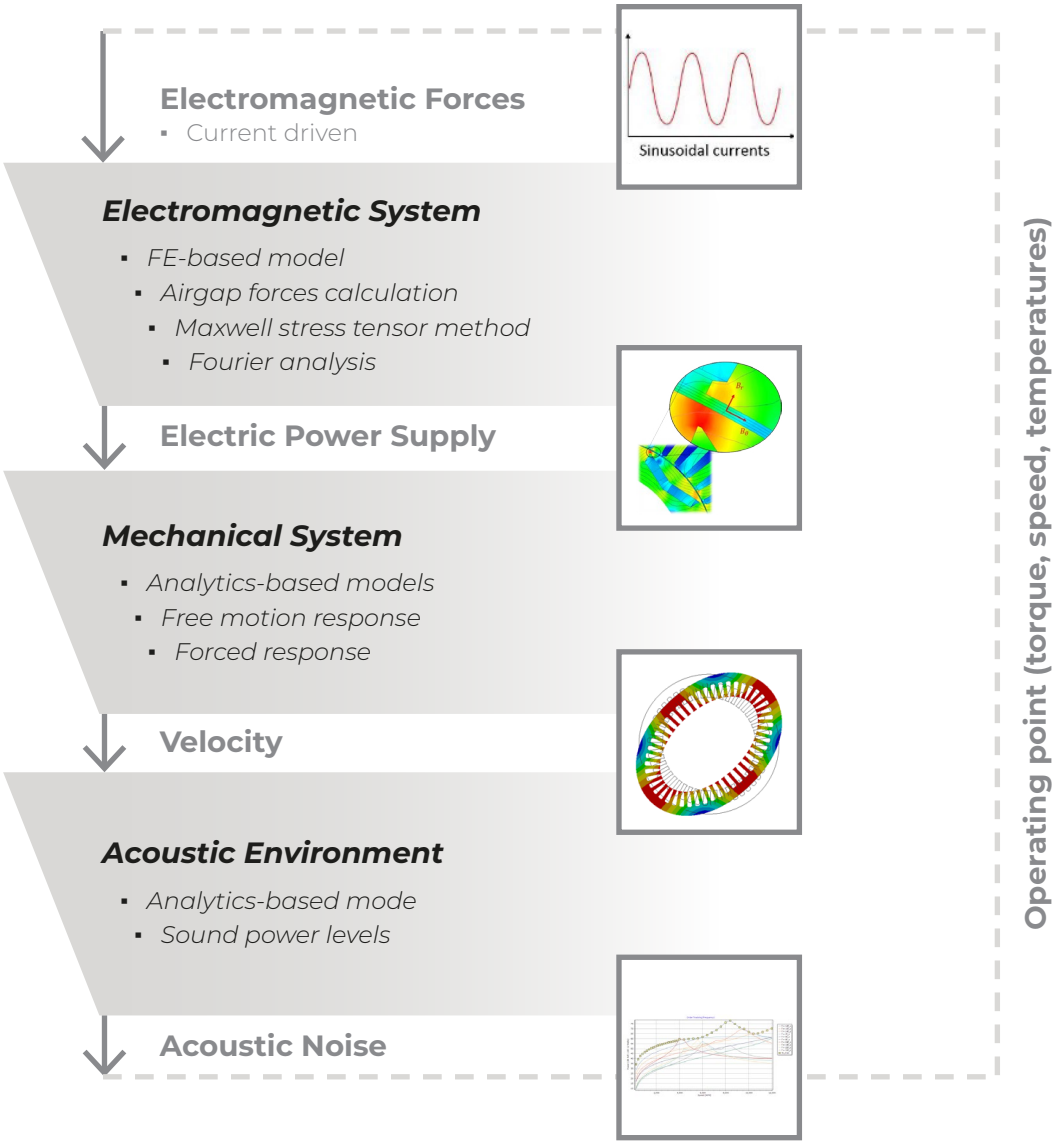


Fast NVH Workflow

A fast NVH workflow is developed for the concept design stage where a quick comparison of noise level for different motor designs/topologies is needed, and only takes a few minutes to predict the noise over a full speed sweep. It can identify the cause of motor noise early on and help make relevant design changes in trade-off with other motor performance targets, allowing the NVH, thermal, and electromagnetic behavior to be investigated at the same time.

Figure 3

Fast noise, vibration, and harshness workflow



The workflow shown in figure 3 is completely integrated into Ansys Motor-CAD. It begins with a current-driven, finite-element-based electromagnetic analysis where airgap forces are calculated using the Maxwell stress tensor method. These forces can be plotted in various forms along with their time and frequency domain harmonics. Then, these forces are used by an analytical mechanical model to calculate free motion and forced responses. Surface velocity is then transferred to an analytical acoustic model to compute the sound power levels. This workflow can be run for different values of torque, speed and temperature.

The NVH workflow in Ansys Motor-CAD provides designers with various representations of force, displacement and acoustic power. In addition to concept comparisons, the speed of the workflow allows for rapid design iteration to investigate many different options to improve NVH performance.

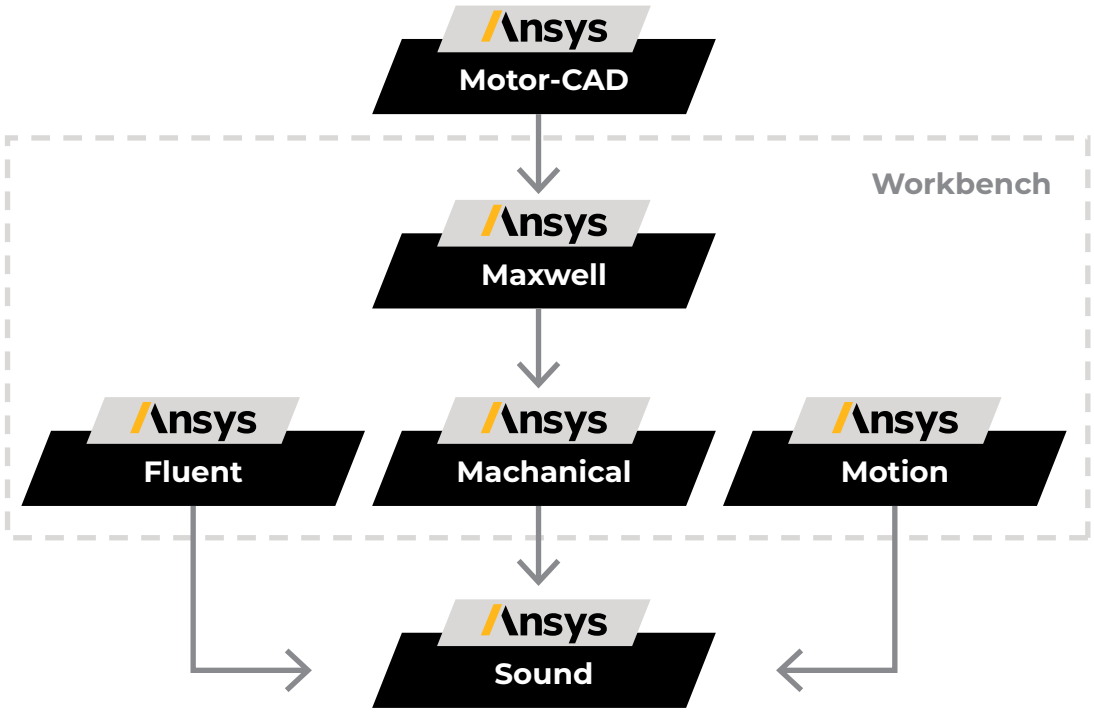
High-Fidelity is the Key

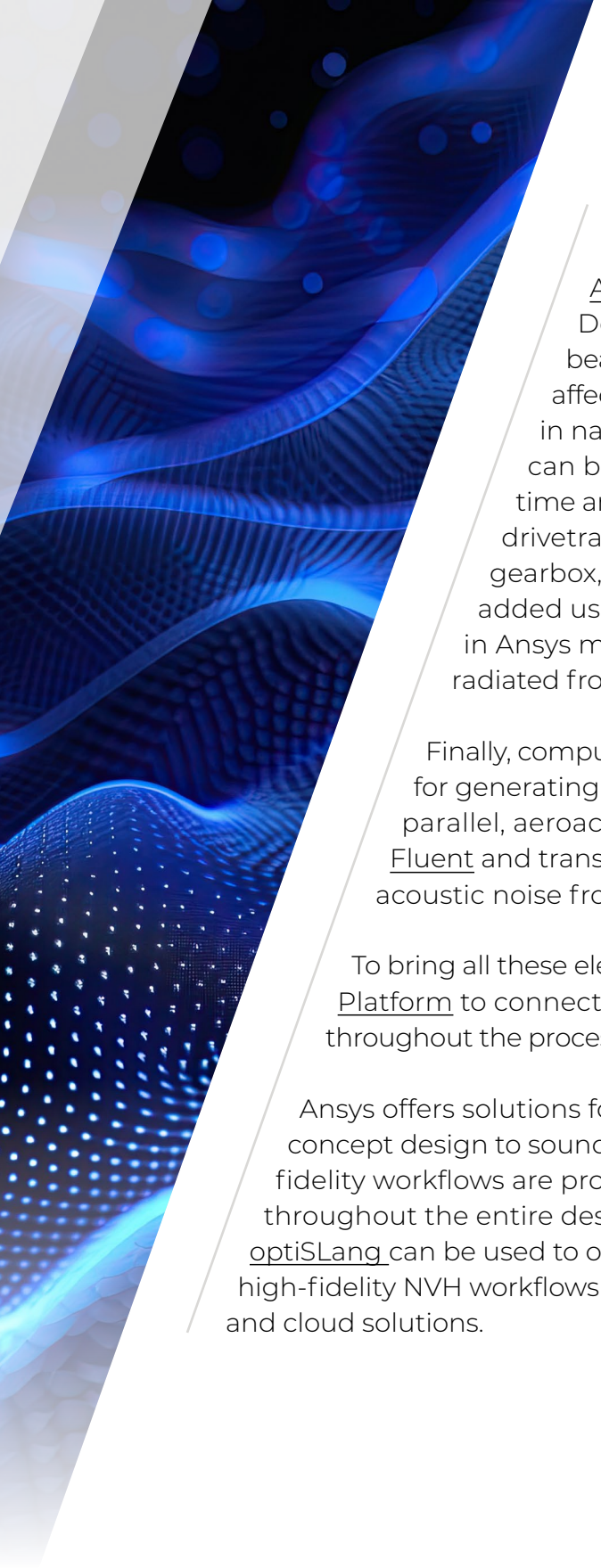
A high-fidelity NVH workflow requires coupled Multiphysics analysis using 2D and 3D finite element method (FEM). We want to take you through a true best-in-class multiphysics workflow from Ansys.

Looking at the complete workflow as shown in figure 4: Firstly, the best design candidate is chosen in Ansys Motor-CAD. Following that, a 2D or 3D Maxwell model can be generated automatically. Detailed magnetic analysis is performed in Ansys Maxwell to calculate electromagnetic forces inside the machine. Circuit-coupled transient analysis provides the user with the capability to consider carrier harmonics from power electronics converters.

Figure 4

High-fidelity noise, vibration, and harshness workflow





Electromagnetic forces are automatically mapped to the mechanical model in Ansys Mechanical for vibroacoustic analysis. Details of electric motor structure such as bearing, housing and mounting can significantly affect the vibrational behavior through a change in natural frequency and overall damping. This can be precisely modeled in Mechanical in both time and frequency domains. In the case of electric drivetrain, the mechanical origin vibration from gearbox, bearing and auxiliary system can also be added using Ansys Motion. The acoustic module in Ansys mechanical calculates the acoustic power radiated from electric machine surface to surrounding.

Finally, computed acoustic noise can be sent to Ansys Sound for generating audible sound and extra postprocessing. In parallel, aeroacoustics noise can be calculated using Ansys Fluent and transferred to Ansys Sound to be combined with acoustic noise from mechanical and electromagnetic sources.

To bring all these elements together, Ansys offers the Workbench Platform to connect all physics and several HPC algorithms throughout the process to accelerate high-fidelity NVH computations.

Ansys offers solutions for NVH simulation in electric machines from concept design to sound perception level. Multiphysics fast and high-fidelity workflows are provided to address the NVH analysis needs throughout the entire design and validation process. In addition, Ansys optiSLang can be used to optimize NVH performance over both fast and high-fidelity NVH workflows thanks to Ansys high-performance computing and cloud solutions.

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ANSYS, Inc., Southpointe,
2600 Ansys Drive, Canonsburg, PA 15317, U.S.A
724.746.3304
ansysinfo@ansys.com