Noise, Vibration and Harshness: Integrating Composite Parts

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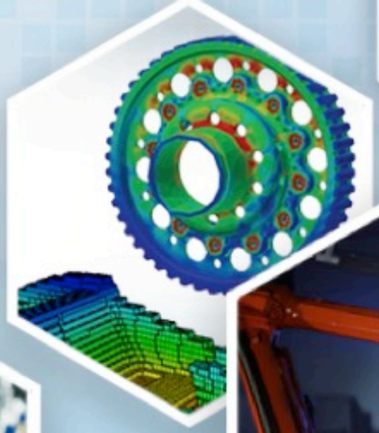
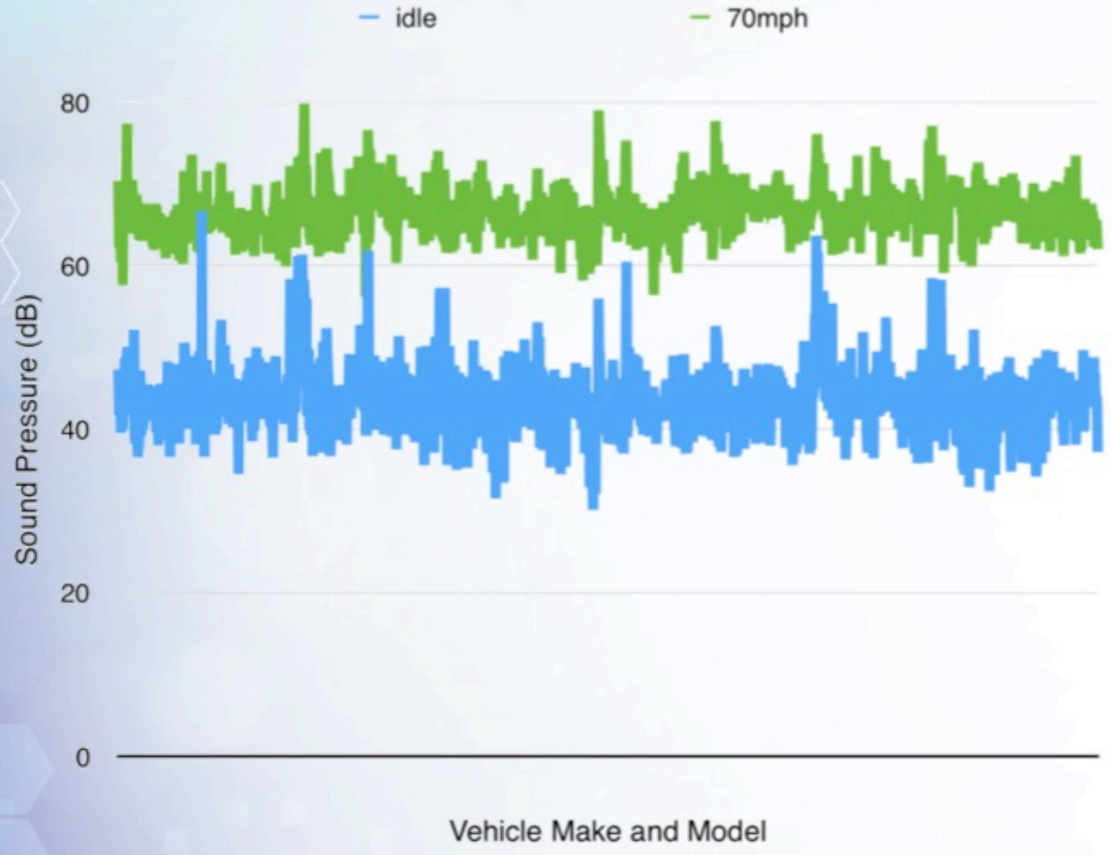
IACMI NDE Technical Fellow



Getting a feel for the noise your car makes

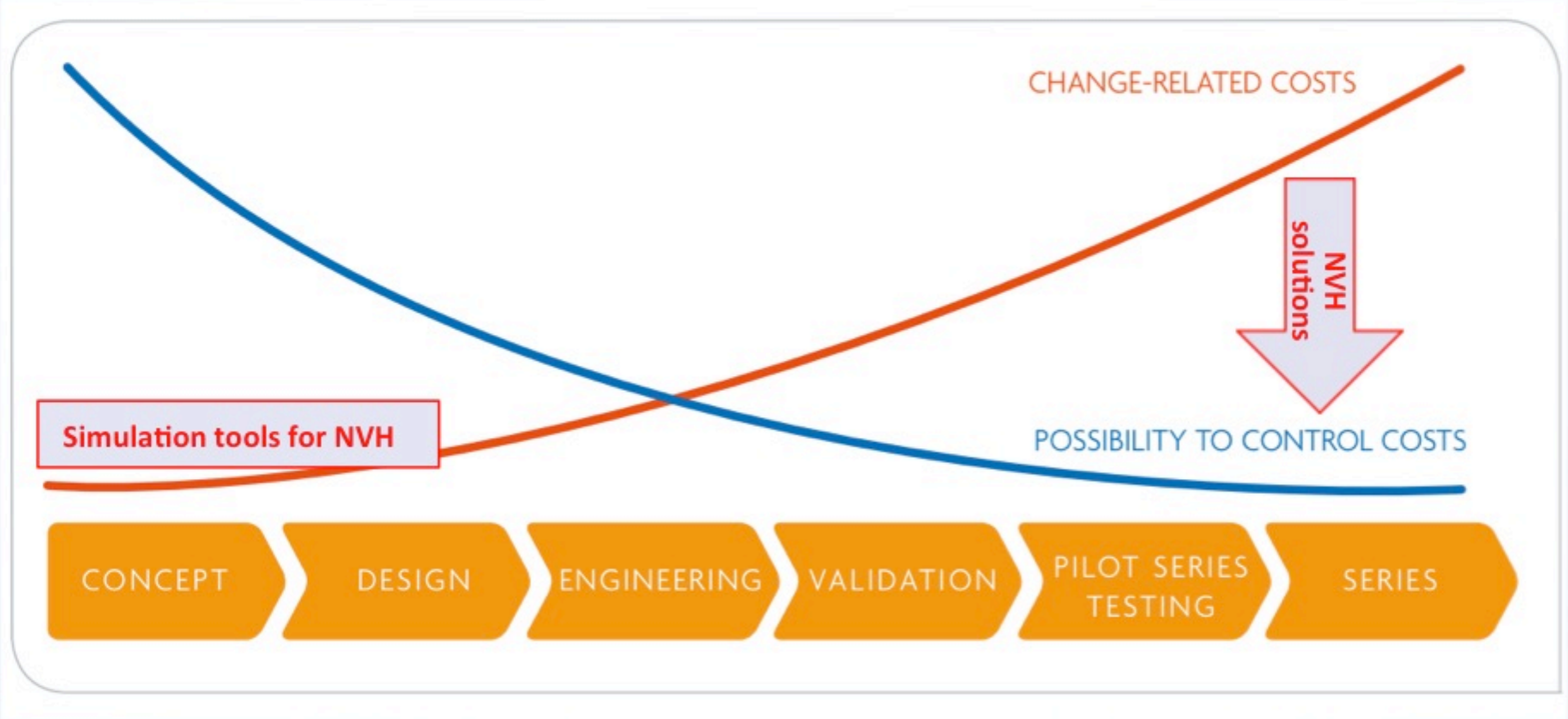


- ~1500 vehicles
- Interior noise levels
- http://www.auto-decibel-db.com/index.html

- How quiet is quiet? https://www.youtube.com/watch?v=uCnsw9oRDsM

Composites, quality and cost in NVH

- Composites must address many metrics such as quality (e.g., sound and ride quality).
- Cost of NVH is lowest if done early in product and process design (or "bolt on" solutions).



Courtesy esi group

"Ford significantly accelerates Vehicle Development Processes using IC.IDO", www.esi-group.com, 2013

NVH quality environment poses challenges

- Composites face similar NVH challenges as other technologies as they add performance in lightweighting and other areas.

#1
- **Elastomer bushings**
- **Variations in compounding**
- **Pronounced as other vehicle noise is reduced**

Figure 1. Adaptability of human hearing – permanent new challenges for acoustic engineers.

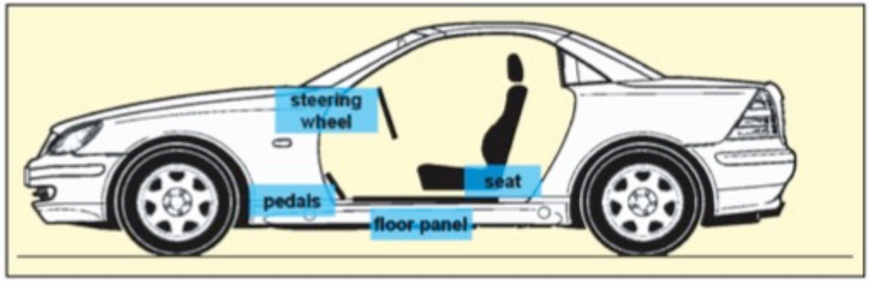


Figure 2. Main contact points of vehicle drivers.

#2
- **Elastomer bushings**
- **Variations in properties**
- **Time and cycles**
- **NVH perceived by the owner**

Courtesy Sound and Vibration Magazine
"Vehicle Interior Noise – Combination of Sound, Vibration and Interactivity",
Klaus Genuit, HEAD acoustics GmbH, 2009

Composites paradigm offers opportunities in NVH

- Composite materials for certain spaces can be tailored in terms of their properties and structure to address NVH needs.

Thinsulate™ acoustic insulation

Courtesy 3M

IACMI R&D Goals ←→ NVH

Five Year Technical Goals

- 25% lower carbon fiber–reinforced polymer (CFRP) cost
- 50% reduction in CFRP embodied energy
- 80% composite recyclability into useful products

Do these goals relate to NVH?

If so, how can IACMI support its partners' needs in NVH for composites?

IACMI R&D Goals and NVH

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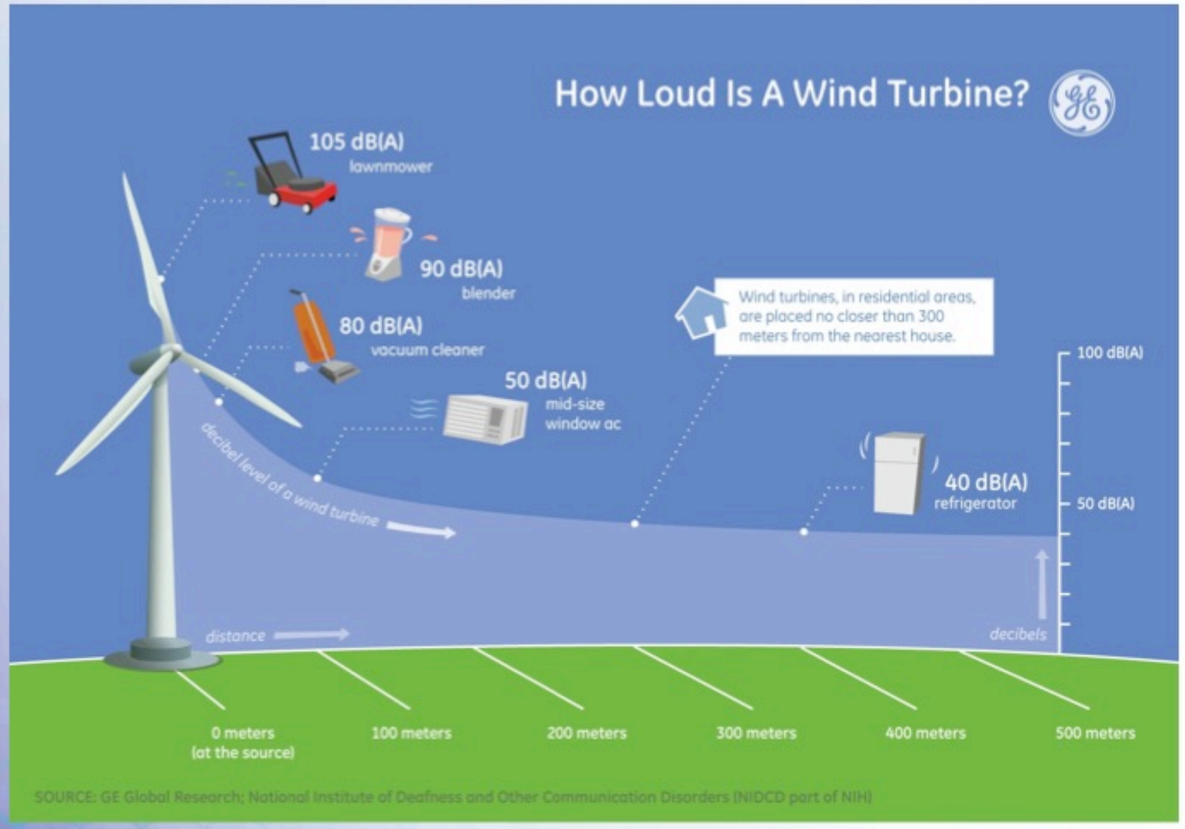
Do these goals relate to NVH? Yes

If so, how can IACMI support its partners' needs in NVH for composites? Collaborate to proactively address NVH

Example: noise considerations for wind turbines

"For utility-scale wind turbines, the maximum rotor rotation speed is generally constrained by noise considerations." ~ Ning and Dykes (2014)



- Noise aspects relate to
  - Setback requirements
  - Performance (tip speed ratio)
  - Utility-scale and micro wind power

Ning, A. and Dykes, K., Understanding the Benefits and Limitations of Increasing Maximum Rotor Tip Speed for Utility-Scale Wind Turbines, J. of Physics, 524 (2014) 012087, doi: 10.1088/1742-6596/524/1/012087

An NVH perspective on automotive lightweighting

Lightweighting in general

- History shows that component-wise automotive lightweighting efforts can be a zero sum game in NVH because noise and vibration energy takes the path of least resistance:

$$F = M \times A \quad \Rightarrow \quad A = \frac{F}{M}$$

Lightweighting in composites

- IACMI's goals of cost and energy reduction in automotive applications could also be viewed through this lens – we want to avoid shifting savings in weight, cost, and energy downstream.

Proactive NVH design strategies for new materials

- The incorporation of dissimilar materials in vehicle designs can promote noise quality issues including squeaks and rattles*.

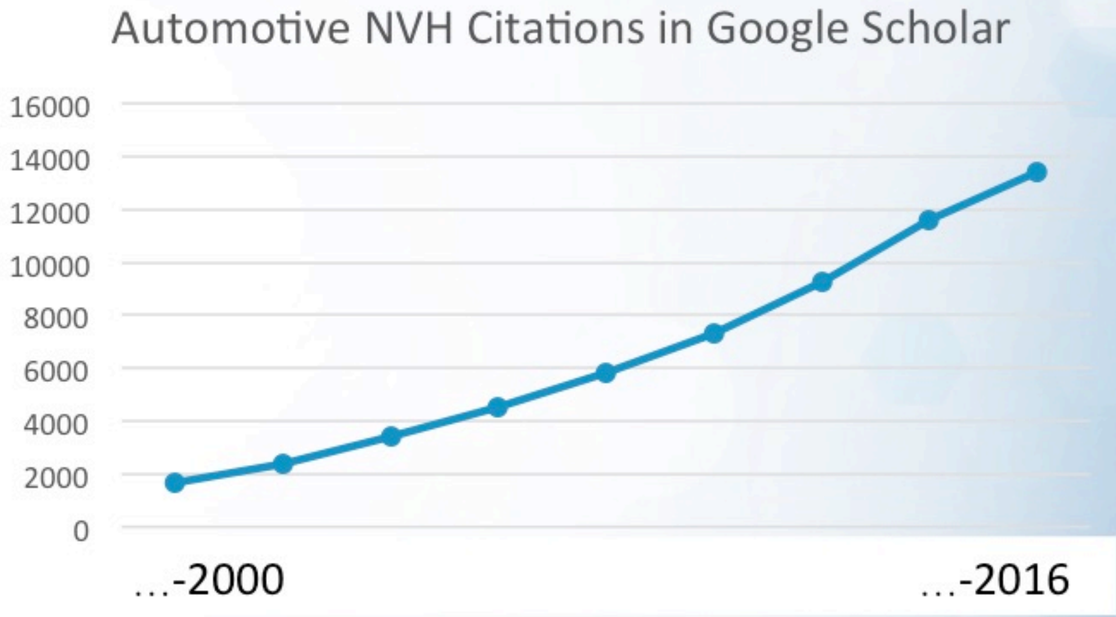
Anti-friction coatings reduce stick-slip and avoid the need for additional fasteners (i.e., weight) to inhibit mobility of components

Courtesy Dow Corning

*Automotive Design
"Making a Big Noise", www.automotivedesign.eu.com
Lou Reade, 2011

Much to learn from in NVH literature

- The NVH literature is extensive on:
  - general noise and vibration remediation in automobiles*
  - material solutions for noise control**
  - attributes that composites bring in NVH***.



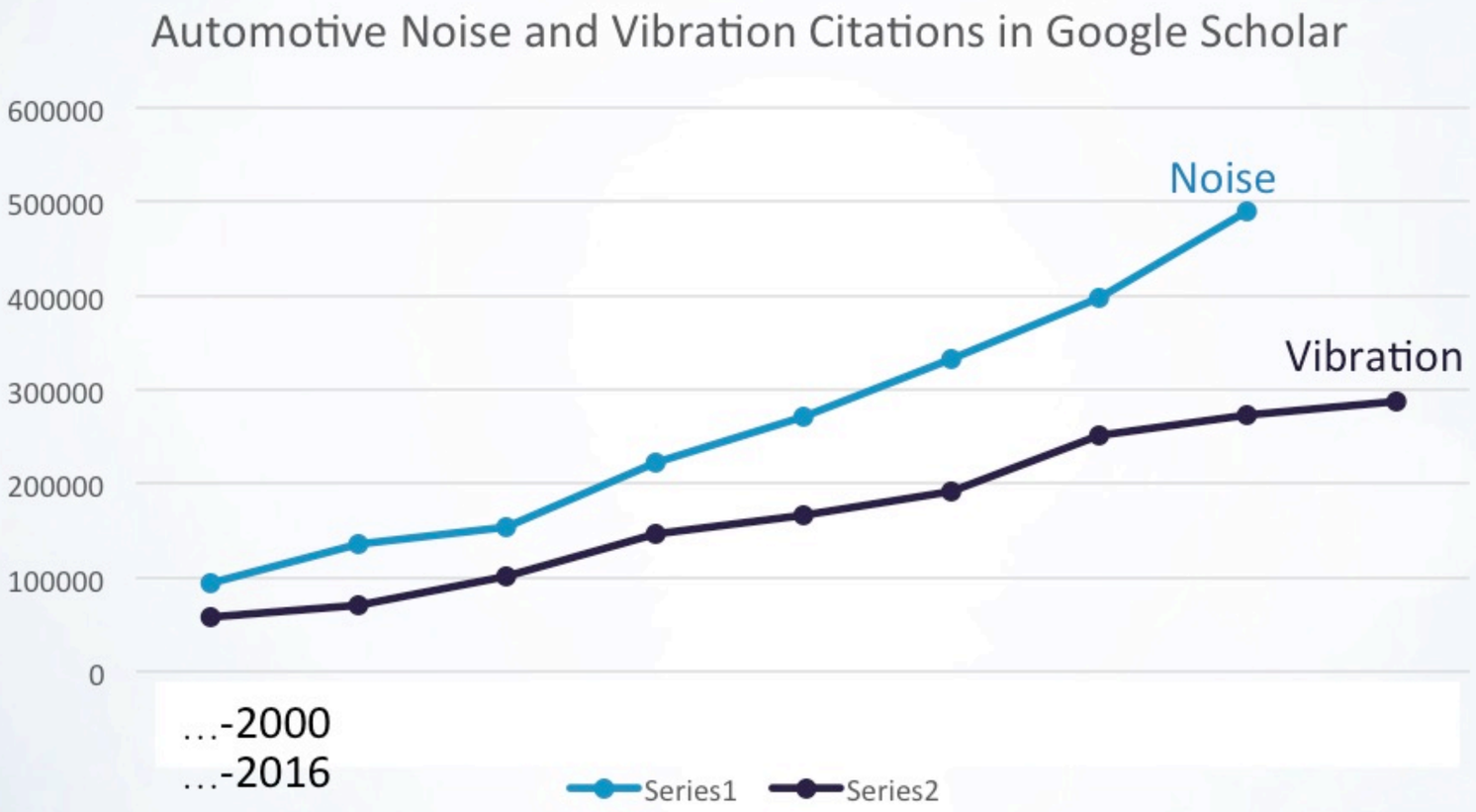
*Harrison, Matthew. Vehicle refinement: controlling noise and vibration in road vehicles. Elsevier, 2004.

**Rao, Mohan D. "Recent applications of viscoelastic damping for noise control in automobiles and commercial airplanes." Journal of Sound and Vibration 262.3 (2003): 457-474.

***Beardmore, P., and C. F. Johnson. "The potential for composites in structural automotive applications." Composites science and Technology 26.4 (1986): 251-281.

Trends in the NVH literature and practice

Empirical
Linear
Analysis
Uncoupled

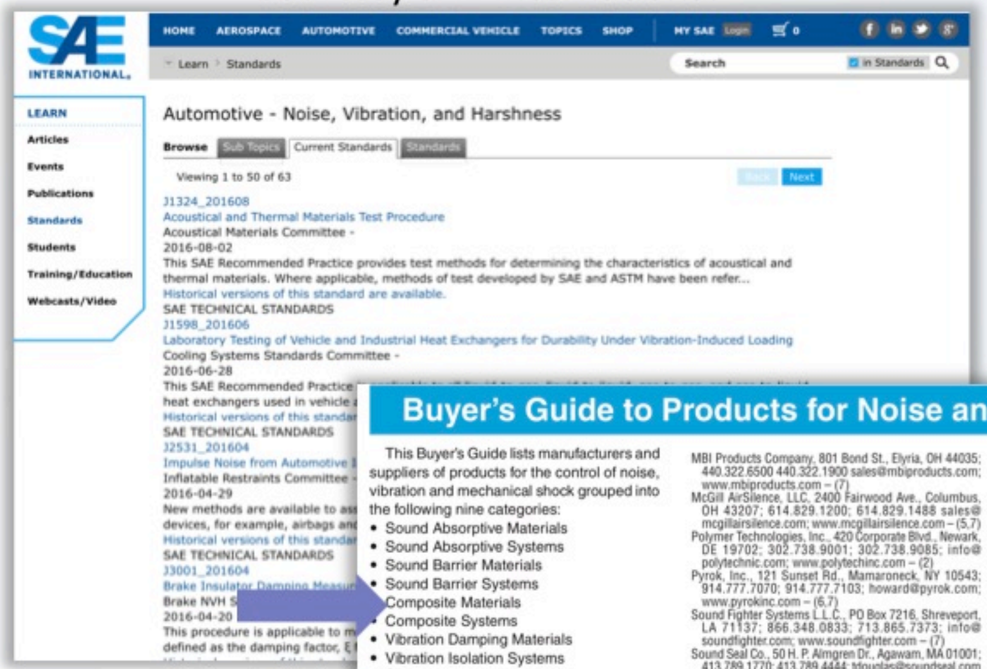


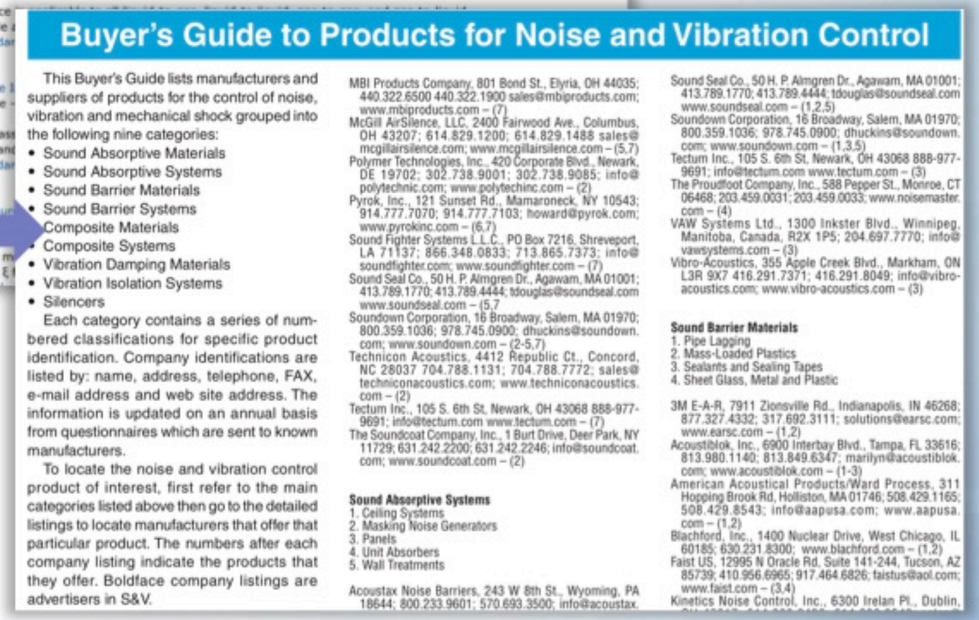
Simulation
Nonlinear
Coupled

NVH Measurement and Material Standards

- SAE/ASTM provide the relevant technical standards for measuring acoustic and vibration properties of materials.
- Various trade magazines like S&V Magazine provide regular updates on the industry.

Courtesy SAE International





Buyer's Guide to Products for Noise and Vibration Control

This Buyer's Guide lists manufacturers and suppliers of products for the control of noise, vibration and mechanical shock grouped into the following nine categories:

- Sound Absorptive Materials
- Sound Absorptive Systems
- Sound Barrier Materials
- Sound Barrier Systems
- Composite Materials
- Composite Systems
- Vibration Damping Materials
- Vibration Isolation Systems
- Silencers

Each category contains a series of numbered classifications for specific product identification. Company identifications are listed by: name, address, telephone, FAX, e-mail address and web site address. The information is updated on an annual basis from questionnaires which are sent to known manufacturers.

To locate the noise and vibration control product of interest, first refer to the main categories listed above then go to the detailed listings to locate manufacturers that offer that particular product. The numbers after each company listing indicate the products that they offer. Boldface company listings are advertisers in S&V.

MBI Products Company, 801 Bond St., Elyria, OH 44035; 440.322.6500 440.322.1900 sales@mbiproducts.com; www.mbiproducts.com – (7)
McGill AirSilence, LLC, 2400 Fairwood Ave., Columbus, OH 43207; 614.829.1200; 614.829.1488 sales@mcgillairsilence.com; www.mcgillairsilence.com – (5,7)
Polymer Technologies, Inc., 420 Corporate Blvd., Newark, DE 19702; 302.738.9001; 302.738.9085; info@polytechinc.com; www.polytechinc.com – (2)
Pyrok, Inc., 121 Sunset Rd., Mamaroneck, NY 10543; 914.777.7070; 914.777.7103; howard@pyrok.com; www.pyrokinc.com – (6,7)
Sound Fighter Systems L.L.C., PO Box 7216, Shreveport, LA 71137; 866.348.0833; 713.865.7373; info@soundfighter.com; www.soundfighter.com – (7)
Sound Seal Co., 50 H. P. Almgren Dr., Agawam, MA 01001; 413.789.1770; 413.789.4444; tdouglas@soundseal.com www.soundseal.com – (5,7
Soundown Corporation, 16 Broadway, Salem, MA 01970; 800.359.1036; 978.745.0900; dhuckins@soundown.com; www.soundown.com – (2-5,7)
Technicon Acoustics, 4412 Republic Ct., Concord, NC 28037 704.788.1131; 704.788.7772; sales@techniconacoustics.com; www.techniconacoustics.com – (2)
Tectum Inc., 105 S. 6th St, Newark, OH 43068 888-977-9691; info@tectum.com www.tectum.com – (7)
The Soundcoat Company, Inc., 1 Burt Drive, Deer Park, NY 11729; 631.242.2200; 631.242.2246; info@soundcoat.com; www.soundcoat.com – (2)

Sound Absorptive Systems
1. Ceiling Systems
2. Masking Noise Generators
3. Panels
4. Unit Absorbers
5. Wall Treatments

Acoustax Noise Barriers, 243 W 8th St., Wyoming, PA 18644; 800.233.9601; 570.693.3500; info@acoustax.

Sound Seal Co., 50 H. P. Almgren Dr., Agawam, MA 01001; 413.789.1770; 413.789.4444; tdouglas@soundseal.com www.soundseal.com – (1,2,5)
Soundown Corporation, 16 Broadway, Salem, MA 01970; 800.359.1036; 978.745.0900; dhuckins@soundown.com; www.soundown.com – (1,3,5)
Tectum Inc., 105 S. 6th St, Newark, OH 43068 888-977-9691; info@tectum.com www.tectum.com – (3)
The Proudfoot Company, Inc., 588 Pepper St., Monroe, CT 06468; 203.459.0031; 203.459.0033; www.noisemaster.com – (4)
VAW Systems Ltd., 1300 Inkster Blvd., Winnipeg, Manitoba, Canada, R2X 1P5; 204.697.7770; info@vawsystems.com – (3)
Vibro-Acoustics, 355 Apple Creek Blvd., Markham, ON L3R 9X7 416.291.7371; 416.291.8049; info@vibro-acoustics.com; www.vibro-acoustics.com – (3)

Sound Barrier Materials
1. Pipe Lagging
2. Mass-Loaded Plastics
3. Sealants and Sealing Tapes
4. Sheet Glass, Metal and Plastic

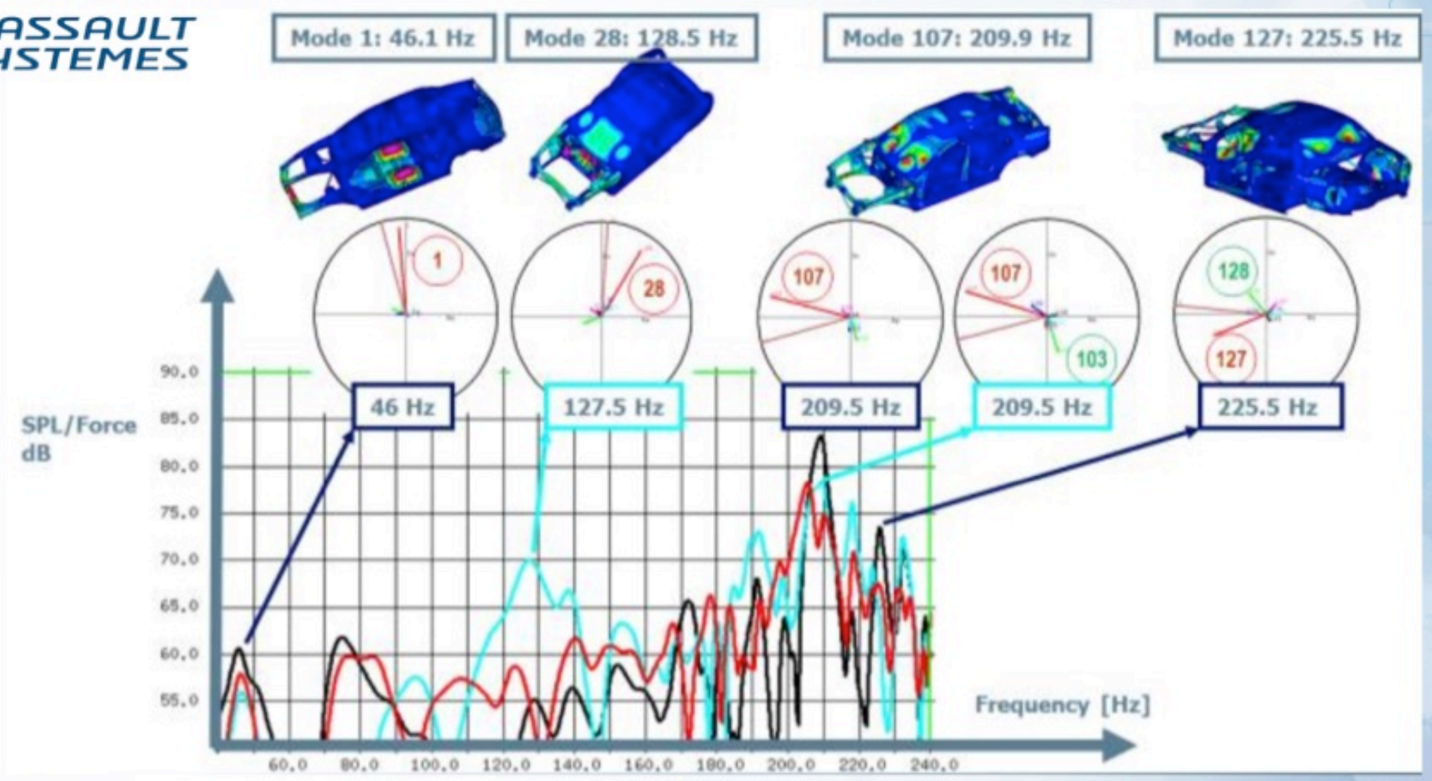
3M E-A-R, 7911 Zionsville Rd., Indianapolis, IN 46268; 877.327.4332; 317.692.3111; solutions@earsc.com; www.earsc.com – (1,2)
Acoustiblok, Inc., 6900 Interbay Blvd., Tampa, FL 33616; 813.980.1140; 813.849.6347; marilyn@acoustiblok.com; www.acoustiblok.com – (1-3)
American Acoustical Products/Ward Process, 311 Hopping Brook Rd, Holliston, MA 01746; 508.429.1165; 508.429.8543; info@aapusa.com; www.aapusa.com – (1,2)
Blachford, Inc., 1400 Nuclear Drive, West Chicago, IL 60185; 630.231.8300; www.blachford.com – (1,2)
Faist US, 12995 N Oracle Rd, Suite 141-244, Tucson, AZ 85739; 410.956.6965; 917.464.6826; faistus@aol.com; www.faist.com – (3,4)
Kinetics Noise Control, Inc., 6300 Irelan Pl., Dublin,

Courtesy Sound and Vibration Magazine

Being Proactive with Simulation Tools

- Modeling and simulation tools represent the first opportunity to achieve NVH gains in composites and reduce the cost of NVH solutions.

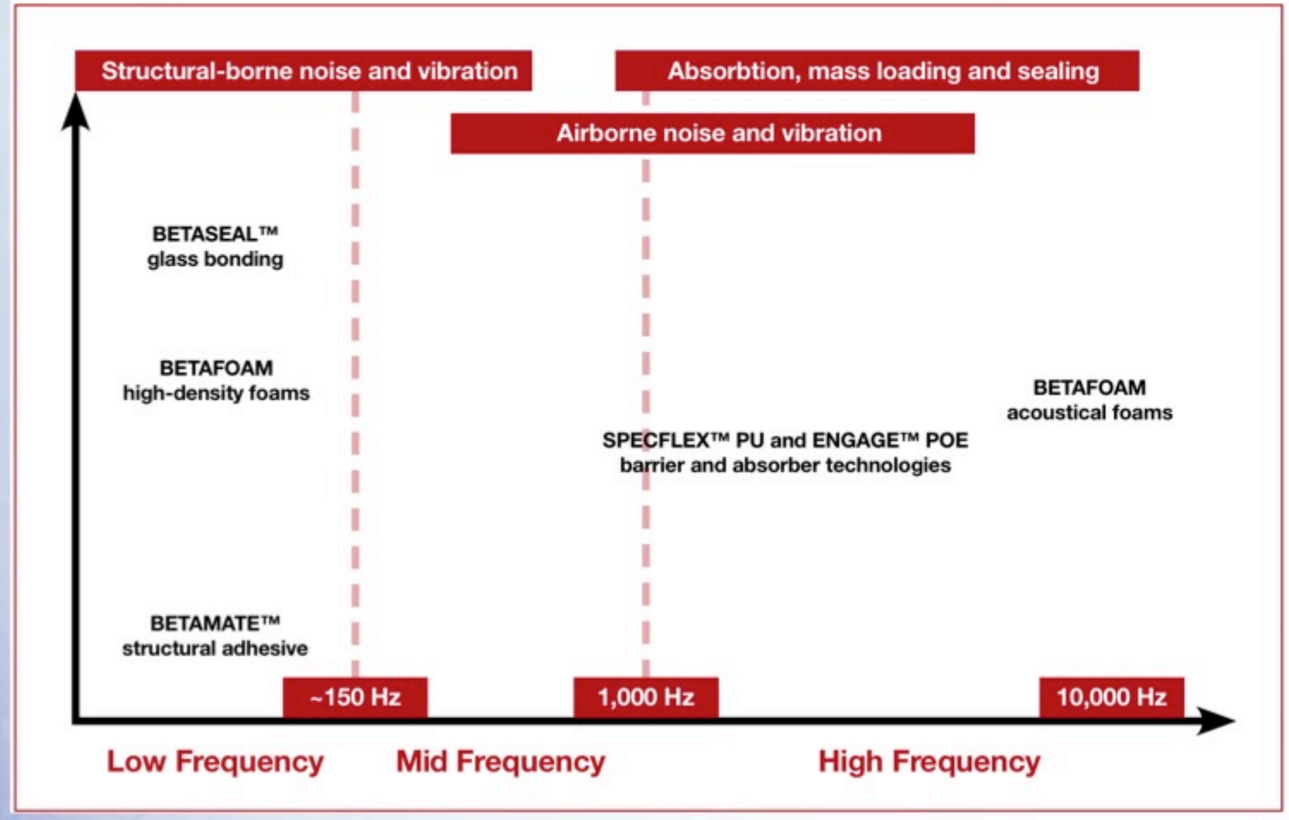
"Evaluate lightweight structures with regard to comfort and acoustics. Analyze the interior acoustics of vehicles. Find out what parts of the vehicle contribute the most to noise emission and vibration. SFE AKUSMOD™ puts you into a position to check and to improve acoustics/NVH in an early stage."



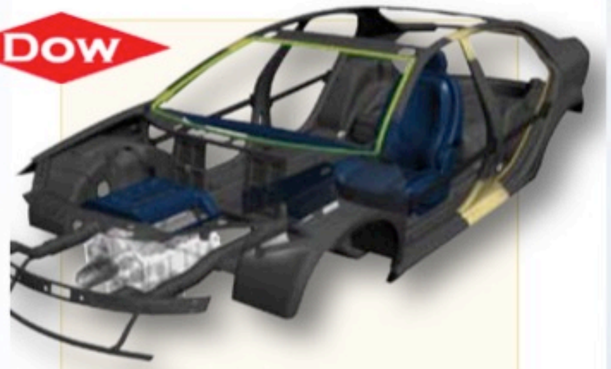
Courtesy Dassault Systemes

Tackling NVH sources strategically

- IACMI's partners are leaders across the supply chain in developing broadband NVH solutions.



Courtesy Dow
"NVH Management", Dow Automotive Systems



Typical NVH management product applications.

The Dow Automotive Systems portfolio also includes a number of products designed to address low-frequency structural-borne noise.

- BETASEAL™ glass bonding systems
- BETAFOAM structural foams
- BETAMATE™ structural adhesives
- ENGAGE™ polyolefin elastomers – also used to optimize heavy-layer processing and performance

Vertical integration across IACMI can be leveraged

- A strength of IACMI is that our partners work with one another in a vertically integrated manner to develop NVH solutions.

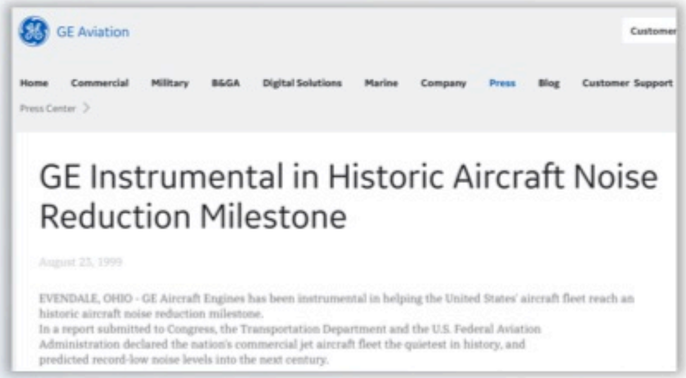
BASF
The Chemical Company

BASF's Basotect® TG melamine foam is used in the engine cover for various Volkswagen vehicles.

Courtesy BASF
"Combating Heat and Noise Associated With Fuel Efficient Engines", http://www.automotive.basf.com/, 2005

IACMI's industry-driven model can be leveraged

Courtesy DuPont



- IACMI's diverse network of industry partners across the automotive sector offers us breadth and depth of NVH solutions, that also span product sectors – e.g., aerospace foams.

What do you think of this NVH strategy?

The NVH strategy for composites manufacturing for IACMI should:

-- be driven by the needs of our industry partners

NVH in project proposals, “market pull” for advanced composites, etc.

-- be proactive to avoid shifting cost to late-stage NVH changes

Focus on integrating modeling and simulation tools, couple with material / structural dynamic characterization for manufacturing processes being developed on projects to inform simulations, promote adoption of composite materials for automotive and wind.

-- leverage the unique supply chain and vertically integrated IACMI partnership in place to overcome the "zero sum game" in NVH

From adhesives to intermediates to structures and the processes that produce them and drive variation in NVH performance, bring teams together to realize light and quiet composites.