CME 3086
Automotive Sound Quality
(Non-credit / 2.4 CEU's)

Course Objective:
To familiarize the attendee with the basic principles and concepts of automotive sound quality with a strong emphasis on practical applications and examples. This course will provide an in-depth understanding of the newly emerging field of sound quality. It is aimed at not only NVH engineers but also to component design and release, engine design, vehicle integration, and program management personnel. This course will increase the participant's ability to deal with NVH and sound quality related issues, problems, and trade-offs.

Topics to be covered include:

- History and definition of sound quality and relevance to today's automotive industry
- Psychoacoustic concepts including frequency sensitivity, critical bands, masking, temporal effect, modulation, and binaural effects. Sounds will be used to demonstrate many of these concepts.
- Sound quality metrics, their basis and use, including loudness (ISO532B and time varying), sharpness, articulation index, fluctuation strength, roughness, impulsiveness, and tonality.
- The sound quality process including measurements using the Binaural Head, analysis procedures and analysis systems, and metric correlation techniques.
- Subjective evaluation strategies and procedures including subject selection, sound preparation, the listening environment, and several types of evaluation methods. Particular emphasis will be given to the paired comparison and semantic differential methods.
- Powertrain sound quality concepts and strategies including the basic structure and properties of a powertrain sound, the relationship of order level balance to the sound impression, the progression of order level throughout an acceleration, non-order related noise sources, and engine component sound quality.
- Designing to achieve powertrain sound quality covering sound quality targets and target cascades, and induction and exhaust system design.
- Diesel Sound quality will address the special sound quality issues relating to diesel engines with emphasis on the high frequency cackle and clatter sounds.
- Vehicle component sound quality includes measurement, analysis, and improvement strategies for the major automotive components including closures, motorized components (seat, windows, pedals, etc), switches, and signals and chimes.

There will be several laboratory exercises throughout the course to give the attendee some hands on experience.

Outline

I. Introduction to Sound Quality
   A. History
   B. Definition
   C. Elements of Sound Quality
   D. Importance

II. Review of Basic NVH Metrics and Analysis

III. Psychoacoustics
   A. The Human Auditory System
   B. Psychoacoustic Methods
   C. Basic Concepts
      1. Frequency Sensitivity
      2. Intensity
      3. Critical Bands
      4. Masking
      5. Temporal Effects
      6. Modulation and Beating
      7. Periodicity
      8. Binaural Effects
   D. Psychoacoustic Lab

IV. Sound Quality Metrics (Models)
   A. Loudness (Stationary Sounds)
      1. Equal Loudness Contours
      2. Loudness vs. dB(A)
      3. Loudness Scales (Sones and Phons)
      4. The Loudness Algorithm (ISO532B)
   B. Time-varying Loudness
   C. Sharpness
   D. Articulation Index
   E. Fluctuation Strength
   F. Roughness
   G. Impulsiveness
   H. Tonality
   I. Others
   J. Metric Lab

V. The Sound Quality Process
   A. Measurement Procedures
   B. Analysis Procedures
   C. Metric Correlation

VI. Subjective Evaluation
   A. Subject Selection
   B. Sound Selection
   C. Listening Environment
   D. Evaluation Methods
      1. Rating Scales
      2. Magnitude Estimation
      3. Rank Order
      4. Paired Comparison
         a. Design
         b. Analysis of Results/PC Models

c. Subject Groupings
d. Similarity Scaling

5. Semantic Differential
   a. Choosing Semantics
   b. Analysis of Results
   c. Developing Brand DNA

E. Subjective Evaluation Lab

VI. Powertrain Sound Quality Concepts and Strategies

A. P/T Noise Paths
B. Engine Orders
C. Measurement Procedures
D. Structure and Properties of a Powertrain Sound
E. P/T Sound Level
F. Order Balance (Relation to sound impression)
   1. Firing Order Harmonics
   2. Orders Below Firing
   3. Orders above Firing
   4. Order Combinations
G. Order Level Progression
   1. Periods and Holes
   2. Linearity
   3. Slope
H. Non-order content
   1. Flow related noise (Induction and Exhaust)
      a. Flow Noise
      b. Shell Noise
      c. Impingement Noise
I. Engine Accessories (pumps, motors, compressors)
J. Powertrain Sound Quality Lab

VII. Designing for Powertrain Sound Quality

A. Sound Quality Target and Cascade
B. Making the Vehicle Tunable
C. Induction System Design
   1. Intake Manifold Design (Strategies and tools)
   2. Air Intake System Design
   3. Air Cleaner Volume
   4. Resonators
   5. Orifice Size and Location
   6. Minimizing flow related noise
   7. Measuring Induction Sound Quality
   8. Attribute Tradeoffs
D. Exhaust System Design
   1. Exhaust Manifold Design
   2. Exhaust Pipe
   3. Muffler Tuning
   4. Resonators and After-silencers
   5. Tailpipe Design
   6. Minimizing flow related noise
   7. Measuring Exhaust Sound Quality
   8. Attribute Tradeoffs

VIII. Diesel Sound Quality
- A. Diesel Noise Sources
- B. Order Balance
- C. Diesel Idle Clatter and Cackle (High Frequency)
  1. Sound Properties
  2. Measurement and Analysis Procedures
  3. Sources
     a. Combustion Noise
     b. Mechanical Noise
  4. Treatment and Design Actions
- D. Turbo Noise

IX. Component Sound Quality
- A. Definition and Importance
- B. Measurement Procedures
- C. The Ford Simple Sound Quality Tool
- D. Closures
- E. Motorized components (seats, windows, mirrors, pedals, etc.)
- F. Wipers
- G. Switches
- G. Signals and Chimes

Prerequisites
None

Course Material
Handout provided by the instructor

Instructor
Norm Otto, Ph.D., Adjunct, Mechanical Engineering

Target Audience
Open

CEU
A total of 2.4 Continuing Education Units (CEU's) will be awarded to each participant who completes the program. The CEU is a nationally recognized means of tracking non-credit continuing education development. It confirms participation in a structured professional development activity or course work. One CEU is awarded for 10 hours of completed activity or course work. A permanent record of each attendee's participation is maintained in the Office of the Registrar at the University of Michigan-Dearborn.

Register

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