Prediction and control of motorcycle engine noise under combustion load

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Contents

Introduction

Customer demands of quieter vehicles

Regulations concerning noise levels

Sound quality can act as a differentiator

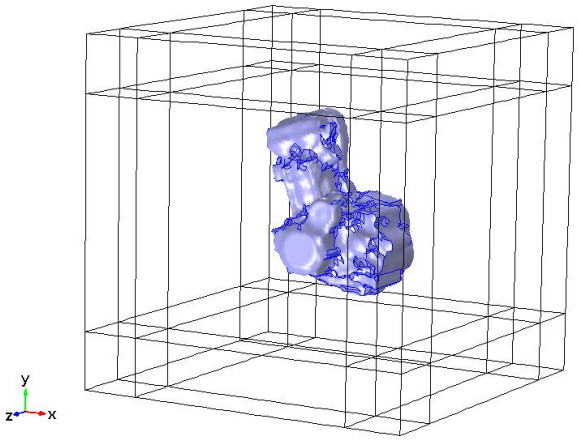
Engine - Source of noise & vibration

Prediction and control of engine NVH performance by structural and acoustic simulation methods

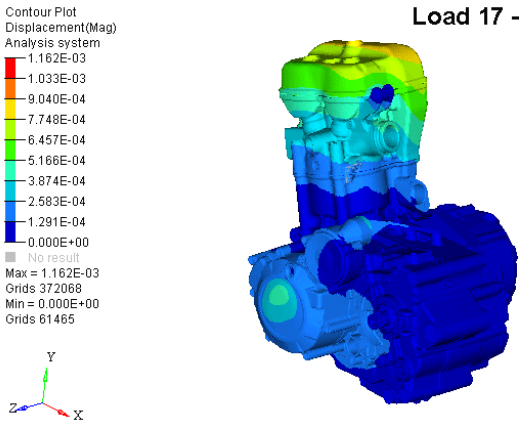
Substantial cost saving and development time reduction of new product

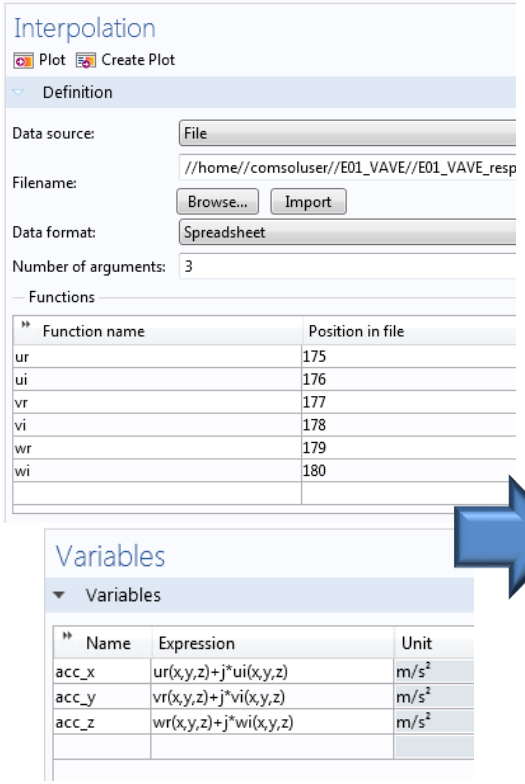
Brief procedure

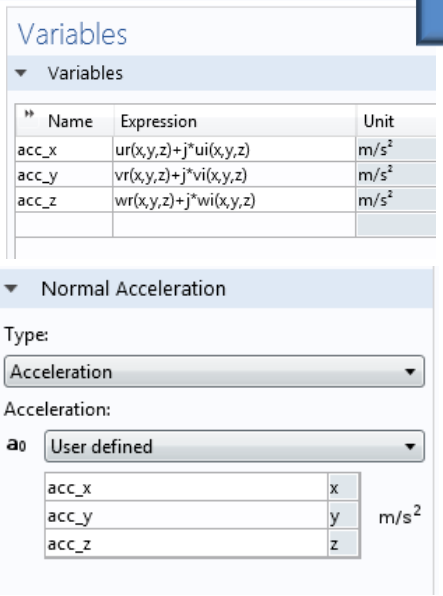
COMSOL Model set up

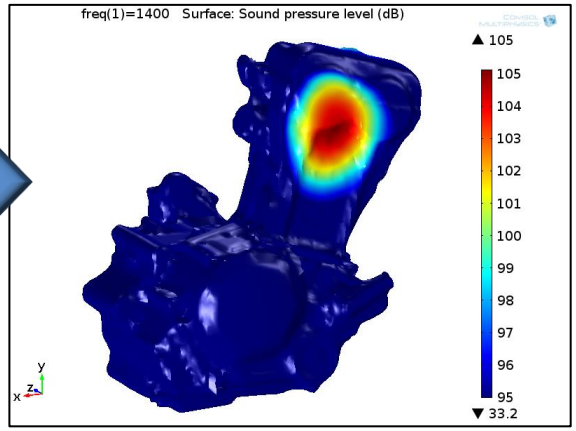


Surface acceleration

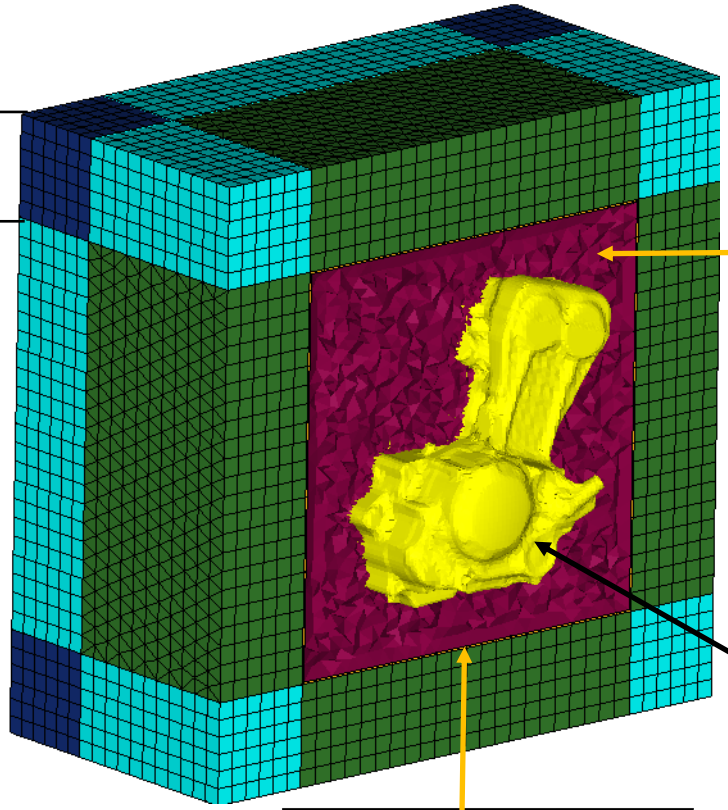








Acoustic Mesh – Cut Section



PML

PML thickness equal to 1/4th the side of engine skin domain

Six layers of elements in PML

Engine skin domain

Side greater than half the maximum wavelength

Maximum element size equal to 1/6th of minimum wavelength

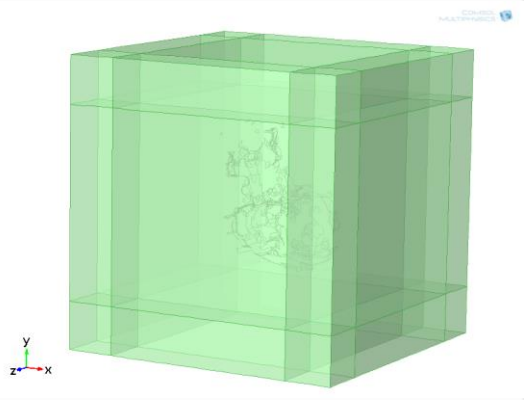
Engine Skin

Boundary Layer

Thickness equal to 1/10th maximum element size

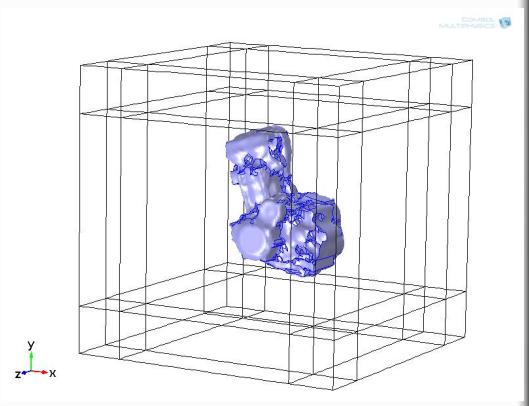
COMSOL Model Setup

Perfectly matched layer



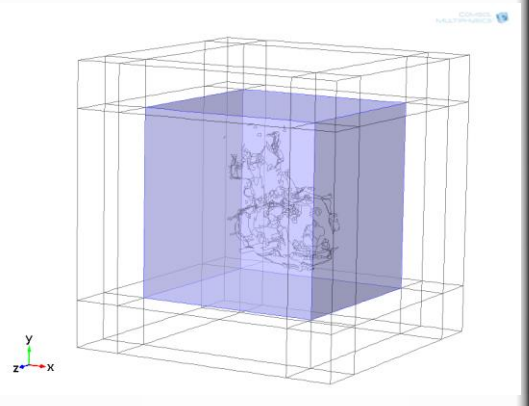
- Importing Acoustic mesh
- Assign appropriate PML domains using Perfectly matched layer feature

Normal acceleration



- Apply nodal acceleration data to engine skin boundaries
- Interpolation of nodal acceleration data
- $n \cdot \left(\frac{1}{\rho_0}(\nabla p) + n \cdot a_0\right) = 0$

Far field calculation



- $p(\boldsymbol{R}) =$

$$\frac{1}{4\pi}\int \frac{e^{-ik|r-R|}}{|r-R|}\left(\nabla p(\boldsymbol{r}) + p(\boldsymbol{r})\frac{(1+ik|r-\boldsymbol{R}|)}{|r-\boldsymbol{R}|^2}(\boldsymbol{r}\right.$$

- Pressure calculation outside the computational domain

Importing surface acceleration data

- Code is developed to convert finite element software nodal acceleration results to .csv format

COMSOL model setup

- Generic java file template is developed to reduce model set up time

Challenges

Computation time

- Increased computation time due to high node count of acoustic mesh for 500 – 3000 Hz
- Solution is split into four steps

a. 500 to 1000 Hz b. 1000 to 1500 Hz

c. 1500 to 2000 Hz d. 2000 to 3000 Hz

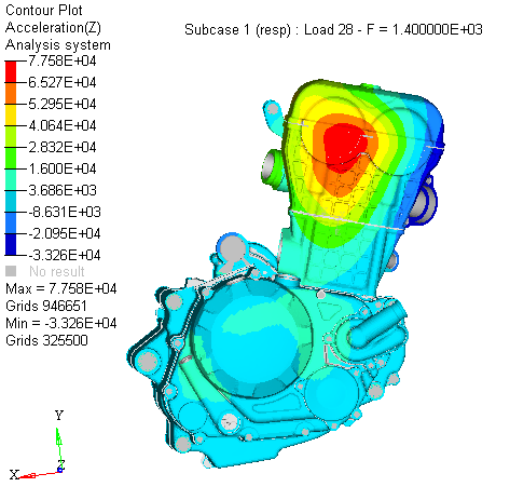
- Computation time is reduced due to low node count of acoustic mesh

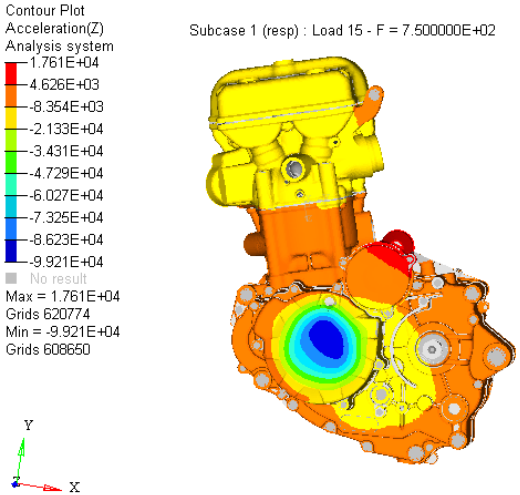
Solving for each frequency step (~ 40 steps)

- Process automation is carried out using Java script
- Compiled model files for Java (Class files) are generated
- COMSOL batch mode is used to solve class files without GUI

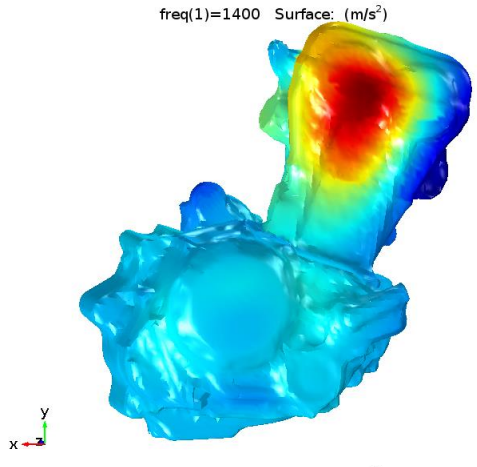
Interpolation in COMSOL

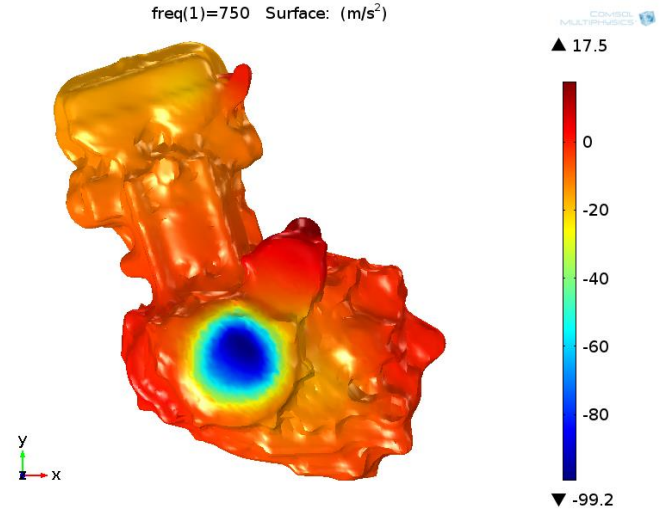
FE Model





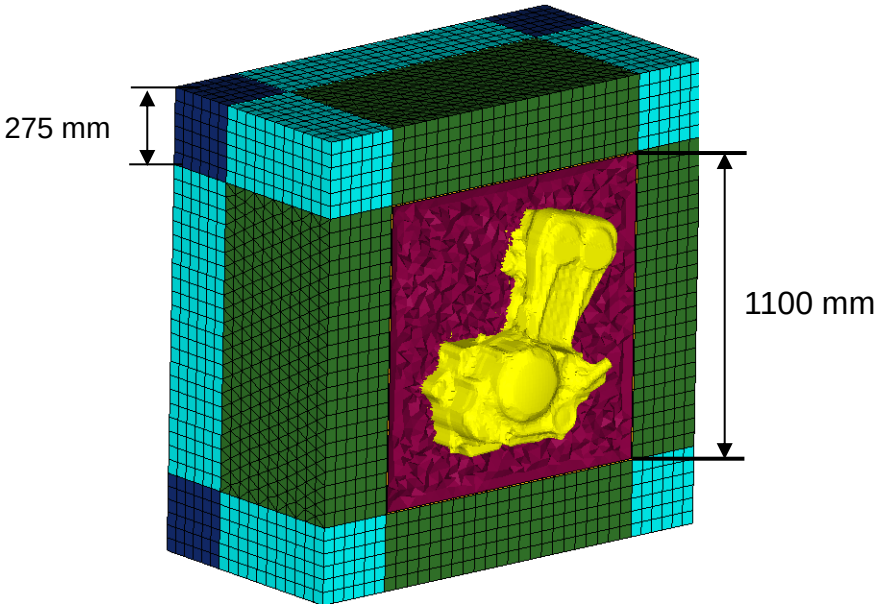
COMSOL





Mesh Convergence

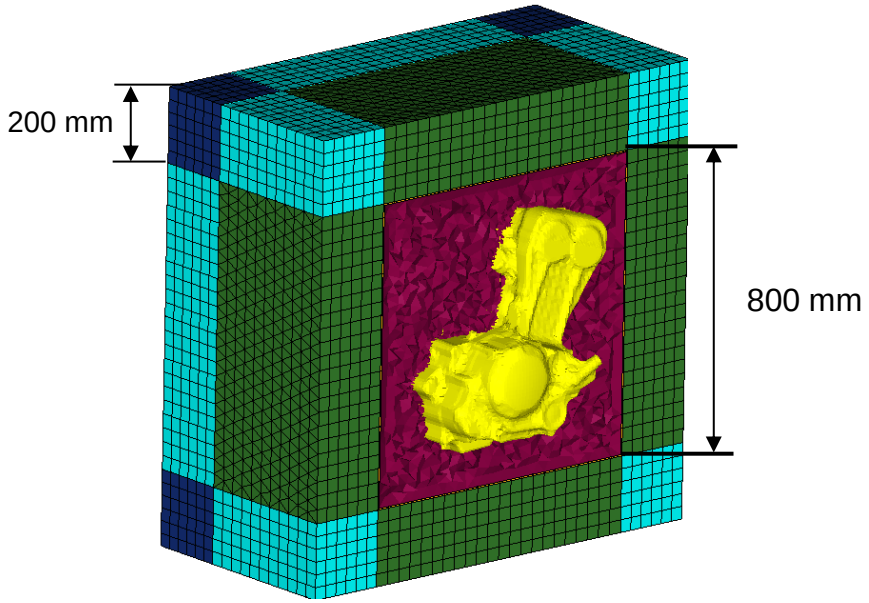
Acoustic Mesh 500 to 1000 Hz



Maximum Element Size = 58 mm
Boundary Layer Thickness = 5.8 mm

Location	SPL @ 1000 Hz [dB]
LH Side	67.20
RH Side	66.04

Acoustic Mesh 1000 to 1500 Hz



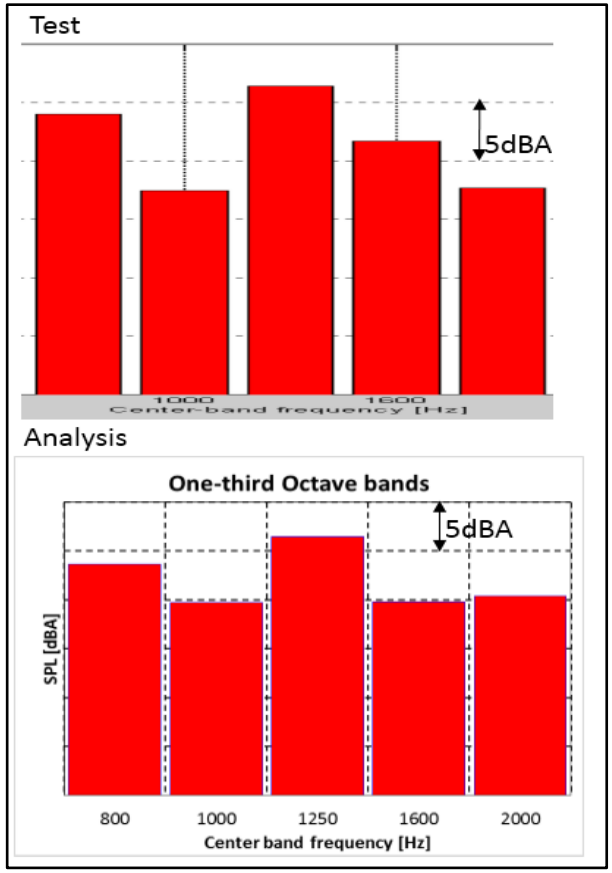
Maximum Element Size = 29 mm
Boundary Layer Thickness = 2.9 mm

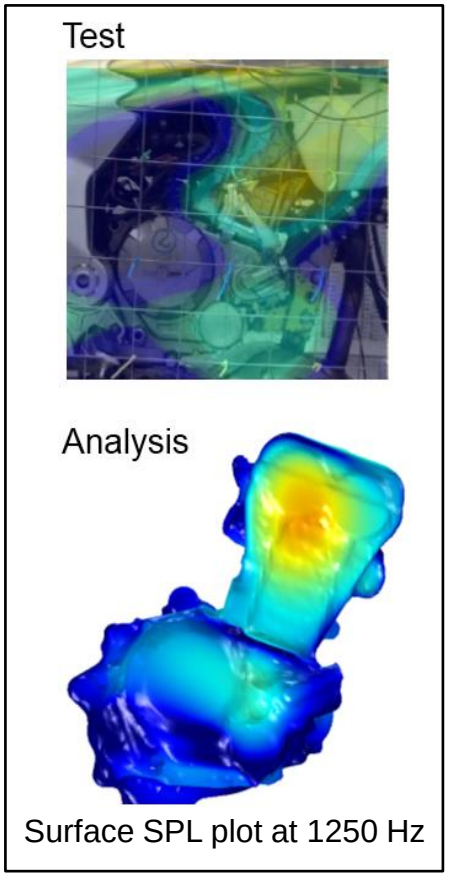
Location	SPL @ 1000 Hz [dB]
LH Side	67.19
RH Side	66.04

Noise Measurement Setup

- Microphone located in front of engine side cover at a distance of 0.5m

SPL and sound intensity plots correlation

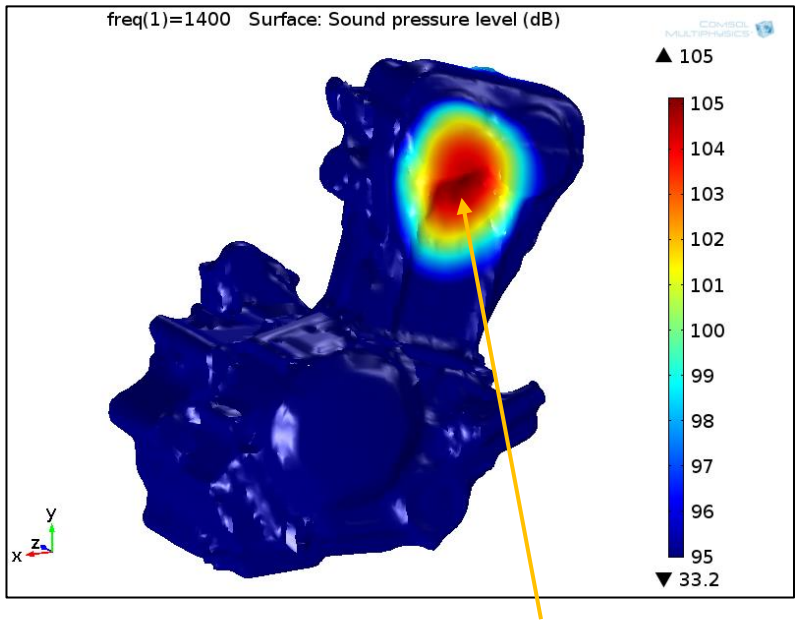




- SPL and sound intensity plots match well with test data

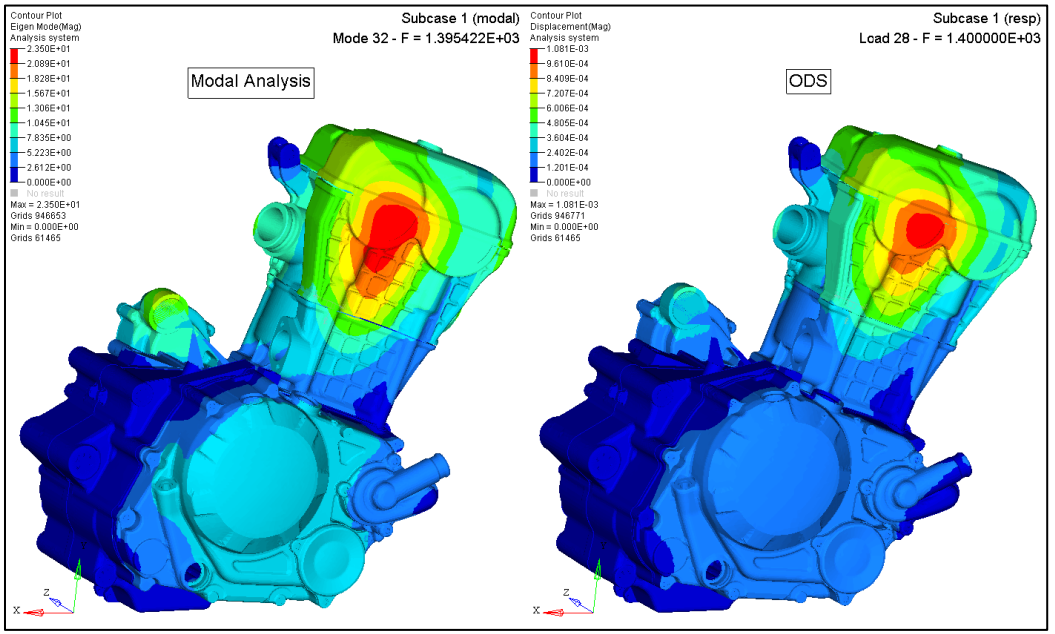
Results of vibration and acoustic analysis

3D Surface SPL Plot



Acoustic Radiation Location

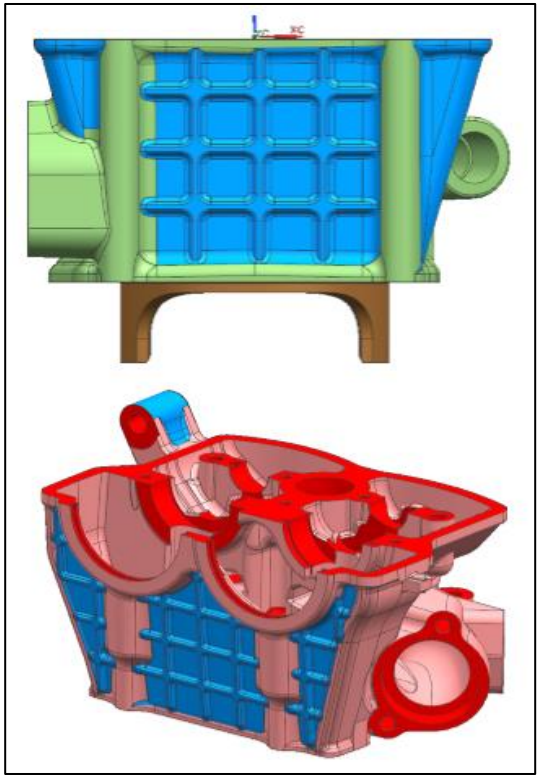
Vibration Analysis



Surface SPL plot helped to identify the critical locations on engine responsible for high SPL

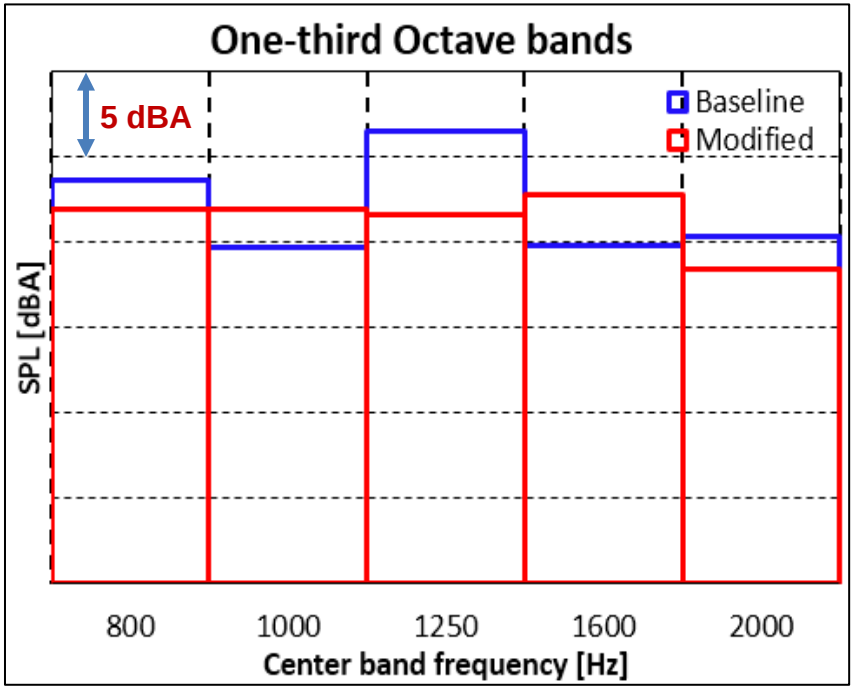
Based on modal analysis and ODS results, structural modifications are carried out in specific areas of engine structure

Modifications



- Rib height and wall thickness increased
- Stiffened mounting location

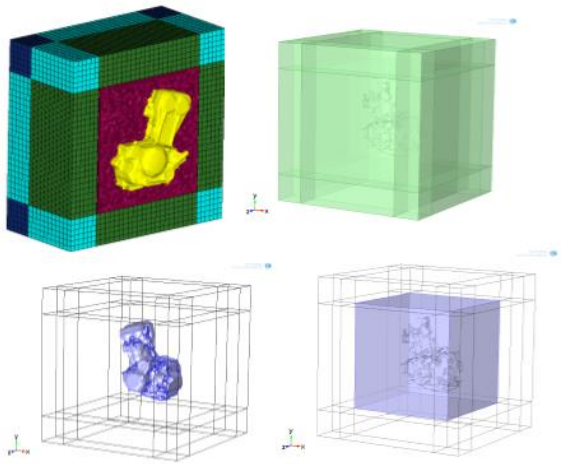
SPL Comparison – Baseline vs. Modified



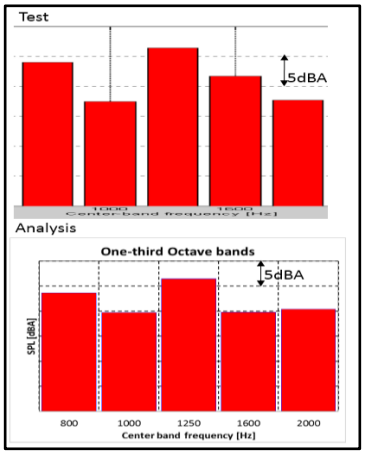
- With modifications, overall SPL is reduced by 3 dBA

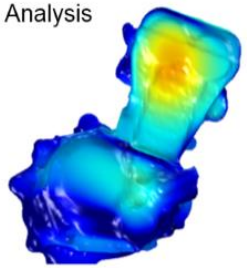
Conclusions

Acoustic analysis of single cylinder motorcycle engine is carried out using COMSOL



Analysis results show a reasonably good correlation with the test data





Process automation is carried out using Java script

- To interpolate nodal acceleration data on engine skin
- To solve the acoustic model for each frequency step

- Corrective actions by carrying out structural modifications can be implemented based on analysis results in early design stage
- Reduces time and cost involved in product development

THANK YOU