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Optimizing Vehicle Components Using Acoustic Transfer Functions

Contents:

LMS Conference on Physical and Virtual Prototyping
November 13-14, 2001 in Paris

LMS International 2001 Conference

Introduction

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- In general, the **Boundary Element Method (BEM)** is well suited to simulate sound radiation.
- However: considerable **computer resources** are needed.
  - CPU time
  - Memory
- **Therefore: usage of approximate methods instead of the rather accurate BEM**
  e.g., Input Power Method
- ***Idea: sound radiation analysis by means of Acoustic Transfer Functions (ATF)***

Numerical Engine Acoustics in SYSNOISE 5.5

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Acoustic Transfer Functions (1)

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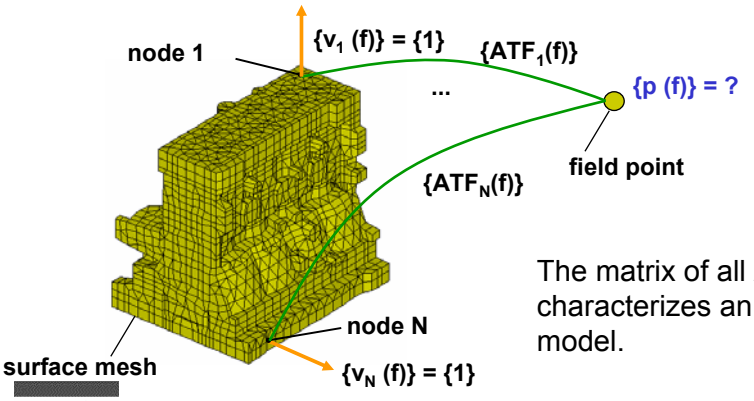
- ***ATF*** is an acoustic transfer function, which gives the ***Relation*** between the surface normal ***displacements/velocities at a surface node*** and the ***sound pressure at a given field point***.



The matrix of all ATF $[ATF_i(f)]$ characterizes an acoustic element model.

Acoustic Transfer Functions (2)

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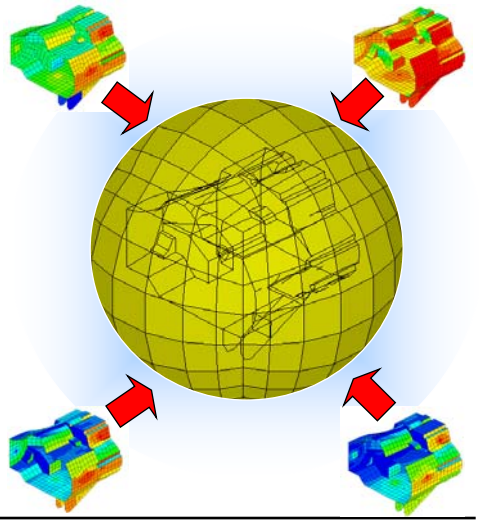
- **Acoustic Transfer Functions depend on:**
  - the shape of the model surface
  - the location of the field points
  - the fluid properties

but NOT **on boundary conditions such as displacements, velocities or accelerations!**



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Acoustic Transfer Functions (3)

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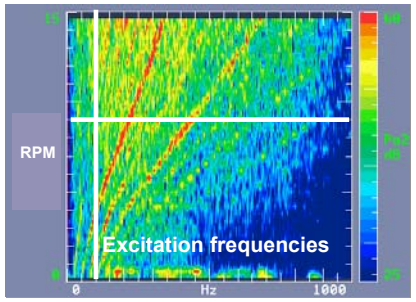
- **Pressure field calculation using ATF** (step-by-step)**:**
  - Model assemblage (*meshing, definition of field points, etc ...)*
  - ATF-Calculation (*needs as much CPU time as **one** BEM calculation)*
  - Input the boundary conditions *(e.g. the surface velocity {$v_n(f)$})*
  - ***Multiplication:***

$$\{p_{FP}(f)\} = [ATF(f)]\,\{v_n(f)\}$$

instead of solving the BEM-system of equations

  - Post-processing of the results
    (e.g. sound pressure sprectra)



Input Power Method

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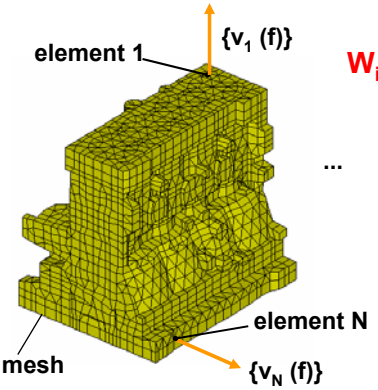
- With the ***Input Power Method*** **an estimation of the radiated noise is possible**. It is based on a summation of the ***element surface velocities*** of the acoustic mesh.



...

$$W_i(f) = \rho c\,(|v_1(f)|^2 + \ldots + |v_N(f)|^2)$$

BEM vs. Input Power Method (1)

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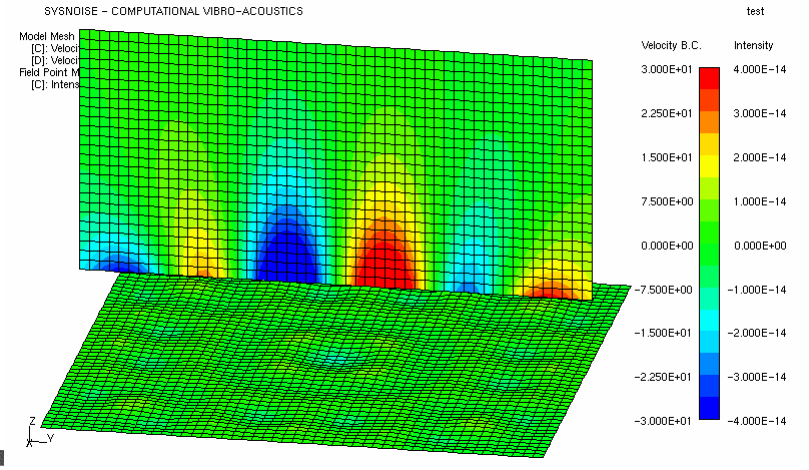
- **Cancellation of acoustical waves**



BEM vs. Input Power Method (2)

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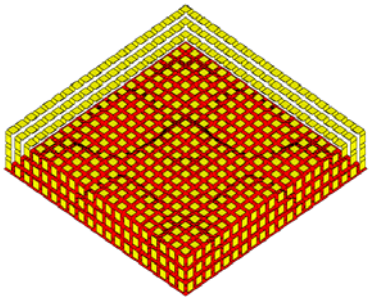
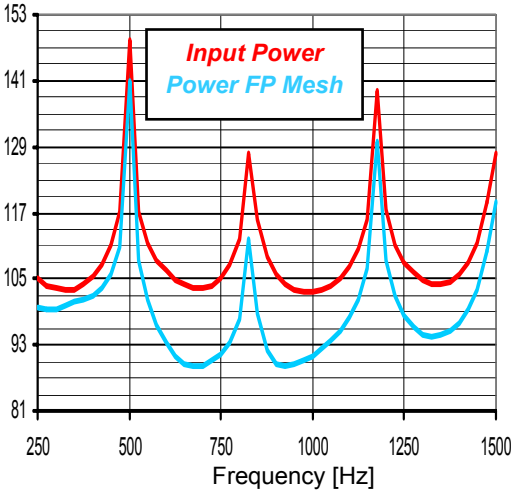
- **Plane plate**
  25 x 25 x 2 mm





BEM vs. Input Power Method (3)

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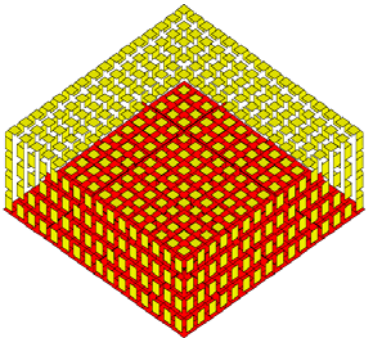
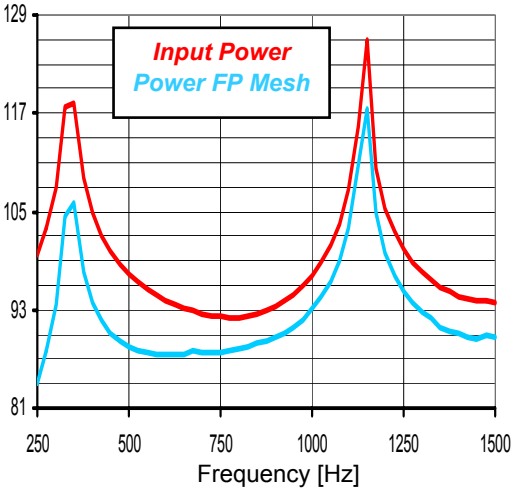
- **Plate with stiffeners**
  25 x 25 x 2 mm
  ribs 8 mm height





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Comparison of two designs (1)

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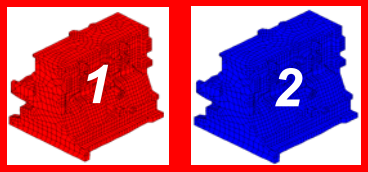
- **Question:** ***Which design is less noisy?***

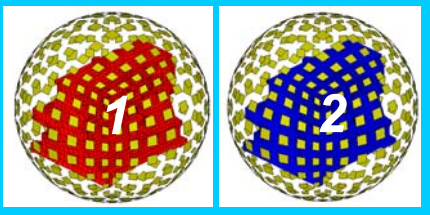
Input Power Method



Result according to:

Input Power 1 - Input Power 2 > 0

Boundary Element Method



Result according to:

FP Power 1 - FP Power 2 > 0

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Comparison of two designs (2)

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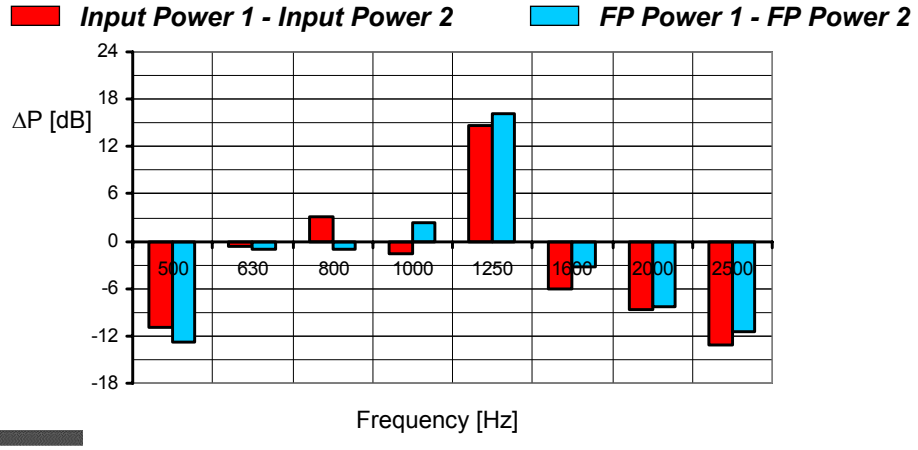
- **Comparison of two oil pans *design 1 and 2***



Comparison of two designs (3)

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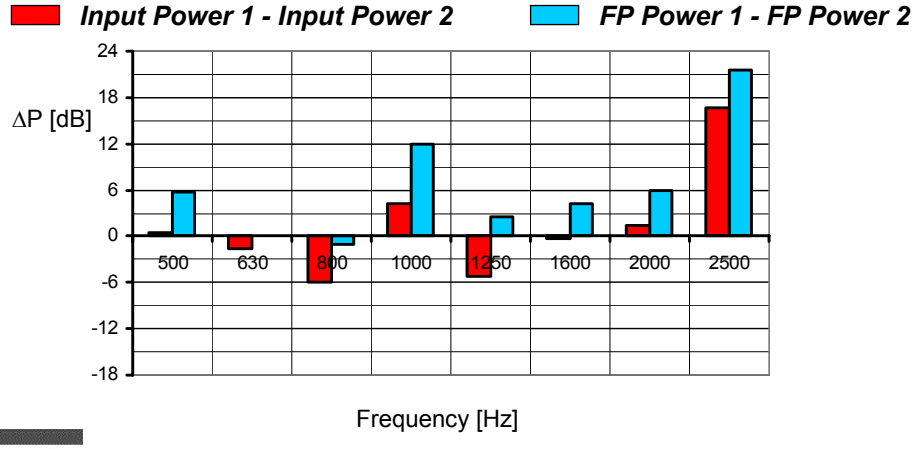
- **Comparison of two oil pans *design 1 and 3***



Optimizing an oil pan using ATF

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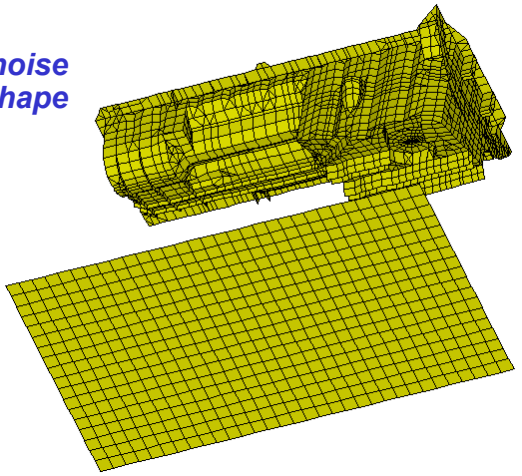
- **Objective**

  Reduction of the radiated noise by an optimization of the shape of the surface

- **Model**
  - oil pan
  - free field conditions
  - field points at street level as a control surface



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Optimizing procedure *step 1*

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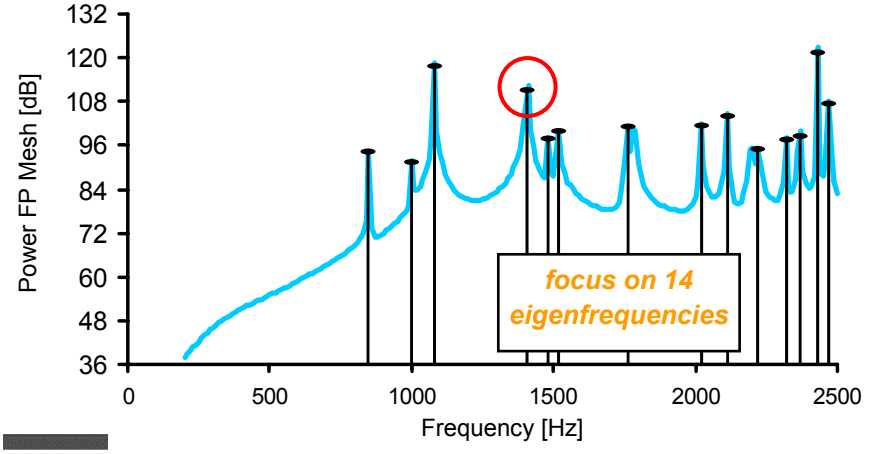
- **FRF of the power radiated thru the field point mesh**



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Optimizing procedure *step 2* (1)

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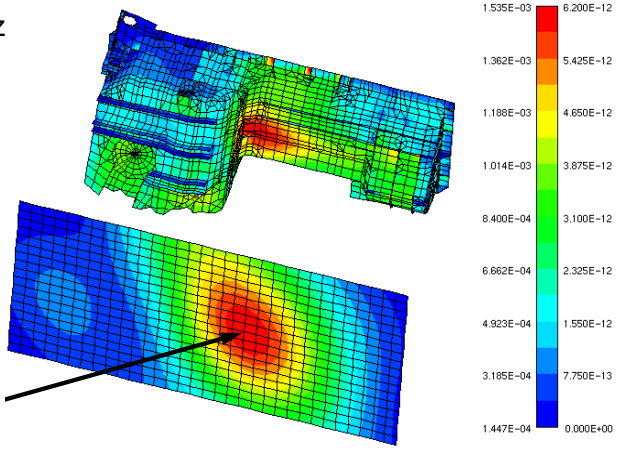
- **Analysis of the intensities and the ATFs**
  - e.g., peak f = 1410 Hz
  - Calculate the maximum of the intensities at the field points
  - Determine the respective acoustical transfer functions



field points: 344, 345, ...

Optimizing procedure *step 3*

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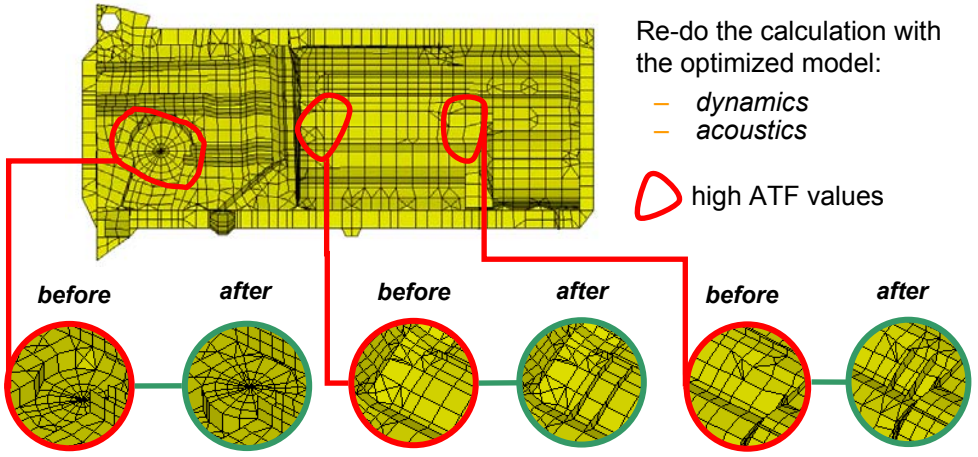
- **Optimization of the model surface**



Re-do the calculation with the optimized model:
- *dynamics*
- *acoustics*

high ATF values

Optimizing procedure *step 4* (1)

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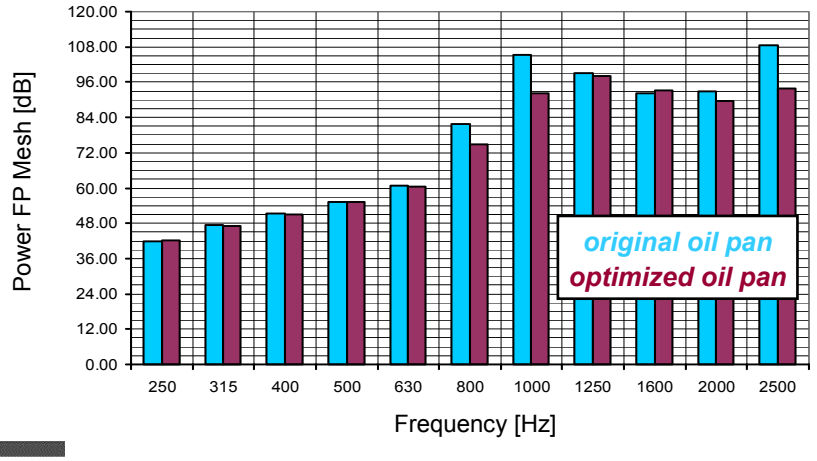
- **Post-processing of the results**



Optimizing procedure *step 4* (2)

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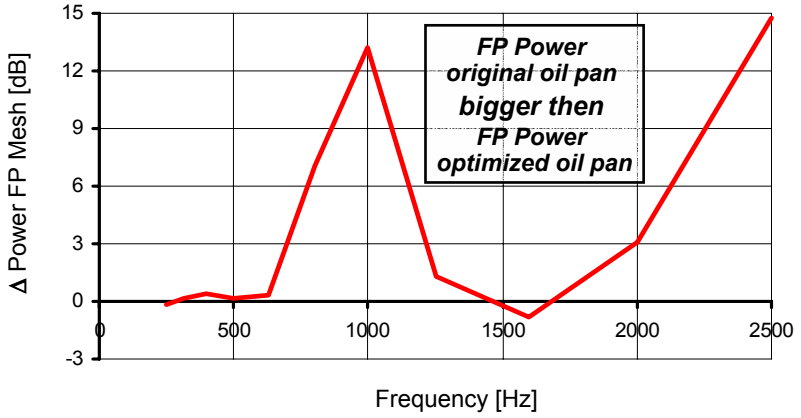
- **Post-processing of the results**



Conclusions

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- ***Acoustic Transfer Functions*** are a ***valuable extension*** of the Boundary Element Method.
- The simplified calculation using the ***Input Power Method*** is **not always reliable.**
- *The* ***discussed procedure*** for acoustical optimization (demonstrated by means of an oil pan)
  - may lead to a significant **reduction of** the radiated **noise**,
  - is a very **efficient procedure**,
  - takes into account the generated sound field in all its complexity.