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Dynamic stiffness optimization using Radioss

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Definition

Dynamic stiffness

- The dynamic stiffness is the frequency dependant ratio between a dynamic force and the resulting dynamic displacement.
- Similarly, the well-known static stiffness is the ratio between a static force and the resulting static deflection.

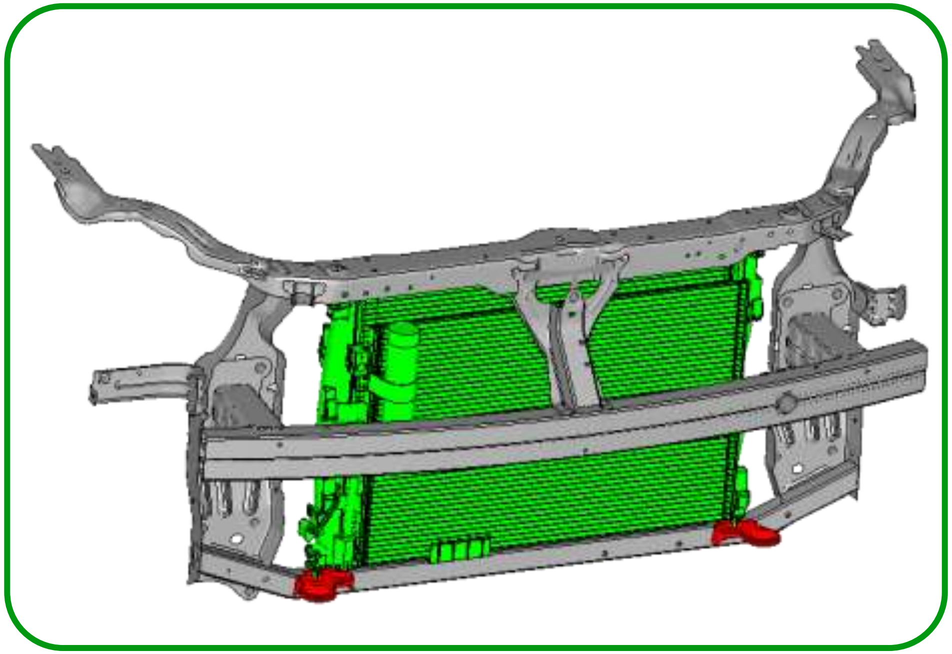
$$\text{Dynamic stiffness} = \frac{\text{Force (frequency)}}{\text{Vibration response}}$$

The increase of the dynamic stiffness will reduce the vibration response of the system

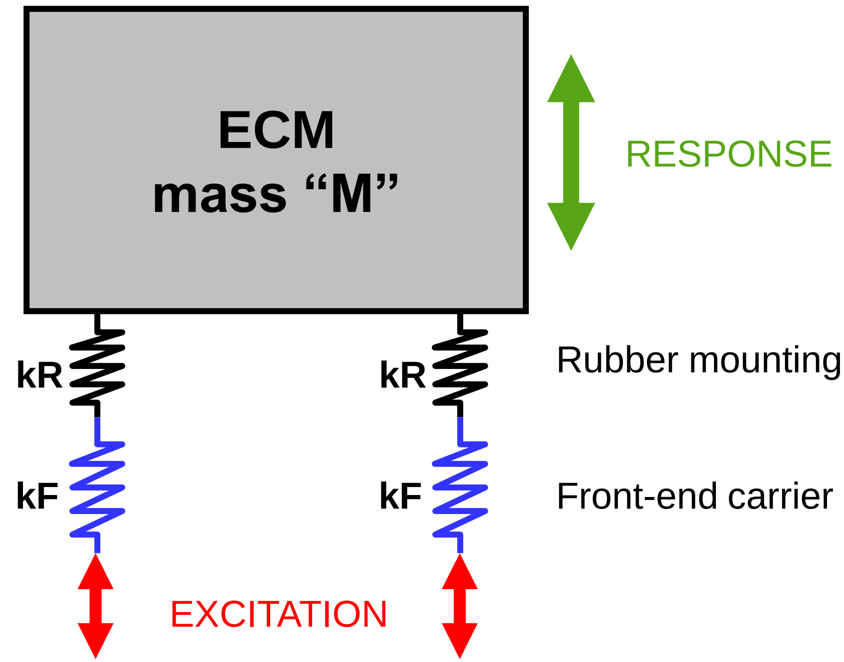
Application on a front-end carrier

Benefits:

- ➔ Reduces the excitation of the ECM
- ➔ Contributes to the noise reduction
- ➔ Orients rubber mountings choice/design
- ➔ Lighten the structure



2D simplification



Equivalent stiffness (per side):

$$\frac{1}{K} = \frac{1}{kR} + \frac{1}{kF}$$

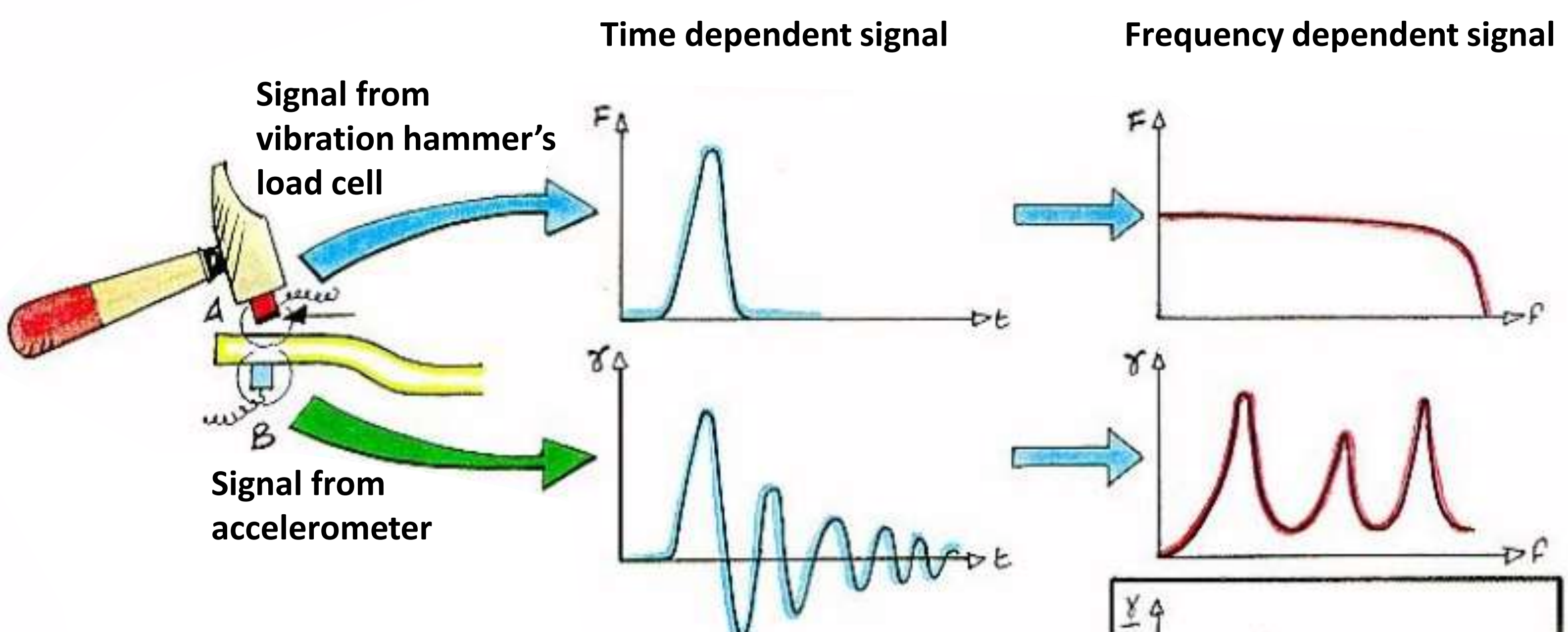
$$K = \frac{kR \times kF}{kR + kF}$$

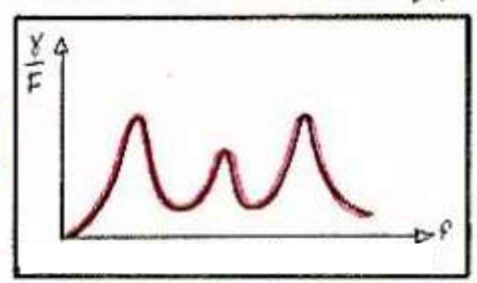
The suspension mode of the ECM is:

$$f_0 = \frac{1}{2\pi} \times \sqrt{\frac{2K}{M}}$$

Accelerance definition

- **Accelerance is the frequency dependent acceleration of a point divided by the force excitation as follows:**





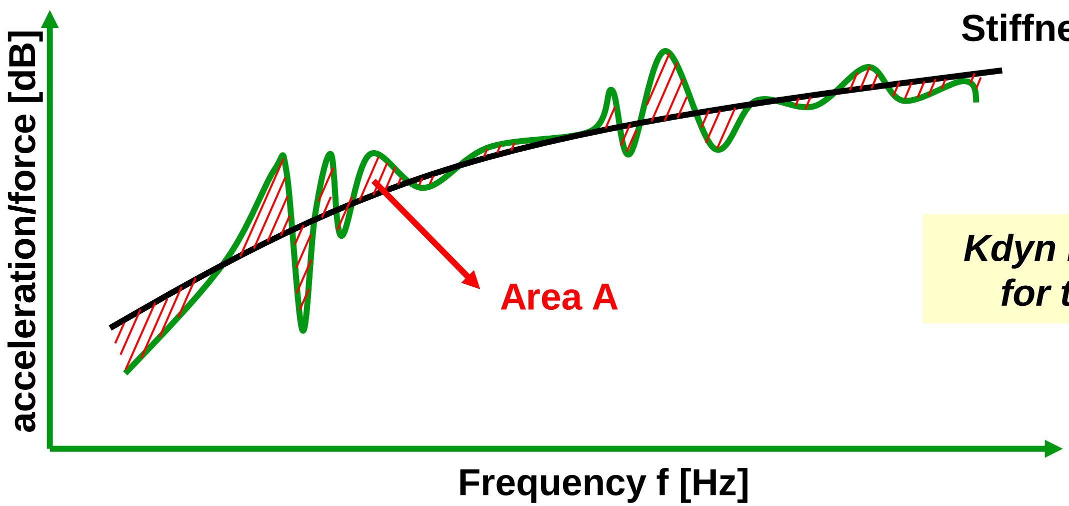
If the input force point 'A' is close to the output acceleration point 'B', we're talking about ACCELERANCE.

If the point 'A' is far from the point 'B', it's the TRANSFER.

Chanal method definition

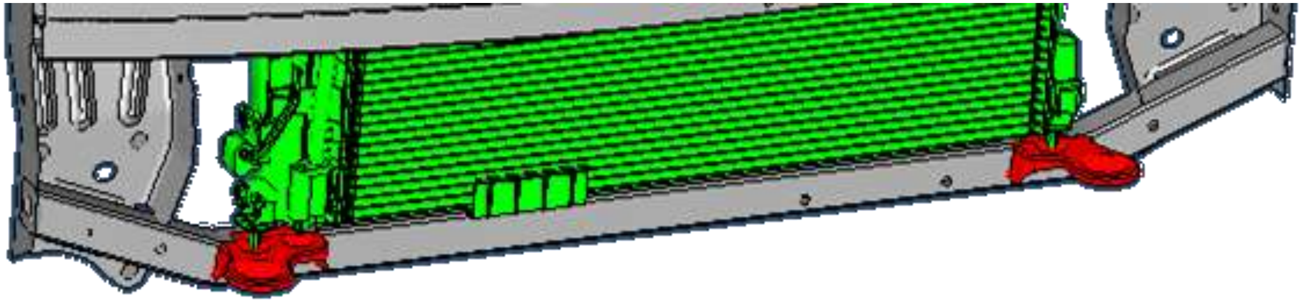
- **The Chanal method consists to find the curve that the area between the accelerance curve and the stiffness curve is a minima.**
- **The resultant stiffness is dependent of the frequency range of interest.**

Stiffness curve = 20 log [$(2 \pi f)^2$ / Kdyn]

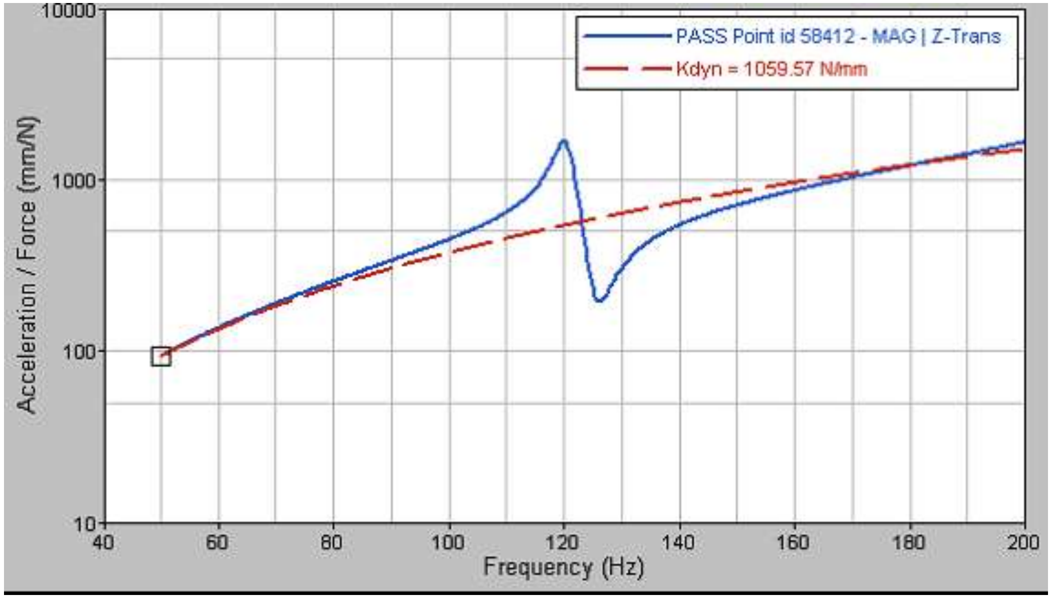


Kdyn is determined looking for the minimum area A

Steel bracket example



- **The 'red' bracket above is 1.2 mm thick. The square tube is 2.0 mm. The accelerance curve over 50-200 Hz with its respective Kdyn is:**



This design don't achieve the minimum stiffness requirement (Kdyn > 1200 N/mm). The mass of the tube and the brackets is 2.5kg.
How can we proceed?

Steel bracket example

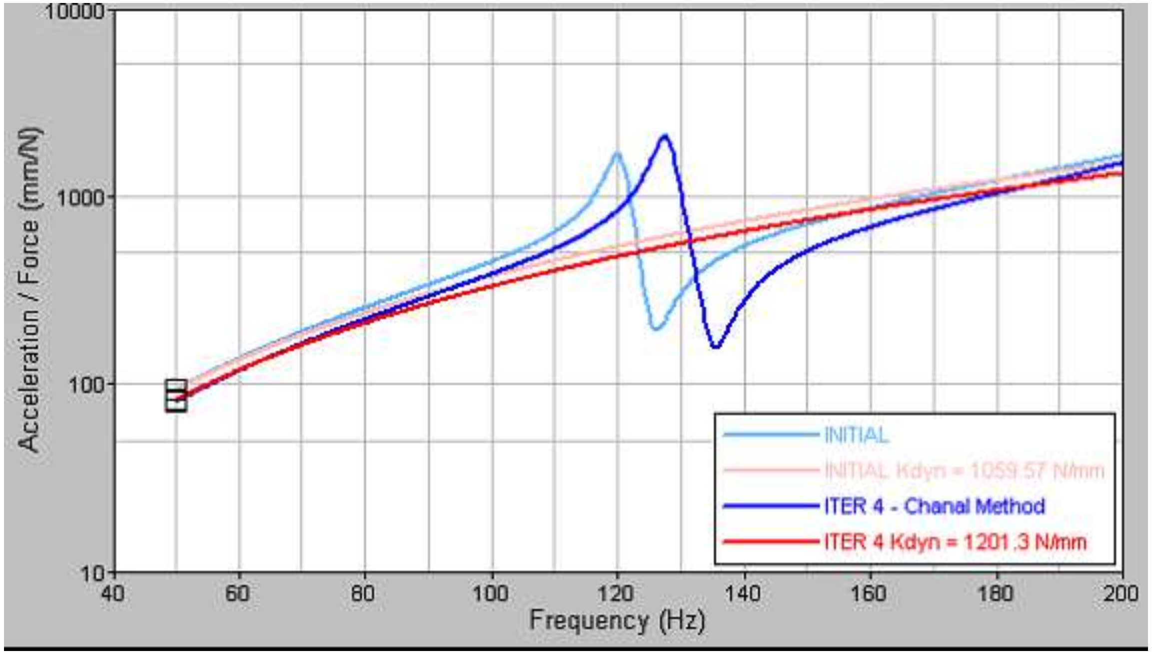
- **The goal of the optimization is to reduce the mass.**
- **The minimum/maximum thickness allowed are:**
  - 1.2 / 2.0 mm for the tube
  - 1.0 / 3.0 mm for the brackets
- **2 DESVARS cards were used (for each component)**
- **The FRF uses a FREQ1 card in order to use the Chanal Method**
- **Optistruct deals with the dynamic stiffness calculated from the DRESP1 (FRACCL) of each acceleration response of the ECM fixing point.**

Steel bracket example

- **Optistruct finds the best design in 4 iterations:**
  - ➔ Tube: 1.2 mm
  - ➔ Brackets: 1.6 mm

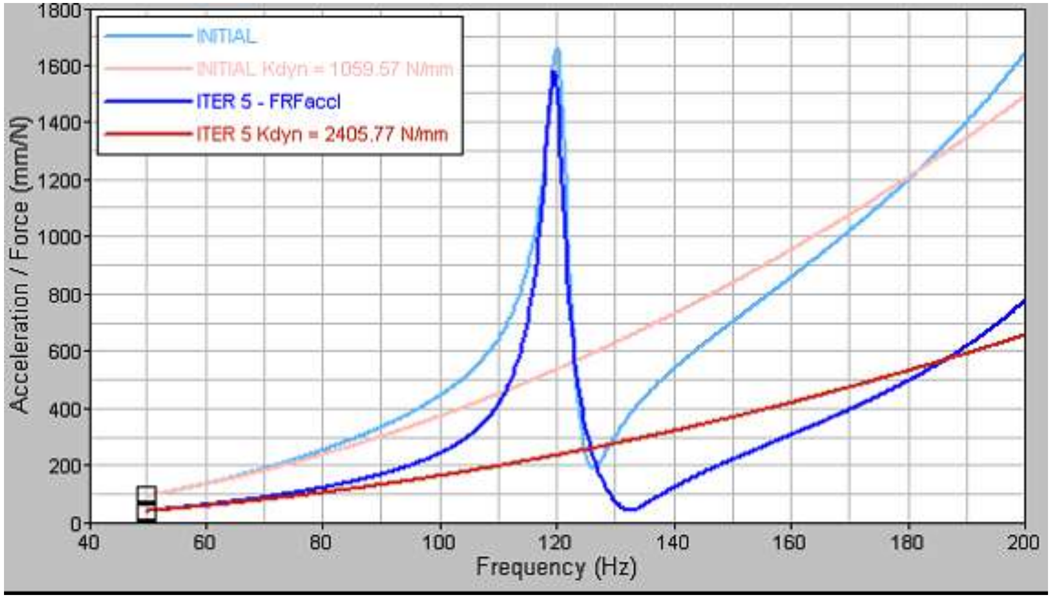
- **The final mass becomes 1.6 kg (-36.2%)**

- **The vertical bending mode of the lower brackets is increased from 121 to 128 Hz**



Steel bracket example

- **Using conventional DRESP1 with FRACCL**
  - → The objective function is min(mass² *x* avg(FRACCL)²)
- **After 5 iterations, the thicknesses are:**
  - → Tube: 1.726 mm
  - → Brackets: 3.0 mm
- **Mass reduction of 4.8%, 2.4 kg.**
- **Computed kdyn is 2406 N/mm (over estimated)**



Conclusions

- **Limitations using conventional DRESP1 with FRACCL:**
  - ➔ Impossible to constrain the dynamic stiffness
  - ➔ The design is often over estimated
  - ➔ The mass should be constrained or used with another response to define a kind of objective function

- **Many possibilities can be used with the equivalent stiffness by Chanal Method equations:**
  - ➔ Size, morphing, free shape and topography optimization when working with sheet metal parts;
  - ➔ Size, free size, free shape, morphing and topology optimization when working with plastic designed parts.