Replacing Strain Measurements by Vibration Measurements

Identification of orthotrotropic Engineering Constants of composite Materials

BYTEC BV

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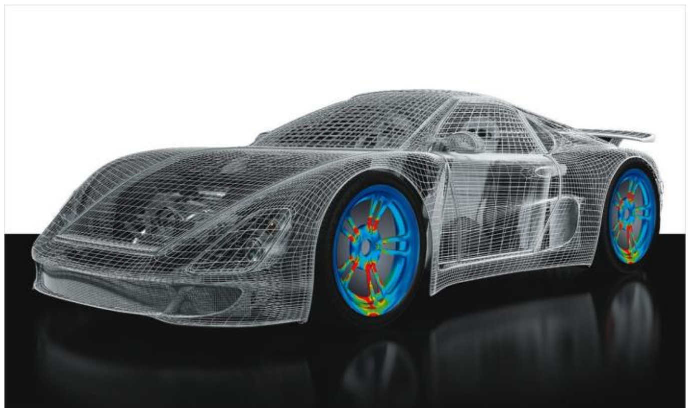
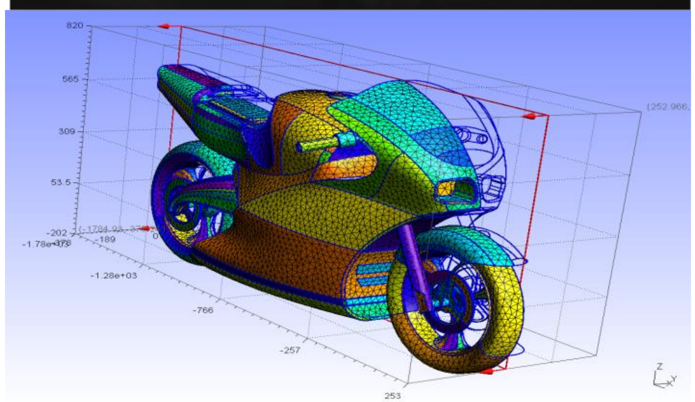
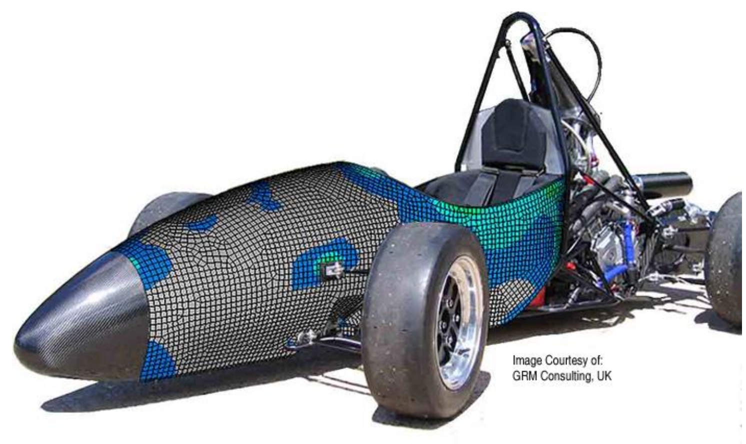
Dynamically loaded Structures



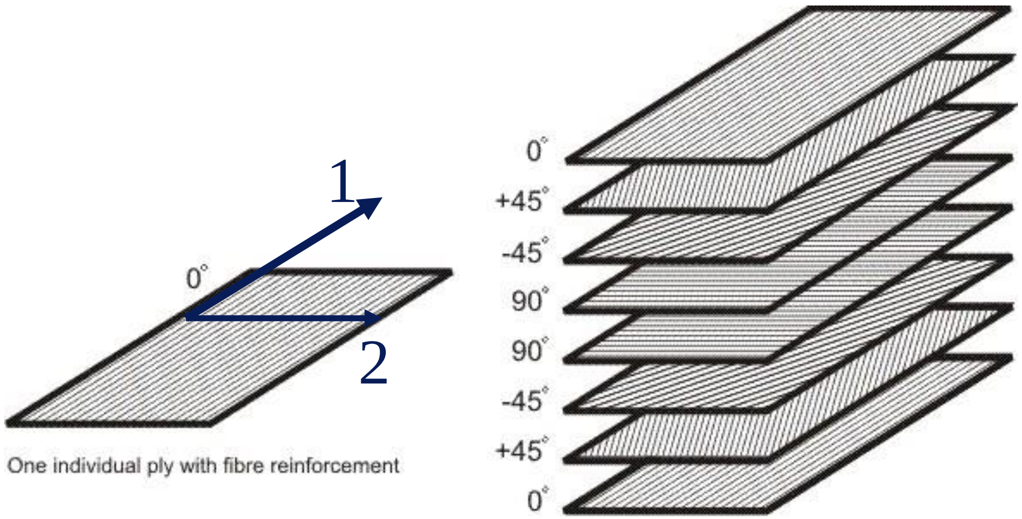


Innovative
Vehicles, cars
Airplanes
Sporting goods



→ Laminated Composite Materials

Laminated Composite materials



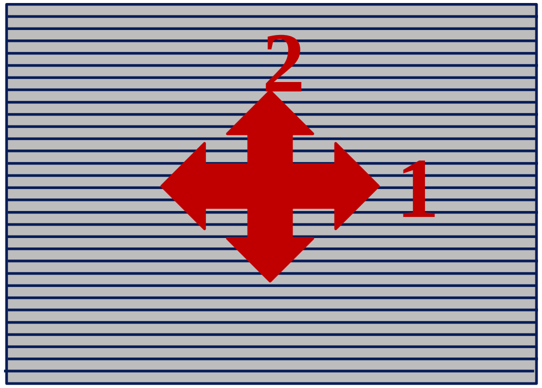
One individual ply with fibre reinforcement

Stacking of plies into a composite laminate with different angles of the fibre reinforcement

Orthotropic layers of fibre reinforced composite material (Uni-directional, Bi-directional, Textile, …)

→ Laminate Analysis Programs

Mechanical properties.

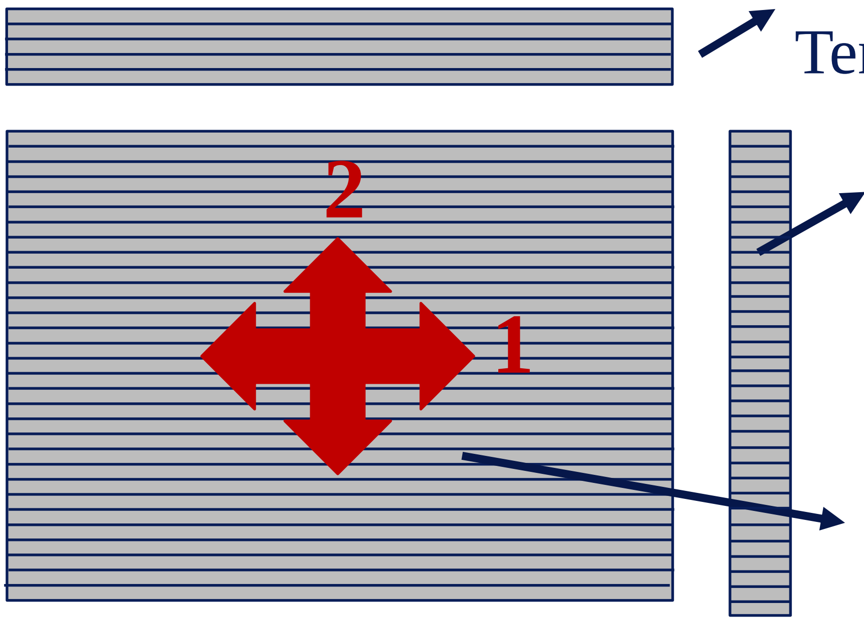


Each Orthotropic Layer :

- 4 Engineering constants: 2 Young's moduli E_1, E_2, Poisson's ratio v_{12} and the in-plane shear modulus G_{12}
- 3 Failure stresses: 2 Normal Failure stresses X_1, X_2 and a shear failure stress S_{12}

Totally 7 important mechanical properties: E_1, E_2 v_{12} G_{12}
X_1, X_2 S_{12}

Measuring the Mechanical properties of Orthotropic layers.



Test Beam in 1-direction

Tensile Test: E_1, ν_{12}, X_1

Test Beam in 2-direction

Tensile Test: E_2, X_2

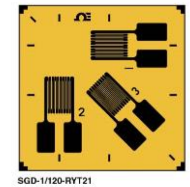
Test Plate

Rail shear Test: G_{12}, S_{12}

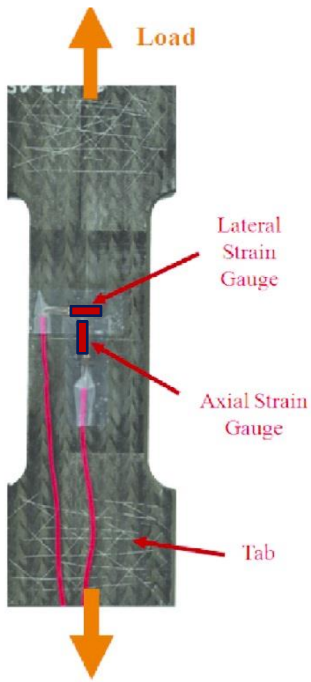
1 First orthotropic material axis (e.g. fibre direction)

2 Second orthotropic material axis (e.g. perpendicular on the fibre direction)

Measuring the Engineering Constants by strain gages

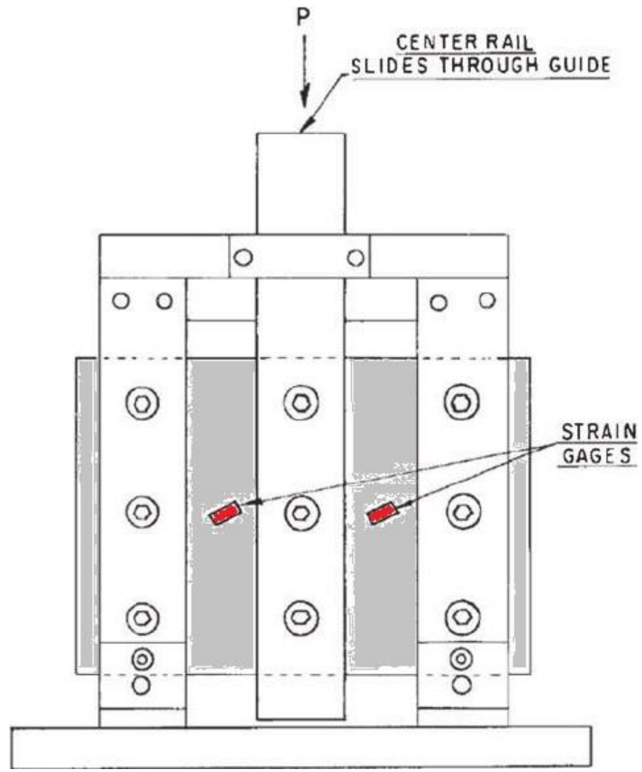


Strain gages



Tensile Test

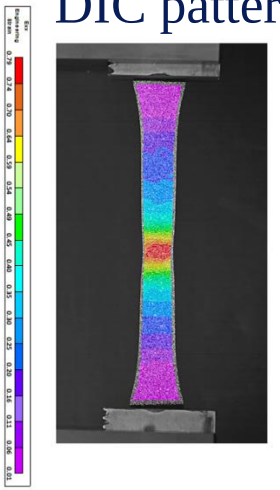
E_1, E_2, ν_{12}



Rail Shear Test: G_{12}

Alternatives for strain gages

DIC patterns

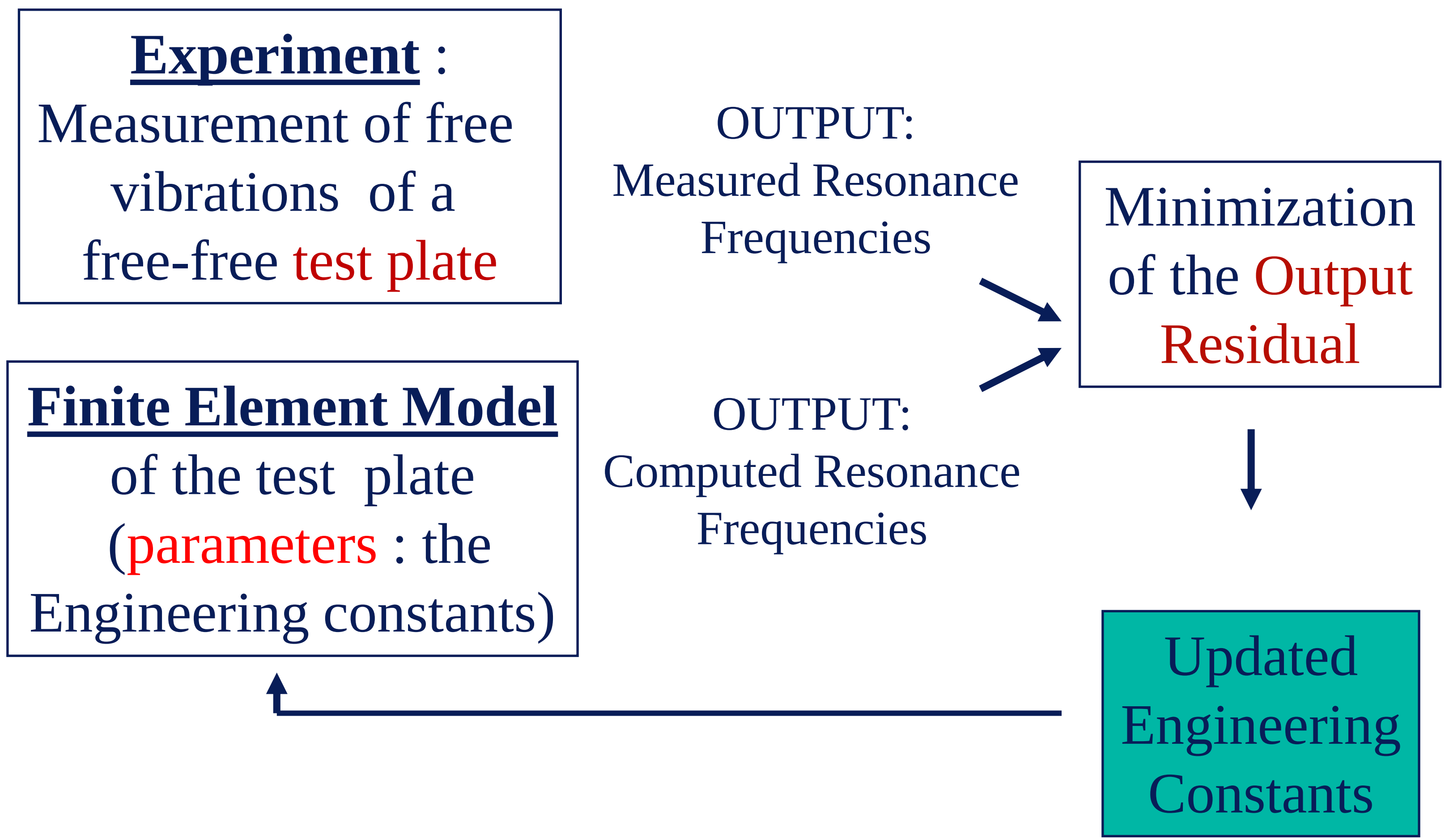


Extensometers

Requires:

- Careful specimen preparations
- Skilful operator
- Expensive equipment
- Expensive consumables
- Time

Overcome all the mentioned difficulties: Identification of Engineering Constants by Vibration Measurements

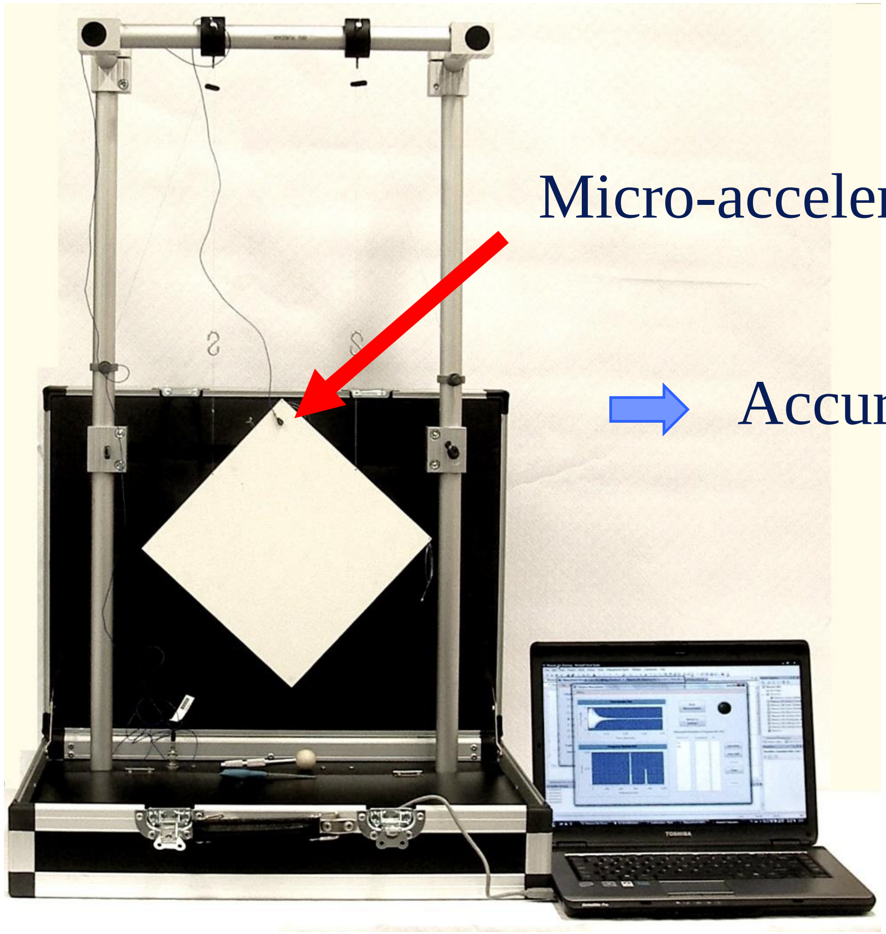


Quality of Vibration Analysis

How good are the final results?

- Are the measured frequencies accurate?
- Is the Numerical computer model accurate?
- Are the starting values reasonably good ?
- Is there enough information in the measured frequencies to extract the Engineering constants?

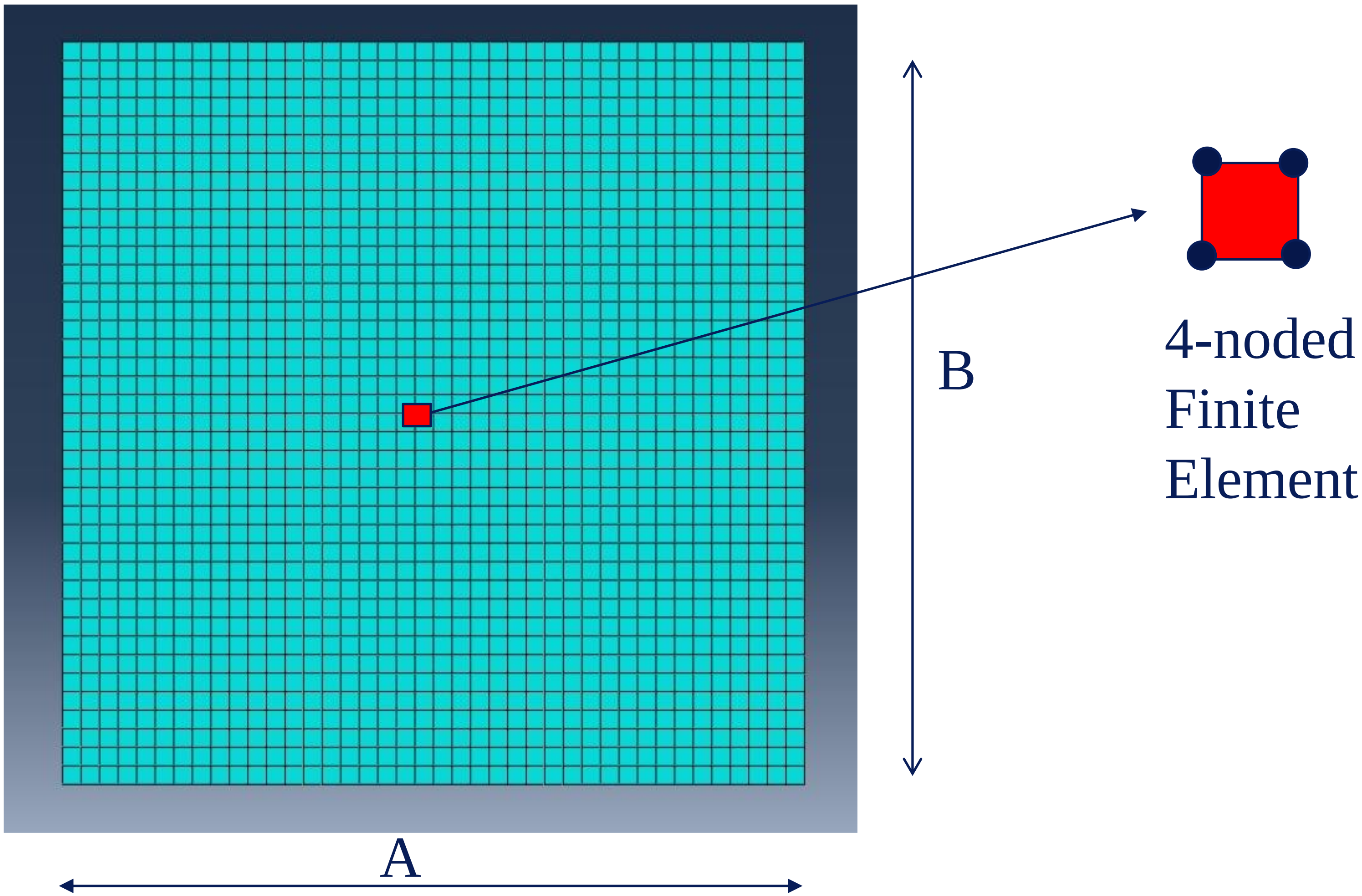
Measurement of frequencies on freely suspended test plates



Micro-accelerometer

Accuracy better than 0.1%

Accuracy of the Finite Element Model of a Test Plate



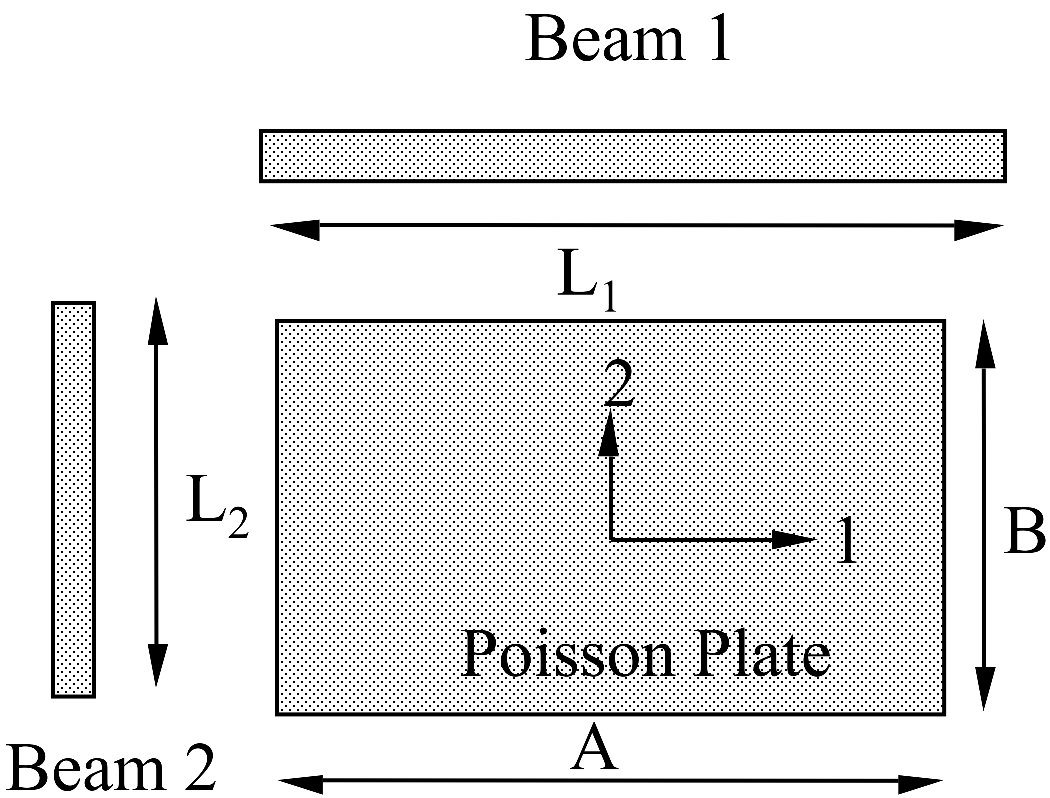
➡ Accuracy better than 0.1%

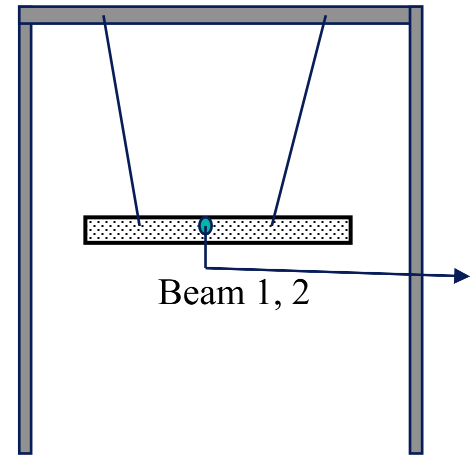
Quality of Vibration Analysis

How good are the results?

- ✓ Are the measured frequencies accurate? Yes!
- ✓ Is the Numerical computer model accurate? Yes!
- Are there good starting values?
- Is there enough information in the measured frequencies to extract the Engineering constants?

Resonalyser Procedure

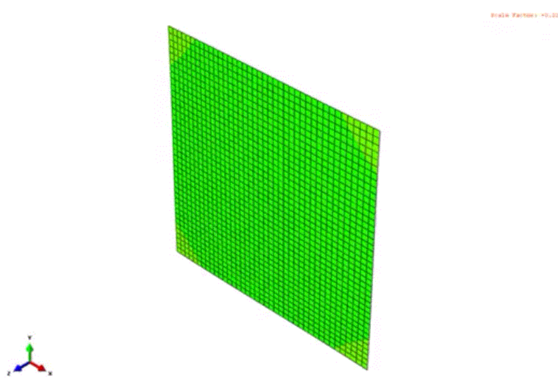




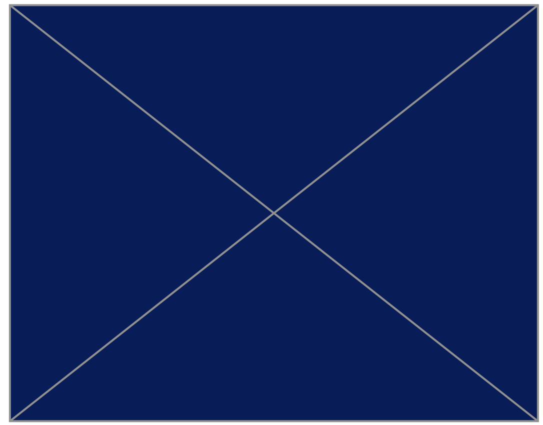
$$\frac{A}{B} = \frac{L_1}{L_2}\sqrt{\frac{f_1}{f_2}}$$

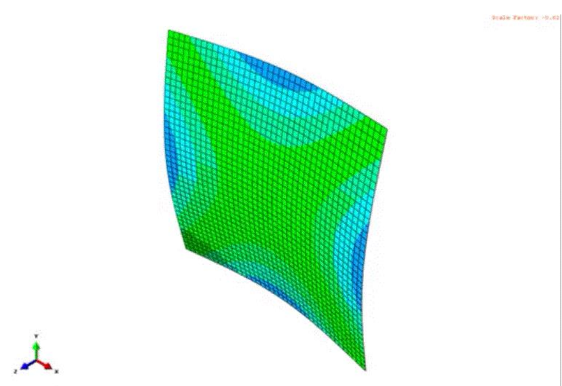
Mode shapes 3 first Resonance Frequencies

Freq 1
"Torsion" mode

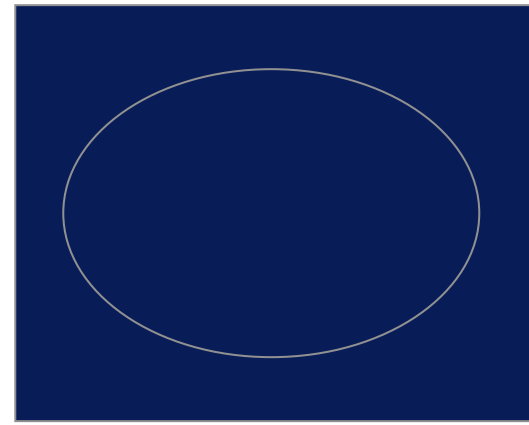


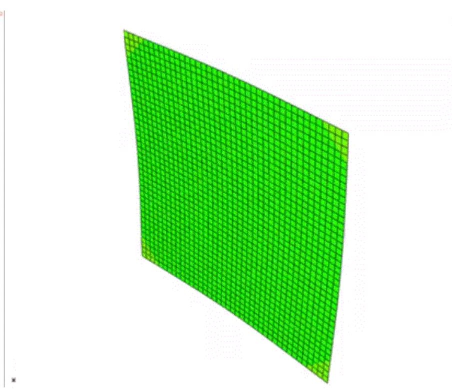
Freq 2
"Saddle" mode



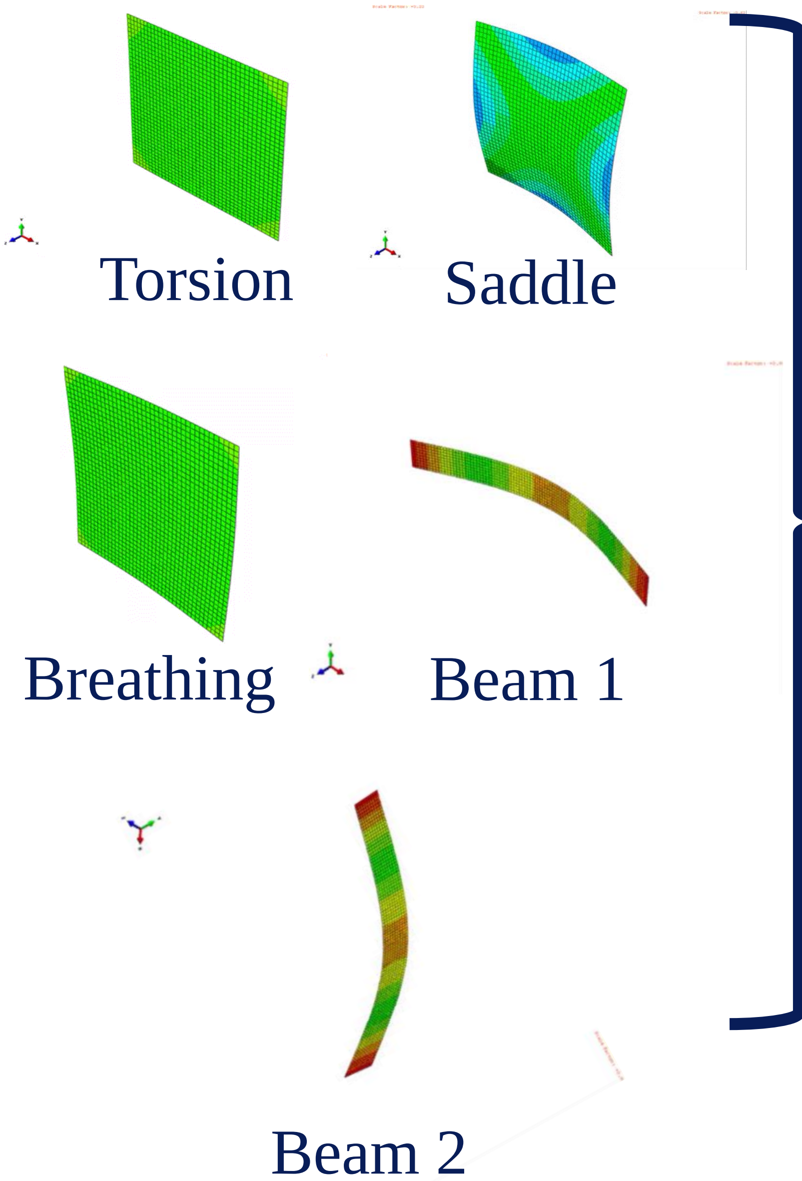


Freq 3
"Breathing" mode





5 frequencies for 4 parameters E_1, E_2, v_{12} and G_{12}



The 3 Resonance Frequencies of the Poisson plate and 2 frequencies of the beams have enough information to identify the 4 Engineering constants

The modeshapes of the beams and plate are fixed.

This allows to generate good starting values using the Virtual Field method

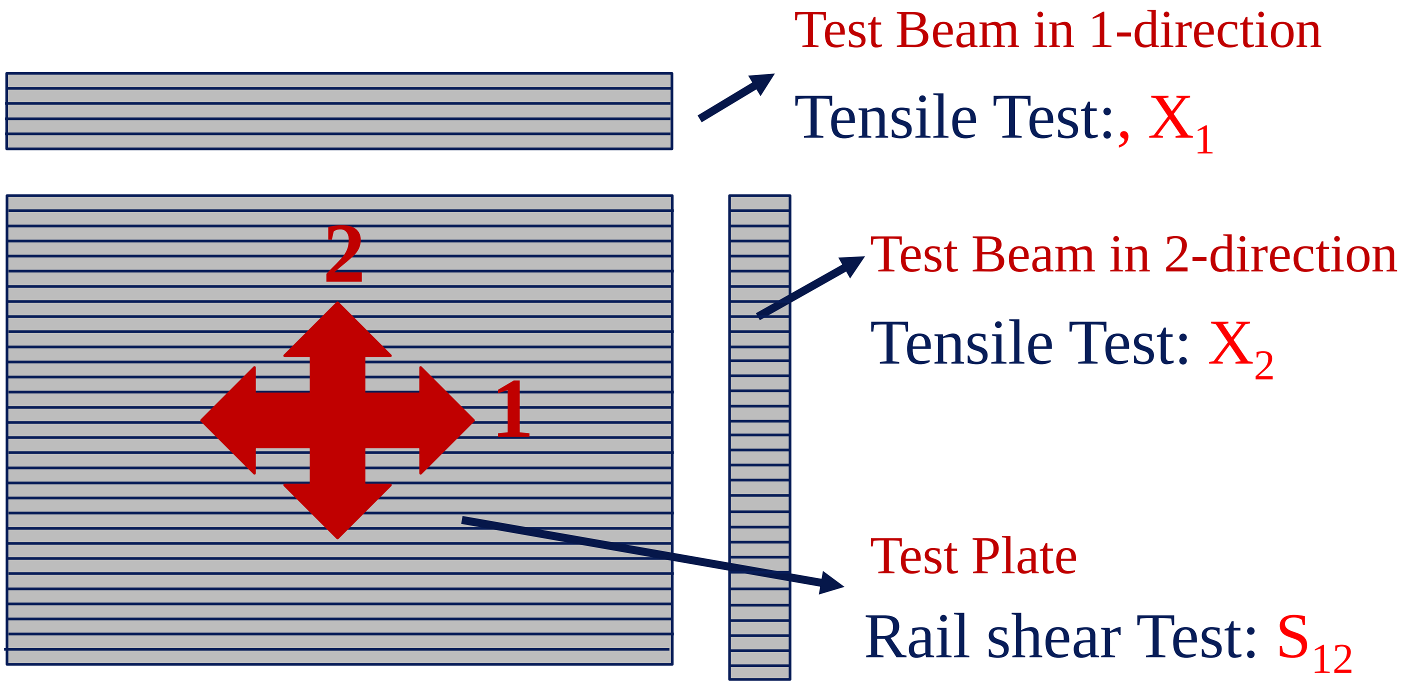
Quality of Inverse Methods

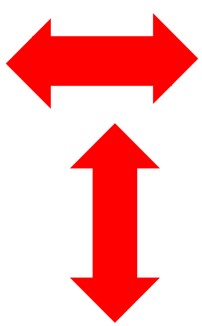
How good are the results?

- ✓ Are the measured frequencies accurate? Yes!
- ✓ Is the Numerical computer model accurate? Yes!
- ✓ Are there good starting values? Yes!
- ✓ Is there enough information in the measured frequencies to extract the Engineering constants? Yes!

⇨ Convergence to Accurate results

Measuring the Failure Stresses without strain measurements





1 First orthotropic material axis (e.g. fibre direction)

2 Second orthotropic material axis (e.g. perpendicular on the fibre direction)

Procedure for the 7 Mechanical Properties of Orthotropic Materials without strain measurement

- Cut 2 beams in the orthotropic directions.
- Measure the fundamental Resonance frequency of each of the 2 freely suspended beams: f_1 and f_2.
- Cut a Poisson test plate according to formula $\frac{A}{B} = \frac{L_1}{L_2}\sqrt{\frac{f_1}{f_2}}$
- Measure 3 first frequencies of the Poisson plate
- Apply the Resonalyser procedure to identify
  E_1, E_2, v_{12} and G_{12}.
- Do a tensile test on the two beams and a rail shear test on the Poisson plate to find X_1, X_2 and S_{12}

Conclusion

Time consuming and expensive strain measurements for the identification of the Engineering constants can be replaced by accurate and fast frequency measurements using the Resonalyser method.

The principle of this disrupting method is to **relief human** experimental **effort** and put more **computer power** at work.

- Learn more about our equipment and technique at *www.resonalyser.com* and have a peek at our SAMPE Amsterdam 2020 video presentation *https://youtu.be/z2bfT4EFaKI*

- Interested in a free demo measurement on one of your own samples?

  Contact our representative **IMCE NV**:

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  ✉ *info@imce.net*