POLITECNICO
MILANO 1863

DEPARTMENT OF
MECHANICAL ENGINEERING

ADVANCED DYNAMICS OF MECHANICAL SYSTEMS

Assignment 1 – Part B
Experimental Modal Analysis of a light rail wheel

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TARGET

Identify the modal parameters of a real system through Experimental Modal Analysis.

Contents:

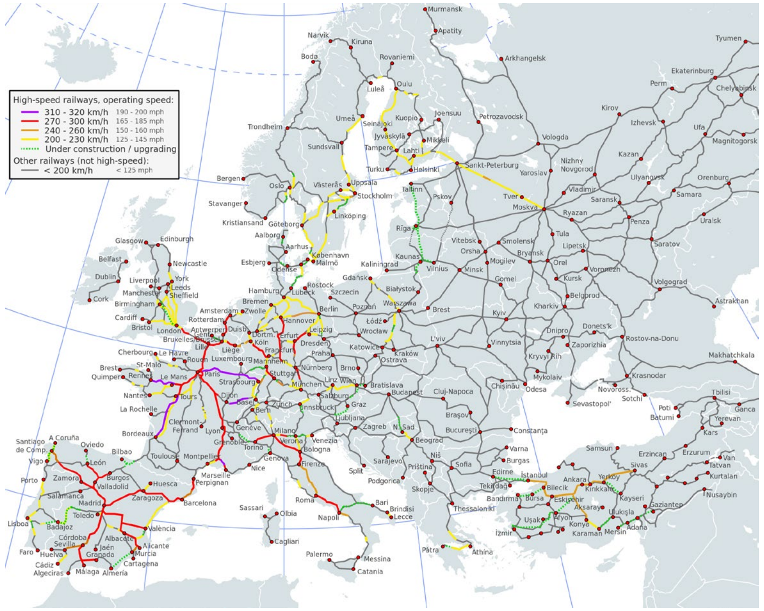
- The structure under test
- Experimental setup
    - ❑ Constraints → how to fix the system
    - ❑ Input → how to excite the system
    - ❑ Output → what to measure
- Signal processing (FRF and coherence function)

CONTEXT AND MOTIVATION (1)

Railway transportation is an efficient, fast and environmentally friendly way of transporting people and goods around continents.

Strengths of rail transportation

- Steel wheels rolling on steel rails (low friction, high loads, self-guidance, high speed)
- Ease of electrification, high power
- High safety during operations



CONTEXT AND MOTIVATION (2)

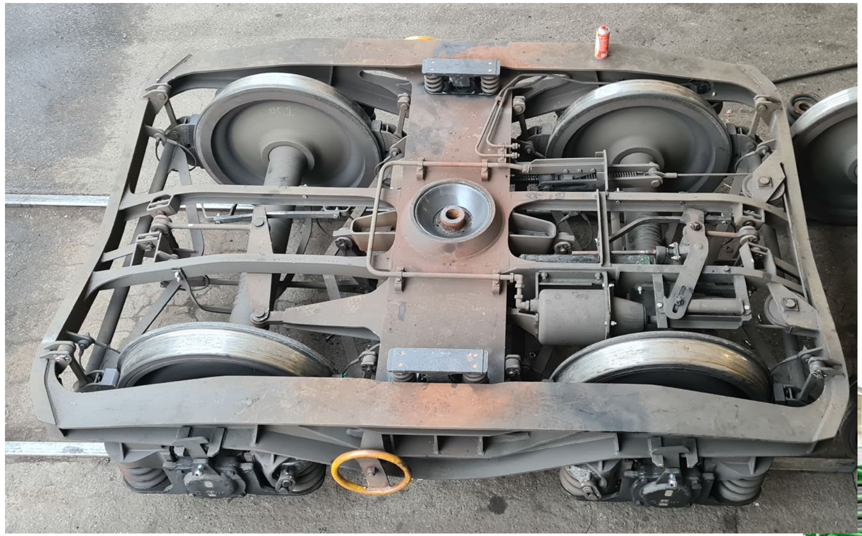
Open problems of rail transportation

- Wheel-rail interaction (safety against derailment, adhesion, vibration)
- Energy efficiency and traction systems (energy usage and management)
- Noise and vibrations (discomfort for bystanders and people living close to railways)
- Wear and maintenance of infrastructure (reduction of safety, ripercussions on regular service)

Many of these problem rely on detailed characterization of components

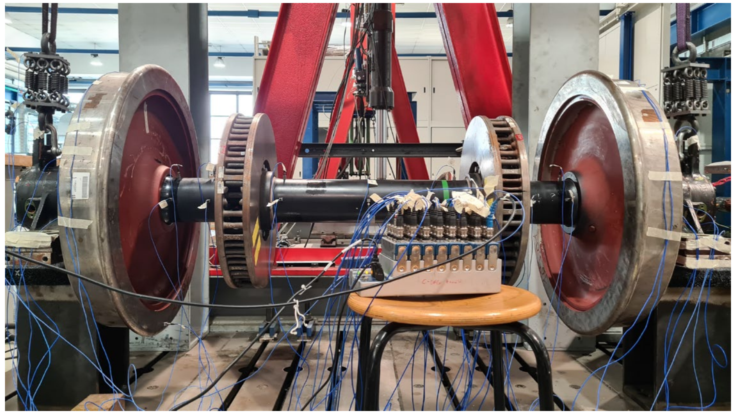
SOME APPLICATIONS OF EMA (1)

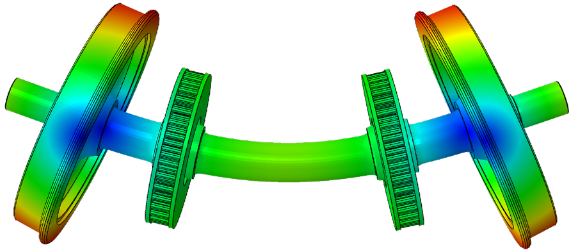
Modal characterization is often employed to evaluate dangerous modal shapes or resonating frequencies on several railway components (bogies, pantographs, carbodies…)



SOME APPLICATIONS OF EMA (2)

Modal characterization allows us also to validate and refine models of railway components obtained via FEM analysis





Impact tests on wheelset → Modal frequencies and damping ratios

FE Model of wheelset → Mode shapes

Modal frequencies and damping ratios + Mode shapes → Modal model of the wheelset → Wheelset receptances

CONTEXT AND MOTIVATION (2)

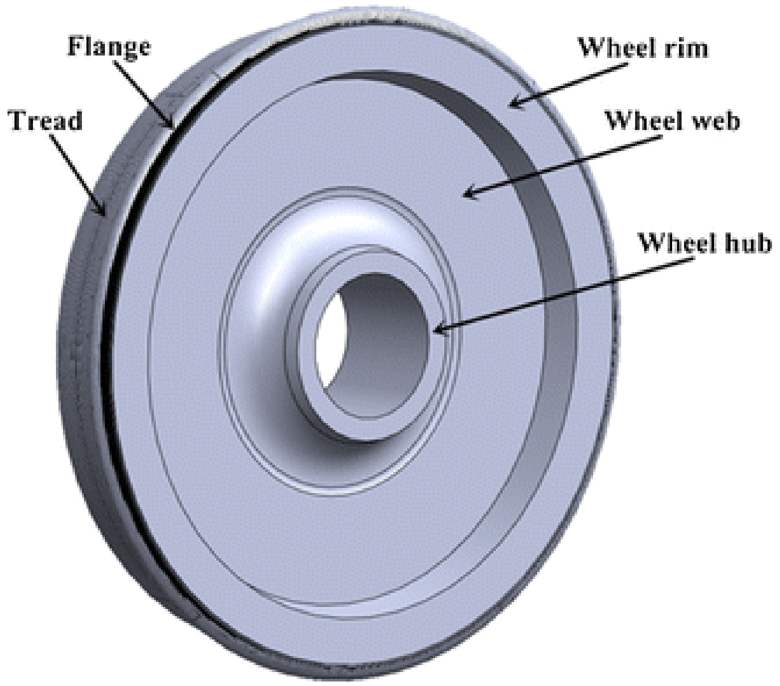
Railway noise can be regarded as environmental noise, resulting from the operation of rail vehicles.

In many railway noise problems (especially rolling noise and curve squeal noise), the wheel plays a fundamental role in terms of sound radiation.

In particular, the axial vibration of the wheel surface results into efficient sound radiation (the surface vibration of the wheel induces a perturbation of the surrounding air and generates a consequent radiated sound field).

THE STRUCTURE UNDER TEST

Resilient wheel of a light rail vehicle



Resilient wheel

Wheelset

EXPERIMENTAL SETUP

Constraints

Resilient wheel suspended through elastic supports (free-free system)

Input

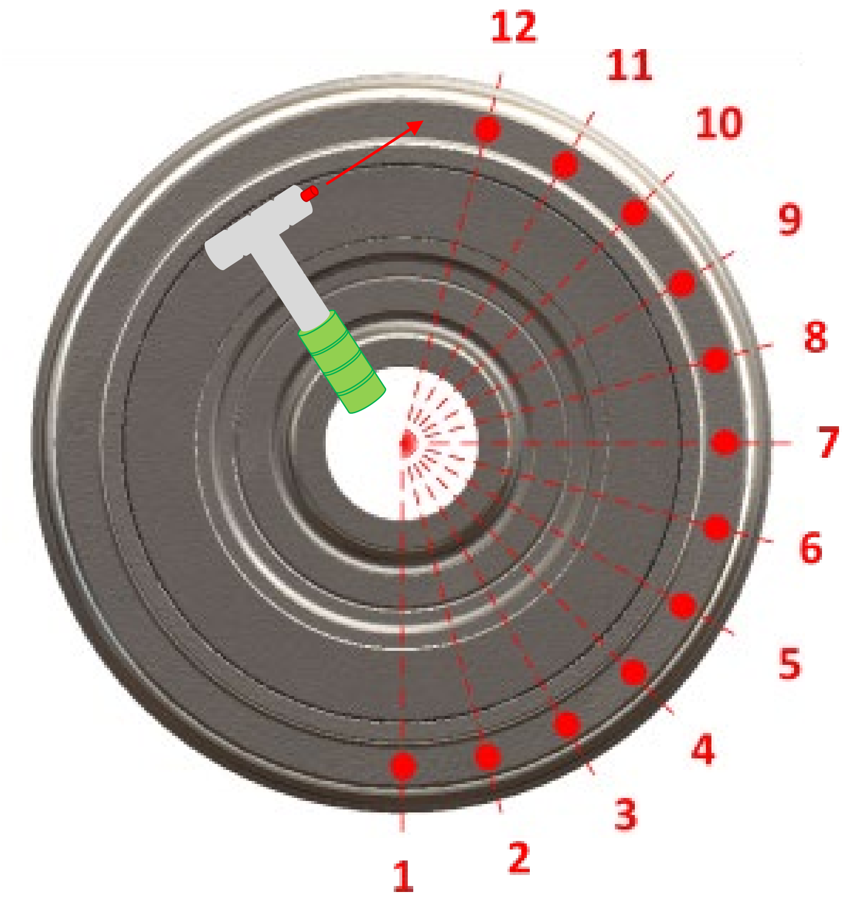
Dynamometric impact hammer applying an axial load

Output

Piezoelectric accelerometers to sense the axial vibration of the wheel rim.

Due to the symmetry of the structure, 12 measurement positions have been considered, which are located only on half of the wheel, with a regular angular spacing of 15°

EXPERIMENTAL SETUP



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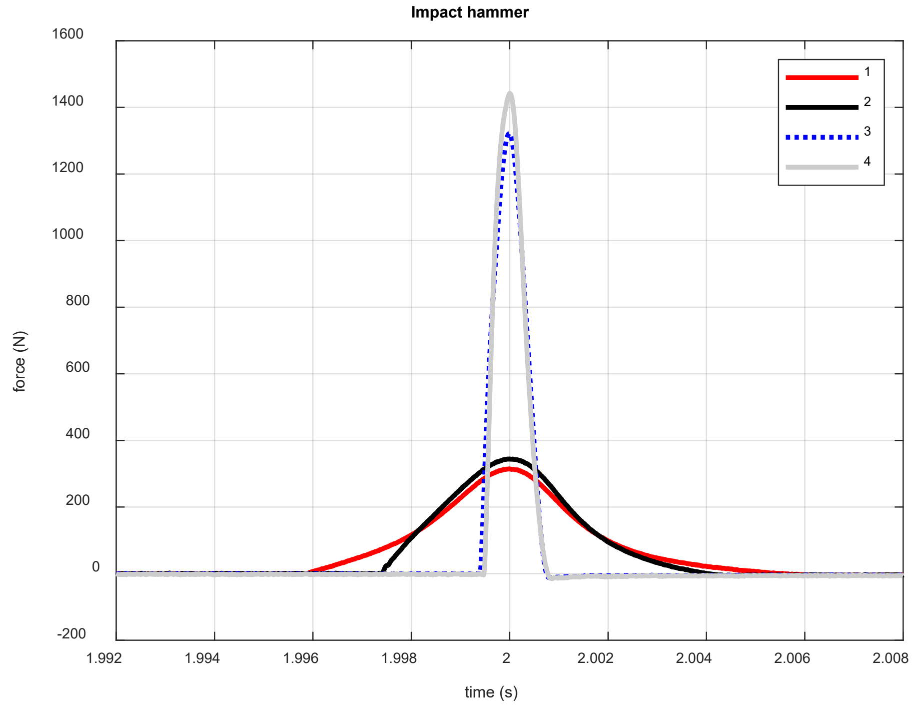
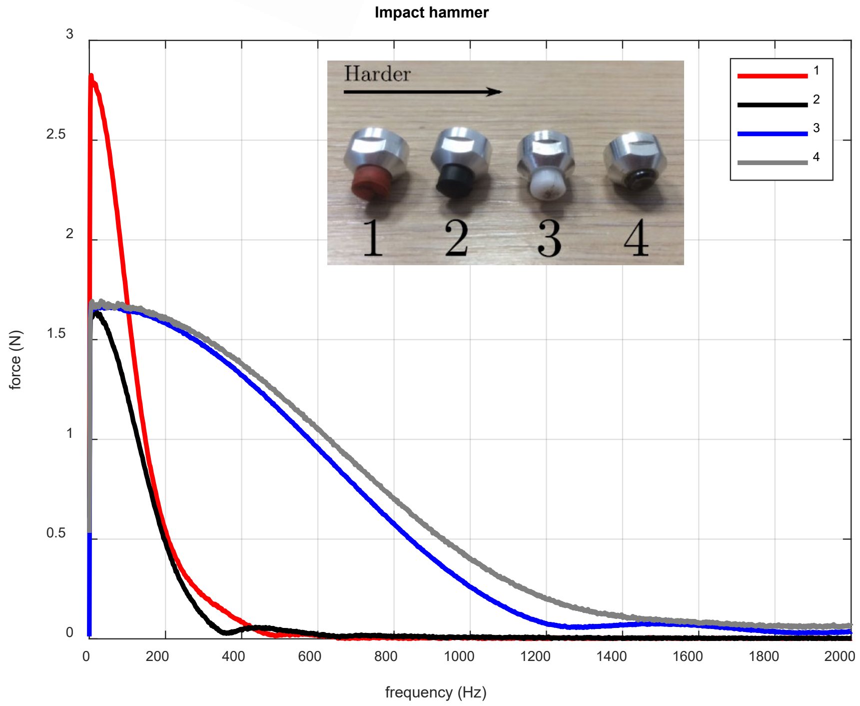
EXPERIMENTAL SETUP
DYNAMOMETRIC IMPACT HAMMER

- Impulsive excitation excites all frequencies (theoretically)
- The bigger the hammer, the lower the frequency range
- The harder the tip, the higher the frequency range





EXPERIMENTAL SETUP
PIEZOELECTRIC ACCELEROMETER

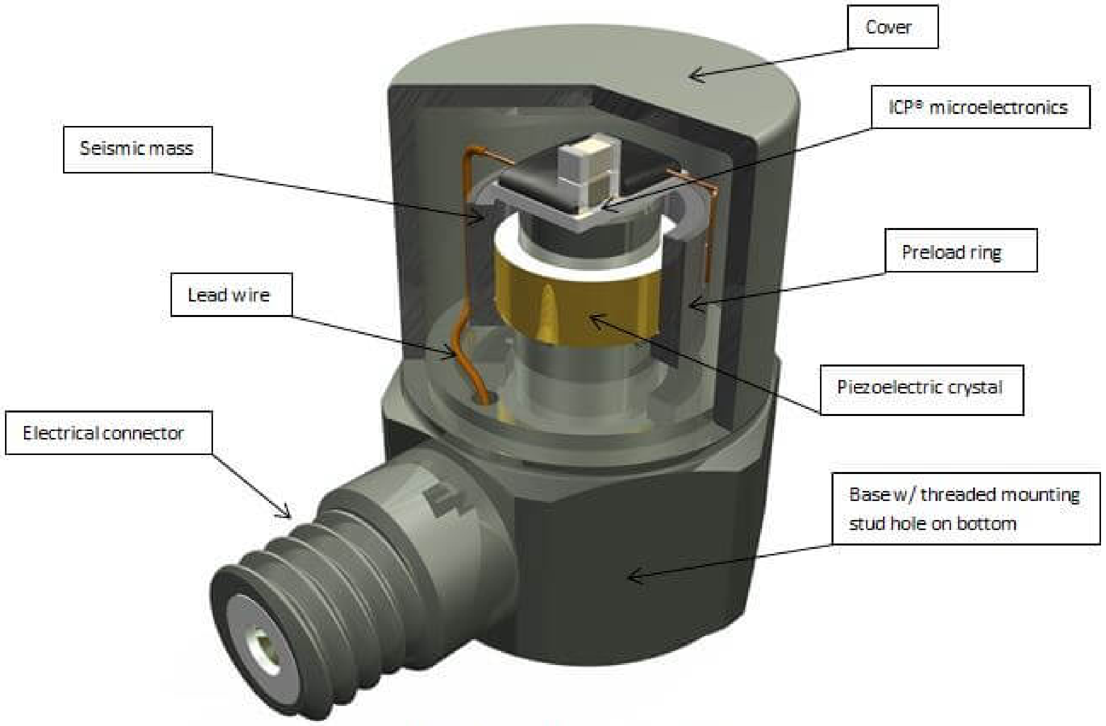
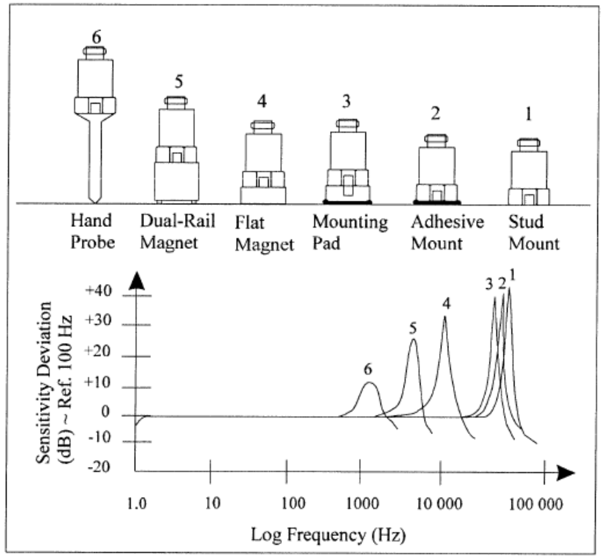


Figure 1: Typical ICP® Accelerometer

Performance	ENGLISH	SI
Sensitivity(± 10 %)	100 mV/g	10.2 mV/(m/s²)
Measurement Range	± 50 g pk	± 491 m/s² pk

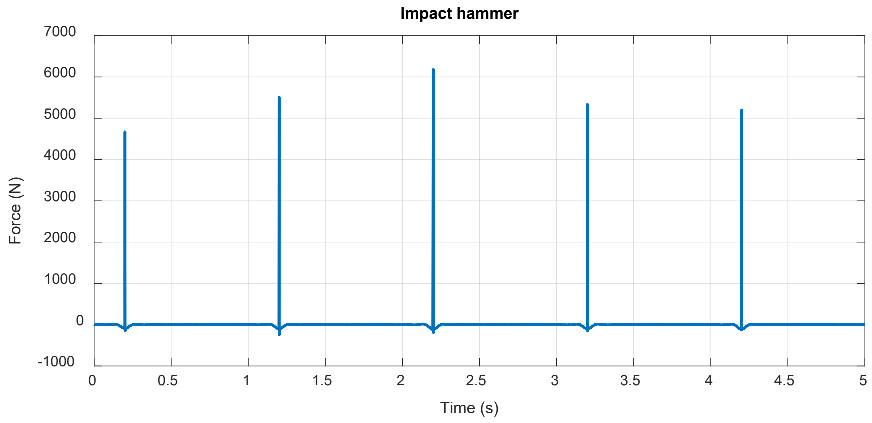
Physical	
Sensing Element	Ceramic
Sensing Geometry	Shear
Housing Material	Titanium
Sealing	Welded Hermetic
Size (Hex x Height)	9/32 in x 18.5 mm
Weight	2.0 gm
Electrical Connector	10-32 Coaxial Jack
Electrical Connection Position	Top
Mounting Thread	5-40 Male
Mounting Torque	90 to 135 N-cm

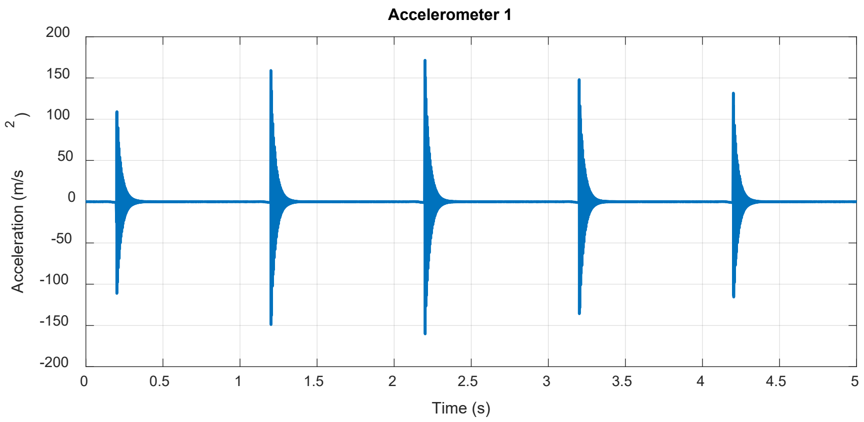


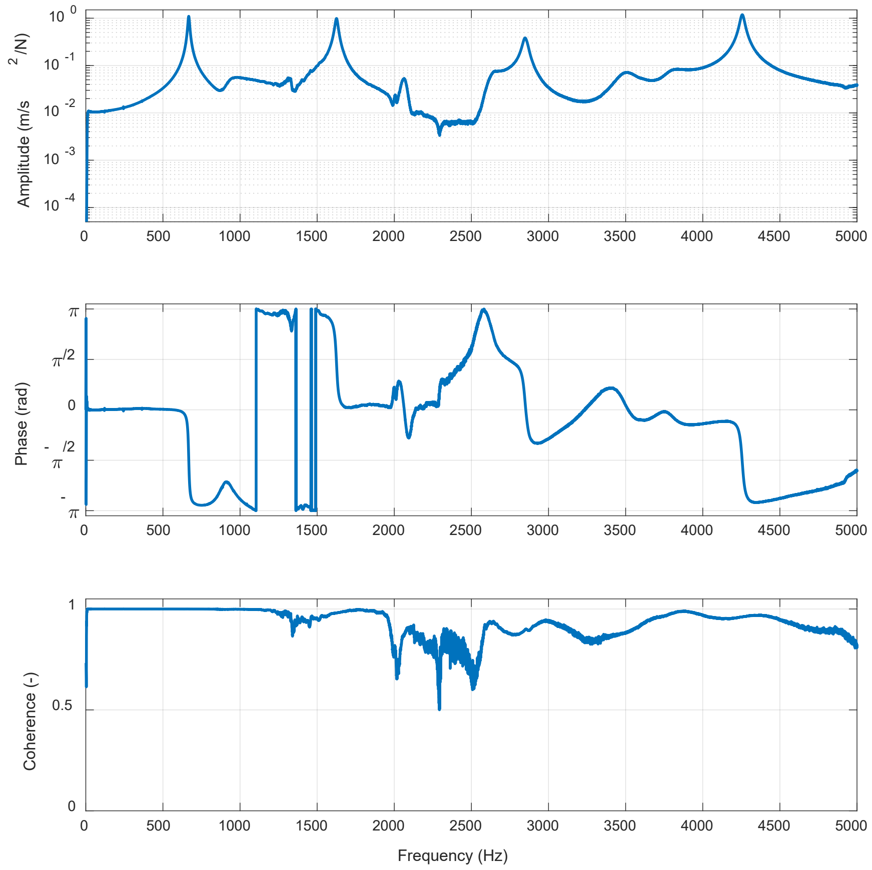
SIGNAL PROCESSING

Time histories

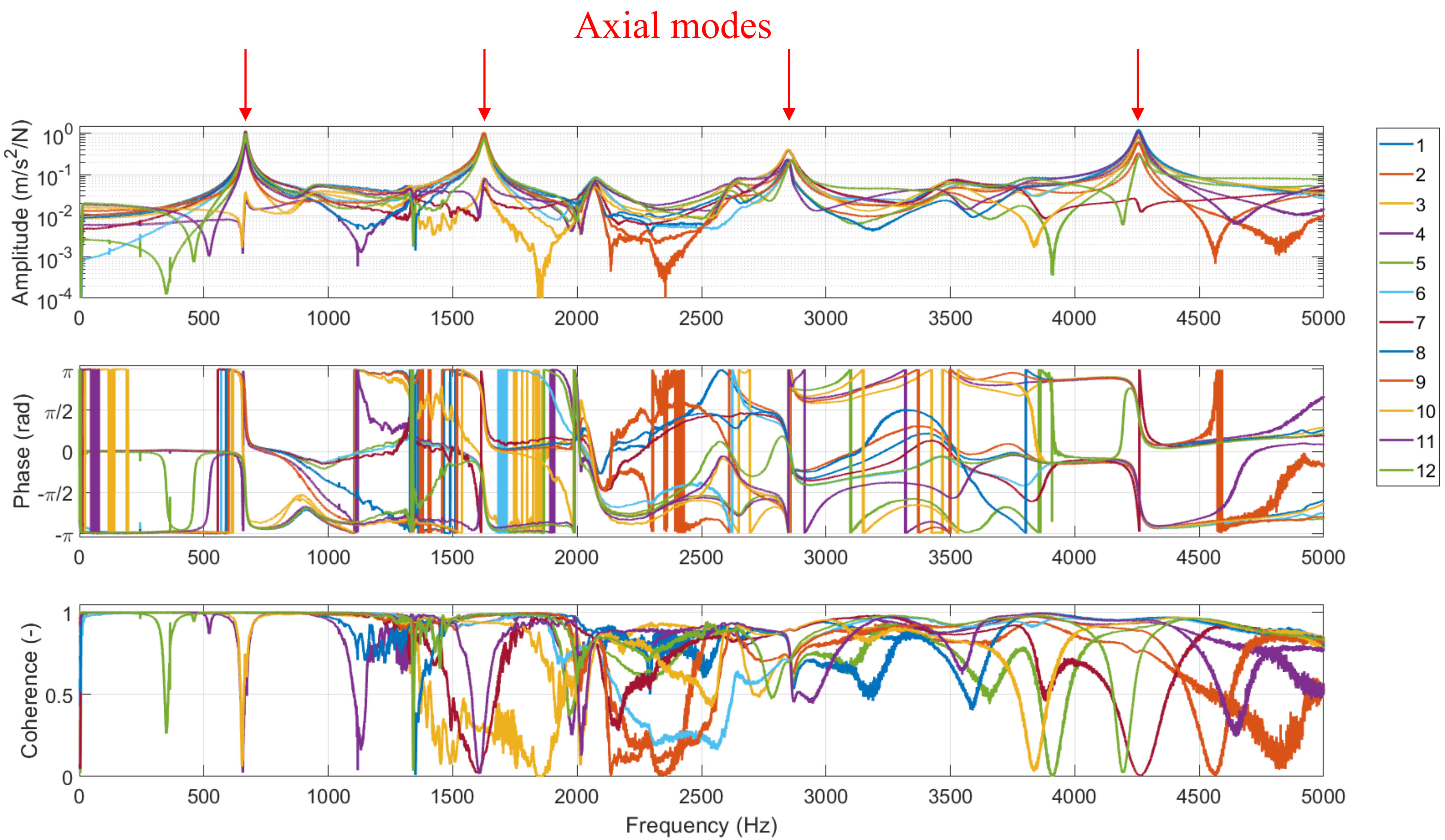
Frequency Response Function







EXPERIMENTAL FREQUENCY RESPONSE FUNCTIONS



DATA PROVIDED

The provided Data.mat file contains the following variables:

- **freq** frequency vector (resolution 0.333 Hz)
- **frf** Inertance ($m/s^2/N$) frequency response functions (complex) collected by columns according to the measuring grid shown in slide 6
- **cohe** coherence function, collected by columns

Hints to plot the identified mode shapes:

- Measuring grid with regular angular spacing of 15° → define an angular spatial domain
- Polar symmetry of the system → polarplot Matlab function

ASSIGNMENT 1 – PART B

Work out the following items and include the corresponding results in your report of Assignment 1.

1. Apply the procedure developed within Part A to the provided experimental data, to identify the modal parameters (**natural frequencies, damping ratios and mode shapes**) of the first two axial modes.
2. Check the quality of the identification comparing the identified FRFs and the experimental ones.
3. Plot a diagram showing the identified mode shapes with the indication of the corresponding natural frequencies and damping ratios.

MODE SHAPE IDENTIFICATION