Assignment 3
Kawasaki Z650

Response to periodic excitation: Paved road excitation

(20 points)

MECA0155 – Dynamics of mechanical systems

Academic year 2024-2025

Objective

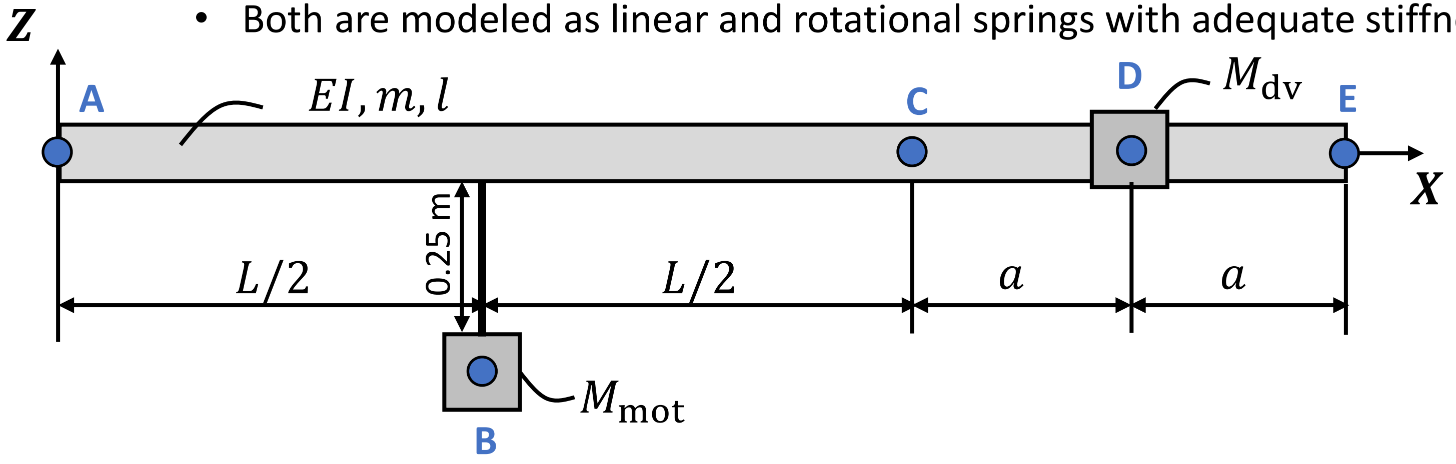
Response of the motorbike frame to the driving on a paved road (periodic excitation)

The aim of the assignment is to :

- compute the FRF between the fork and the driver seat using numerical modal data ;
- calculate the stationary response of the frame due to the forced periodic excitation of the paved road profile ;
- investigate the influence of the damping ratio on the response.

Simplified model of the motorcycle frame (same as in Part 2)

- The model simulates a constant speed motion on a paved road
  - The frame is represented as a beam whose characteristics are listed in the general presentation of the project
  - Two concentrated masses are located at points B and D
    - B: represents the engine and the auxiliaries, located at mid-distance between the fork (A) and the swingarm (C) and at 250 mm below the frame ; linked to the beam with a rigid link
    - D: represents the driver, assumed to be on the frame
  - The frame is supported by the fork and the swingarm
    - Both are modeled as linear and rotational springs with adequate stiffness



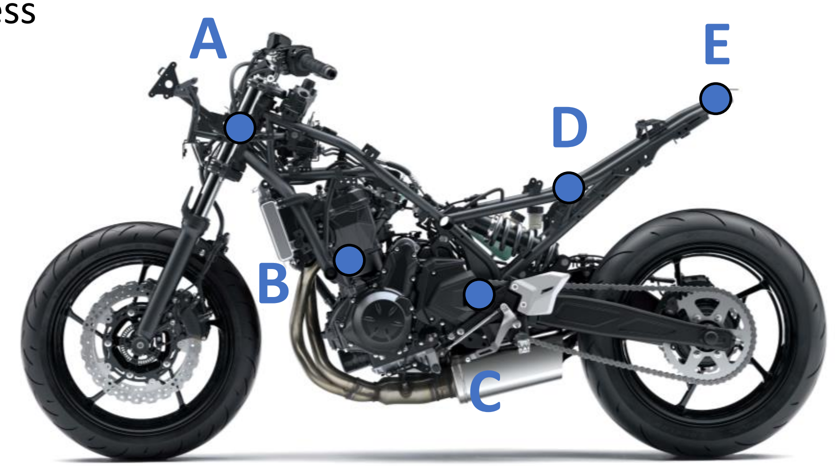


Figure 1 – SDOF model with $l = L + 2a$, $a = \frac{L}{4} = 0.2$ m.

The exciting force

- The total force applied at the fork (A) in the Z direction writes:

$$F_Z = F_0 \sin(\Omega t)$$

where

  - $F_0 = 450\ \mathrm{N}$
  - Wavelength: 0.2 m (length of a cobble)
  - $\Omega \equiv$ excitation frequency
    - At 50 kph:
      $T = \frac{0.2}{\frac{50}{3.6}} = 0.0144\ \mathrm{s}$
      $\rightarrow \Omega = 436\ \mathrm{rad/s}$

Modal testing

- The frame is instrumented by a total of 14 accelerometers
  - 13 accelerometers are distributed equally along the frame and 1 is located at the engine point (B)
    - Among the 13 equally distributed accelerometers, the fork (A), the swingarm connection (C), the driver seat (D) and the passenger seat (E) have their own accelerometer.

Reference point	Distance from the fork along the frame [mm]	Reference point	Distance from the fork along the frame [mm]
P1	0 (A)	P8	600
P2	100	P9	700
P3	200	P10	800 (C)
P4	300	P11	901
P5	400 (B)	P12	1000 (D)
P6	400	P13	1101
P7	500	P14	1200 (E)

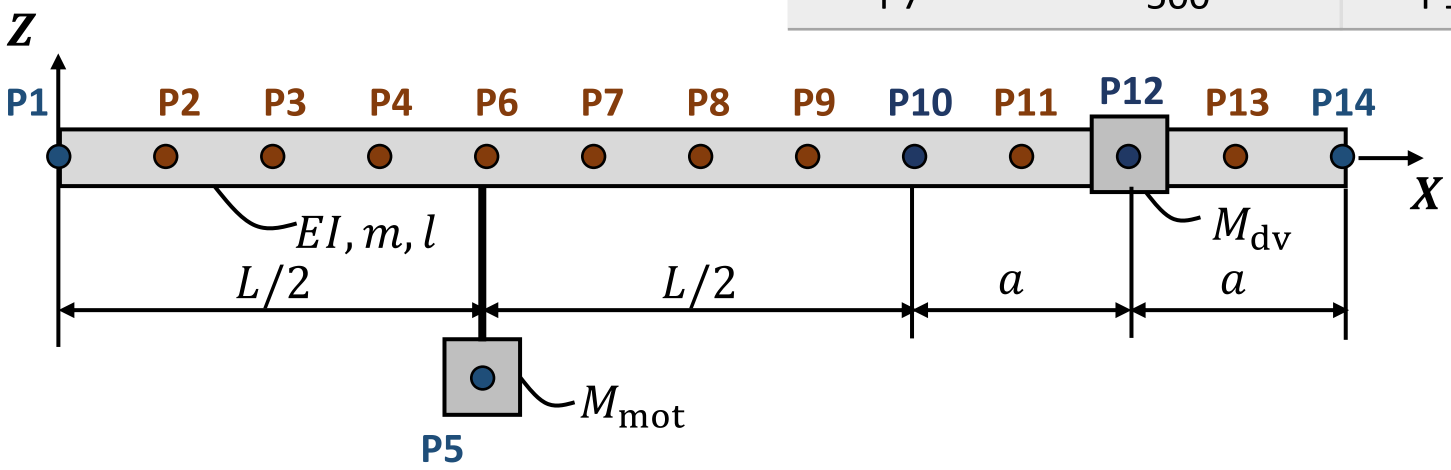


Figure 1 – SDOF model with $l = L + 2a$, $a = L/4$. Use $a = 0.2$ m.

Numerical data available on eCampus

- The file ‘P2024_f_eps_Part3.txt’ contains 4 identified frequencies (1st column) and modal damping factors (2nd column) corresponding to the first four ‘bending’ modes (in the XZ-plane).

Frequency [Hz]	**Damping ratios [-]**
…	…

- The file ‘P2024_modes_Part3.txt’ contains the amplitudes **[mm]** of the corresponding identified mode-shapes (columns 1 to 4) under the format:

Mode 1	**Mode 2**	**Mode 3**	**Mode 4**
…	…	…	…
…	…	…	…
…	…	…	…

14 lines corresponding to locations P1 to P14

The measured mode-shapes are mass-normalized.

Numerical data available on eCampus

- The file ‘P2024_frf_Part3_f_ds.txt’ contains the frequency response function at the driver seat (D) for an excitation at the fork (A) in the frequency range [0 – 1500] Hz. These data are directly generated from the simulation software :

Frequency [Hz]	$\boldsymbol{Re(FRF)}$ **[m/s²/N]**	$\boldsymbol{Im(FRF)}$ **[m/s²/N]**
…	…	…

Project statement (1/2)

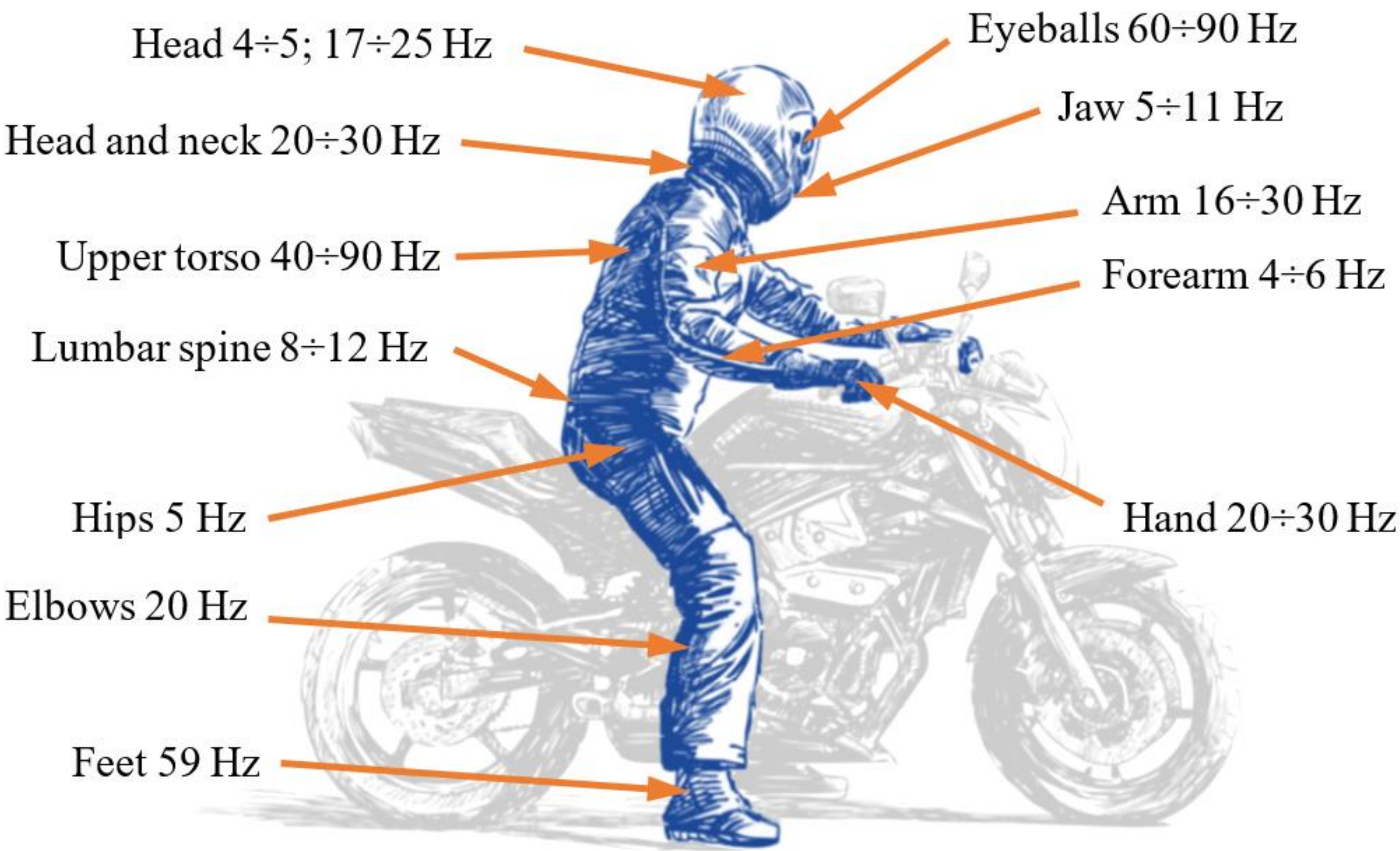
The response of the frame to the vertical periodic excitation will be calculated from the numerical modal model as suggested in the following steps:

- Plot the time evolution of the vertical excitation force on a time interval of 0.15 second.
- Compute the FRF matrix in terms of acceleration using the numerical data available in the *f_eps* data file and in the *modes* data file.
  - Plot the Bode diagram in amplitude and the Nyquist diagram between the excitation point and the driver seat.
  - For the Bode diagram in amplitude, use a semilogarithmic scale to put in evidence the resonance as well as the antiresonance frequencies.
  - Check your results by comparing with the FRF data available in the *frf_f_ds* data file.
  - Analyse your graphs.
- For each reference point of the frame, compute the maximum amplitude of the response (acceleration) to the periodic excitation and show the evolution in a graph.
- Plot the time response (acceleration) at the driver seat in terms of acceleration.
  - Analyse these two graphs.

Project statement (2/2)

- To investigate the effect of the damping ratio on the response, we assumed that the fork is now blocked. As a consequence, the damping ratio drops.
  - In the file 'P2024_f_eps_Part3.txt', impose each damping ratio to be 0.02 (i.e., $\epsilon = 2\%$).
  - For constant motorbike speeds between 50 and 70 km/h, compute the maximum amplitude of the response (acceleration) to the periodic excitation at the driver seat and show the evolution in a graph. What are your observations ? How do you explain it ?
- Have a look at the natural frequencies of the main parts of the human body (cf. next slide).
  - We still consider that the fork is blocked.
  - Discuss the potential risks for a pilot driving on a paved road. Consider at least two human parts.
  - You can generate new graphs inspired from previous questions.

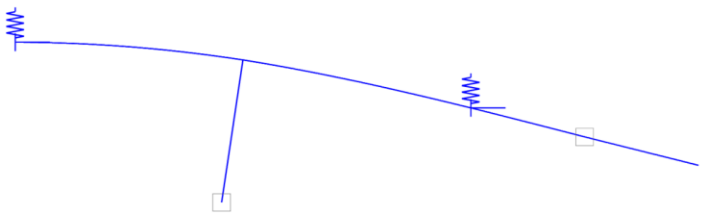
Natural frequencies of selected organs and parts of the human body



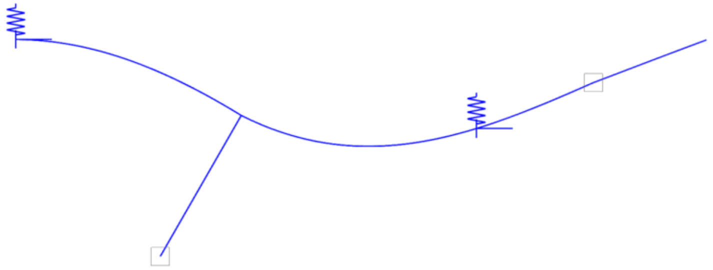
Dębowski, A. (2021). Analysis of the effect of mass parameters on motorcycle vibration and stability. *Energies*, *14*(16), 5090-. https://doi.org/10.3390/en14165090

Bending modes

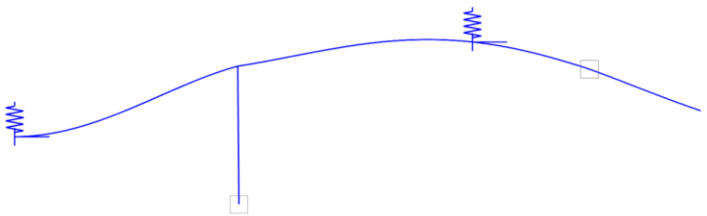
Mode 1: 3.71 Hz (RBM)



Mode 5: 87.49 Hz



Mode 7: 430.10 Hz



Mode 10: 1049.0 Hz

Specific guidelines for assignment 3

1) Pay attention to the clarity of the figures (axes, units, grids, legend, etc.)
2) The length of the report will not exceed 8 pages including figures.
3) You can ask your questions on the dedicated forum on eCampus (preferably).
4) The deadline for the submission of the report (on eCampus platform) is fixed to

November 29, 2024 at 18:00