**EML4507 Fall 2023 Projet 1**

In this project, a bicycle frame is designed using aluminum tubes. The schematic dimensions of the bicycle are shown in the figure, where the bike is composed of **six tubes**. The goal is to minimize the weight of the tube by changing the outer diameters of individual tubes while the bicycle can support loads and be safe from buckling. The minimum outer diameter is 8mm. The following two load cases should be considered.

(a) Vertical loads: When an adult rides the bike, the nominal load is estimated as a downward load of 2,000N at the seat position and a downward load of 600N at the pedal crank location. When a dynamic environment is simulated using the static analysis, the static loads are often multiplied by a dynamic load factor $G$ and safety factor $S$. In this design project, use $G = 3$ and $S = 1.5$. Use a pin-joint boundary condition (U1 = U2 = 0) for the rear dropouts and a horizontally sliding boundary condition (U2 = 0) for the front dropout.

(b) Horizontal impact: The frame should be able to withstand a horizontal load of 1,500N applied to the front dropout with rear dropouts constrained as a pin-joint. Use the same boundary conditions with Part (a). Use $G = 3$ and $S = 1.5$.

For the project, perform the following simulations:

(1) **Fully stressed design**: Create the finite element model of the bike frame with the initial diameter $d$ = 12 mm. Based on the beam stress (S11, at the both and top surfaces), calculate the new diameter of individual tube using the fully stressed design. Repeat the fully stressed design upto 10 iterations. The new diameter must be determined based on a higher stress from the two load cases. The minimum tube diameter is 8 mm.

(2) **Buckling analysis**: Once the fully stressed design is obtained, perform buckling analysis for two cases and verify that the first eigenvalue from both cases is higher than 1.0. If the first eigenvalue is lower than 1.0, you need to increase the diameter of the buckled tube further to make the lowest eigenvalue to be 1.0.

**Abaqus modeling**: In Abaqus, use length **unit = mm and force unit = N**. You need to convert other units accordingly. In the report, provide a table of units (length, force, stress, density, mass) so that Abaqus results can be interpreted accordingly. Make 5 beam elements (linear, cubic formulation) for each linear portion of the tube, except for the front dropout tube, which is modeld using 2 beam elements. You need to define separate sections for each tube because you need to change the diameter of each tube. Apply displacement boundry conditions at the initial step. Then, make four additional steps using "linear perturbation": Vertical-static, Vertical-buckling, Horizontal-static, Horizontal-buckling. You may define loads at different steps separately. You need to select (SF: section forces and moments) in field output to plot bending moment diagram. For stress calculation, use the stress in the report file, not based on the contour plot. You are supposed to make a single CAE file that includes all four steps (2 static and 2 buckling steps).

**Reporting**: The report should be in the conference paper format (template will be available in class website). The report is supposed to be readable and complete by itself, for example, including introduction, approach, assumptions, results, conclusion, discussion, and references. In your report, you must include at least the following information: (a) table of units, (b) plot of FE geometry with node and element labels and boundary/load conditions, (c) a table of design iterations that shows the maximum stresses for each tube, tube diameters, and the weight of the bike, (d) bending moment diagram and von Mises stress plot at the final design for the two static cases, (e) plot of deformed geometry with the magnification factor for the two static cases, and (f) the first mode shape and critical load factor for the two buckling load cases.

Report must be less than 10 pages. Submit your report in the form of PDF file. All results must be analyzed and summarized.

Table. Properties of Aluminum

| Material Property | Value |
|---|---|
| Young's Modulus ($E$) | 70 GPa |
| Poisson's Ratio ($\nu$) | 0.33 |
| Tube material thickness | 0.8 mm |
| Density ($\rho$) | 2,580 kg/m$^3$ |
| Yield Strength ($\sigma_Y$) | 210 MPa |

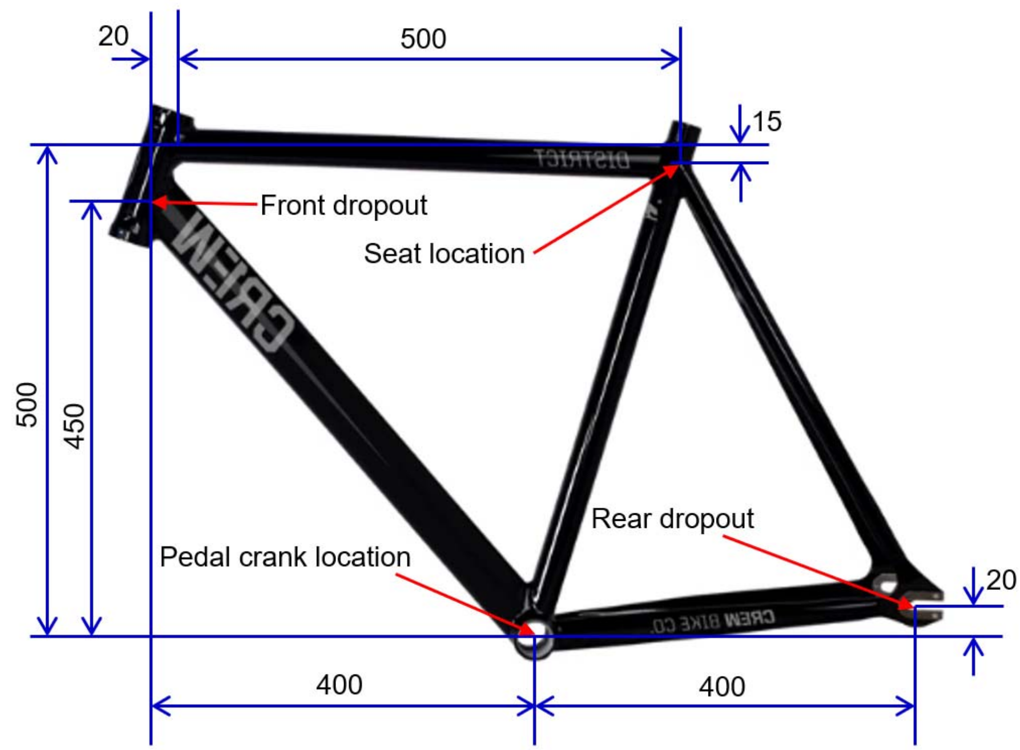


Figure. Bicycle frame structure (unit mm)