ME 498: Mechanical Design Optimization Project Proposal

The project I've chosen is to perform a shape optimization on a high load connecting rod that connects the crankshaft to the piston in a diesel engine. These conrods are critical components, but they're traditionally over-engineered and heavy to handle the extreme compressive forces, which creates a high risk of buckling. My motivation is to minimize this reciprocating mass, which has a direct relation to the efficiency of the engine, engine vibration, and lowers bearing loads. So, optimizing its shape for mass while maintaining strength is a classic and valuable engineering problem.

To make this solvable with my own code, I'm going to idealize the conrod as a 1D beam element, but its properties will be defined by a varying, parametric 3D cross-section. This approach captures all the critical 3D mechanics (especially for buckling) without needing a commercial FEA package. The model will be treated as pinned at both the small end (piston) and big end (crank) and will be analyzed against two static load cases: the peak compressive force from combustion and the peak tensile inertial force at max RPM.

The optimization statement is straightforward. The main objective is to minimize the total mass of the rod. The design variables will be the parameters that define the optimized shape (I-beam) as a function of position (x) along the rod's length: web height, flange width, web thickness, and flange thickness. This optimization will be heavily constrained. The design must prevent buckling failure, where the critical load (P_{cr}) derived from the cross-section's moment of inertia $\big(I(x)\big)$ must exceed the compressive load by a decided factor of safety. Other key constraints include preventing fatigue failure from tensile stress, preventing yield failure from compressive stress, maintaining axial stiffness to limit deflection, and adhering to strict geometric constraints to ensure the rod has clearance inside the engine. Below is a simplified diagram representing the loading condition.