Engine exhaust-valve cam

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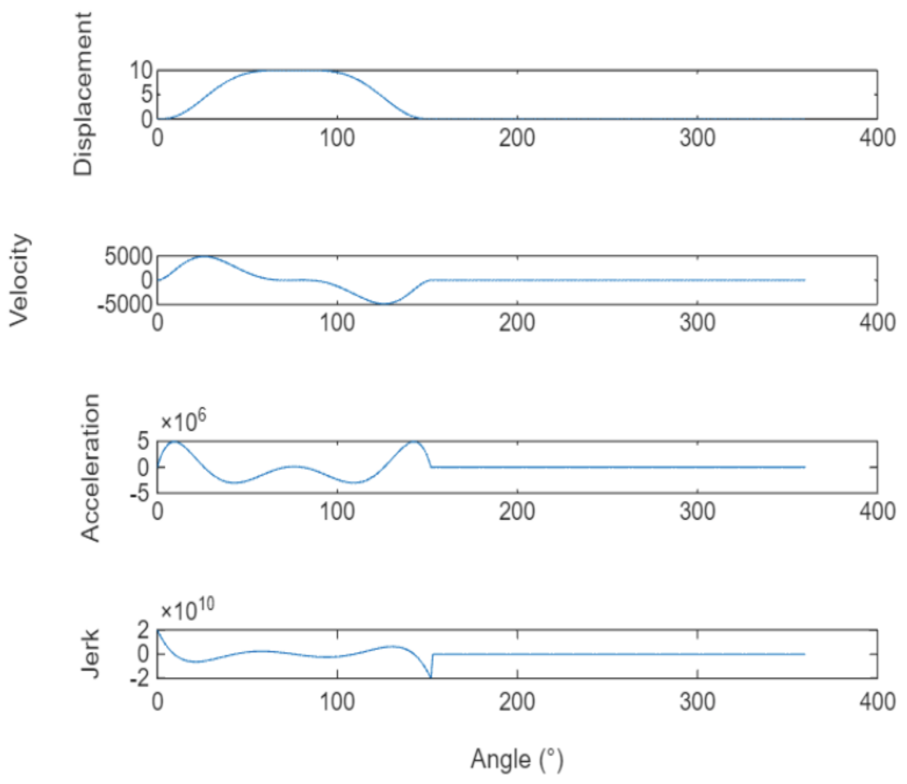
Problem Description

This project involves designing an engine exhaust valve cam that achieves a 10 mm valve lift over 132° of camshaft rotation. The valve-open duration is defined between cam-follower displacements of 0.5 mm above the dwell position. The engine crankshaft operates between 1000 and 10,000 rpm, with the camshaft rotating at half that speed. The cam must take up valve clearance with minimal impact, reach full lift at 66°, and then return to zero lift at a controlled rate by 132°. A suitable spring must be selected to prevent valve float (follower jump), considering a follower train mass of 200 grams.

An engine exhaust valve is a critical component used in the cylindrical head of an internal combustion engine.

Kinematic Design and Analysis

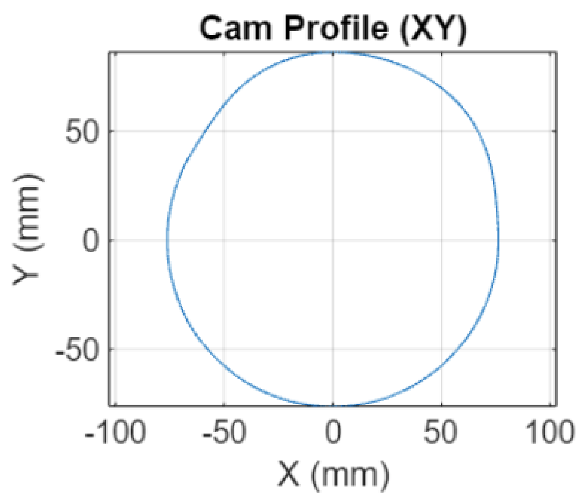


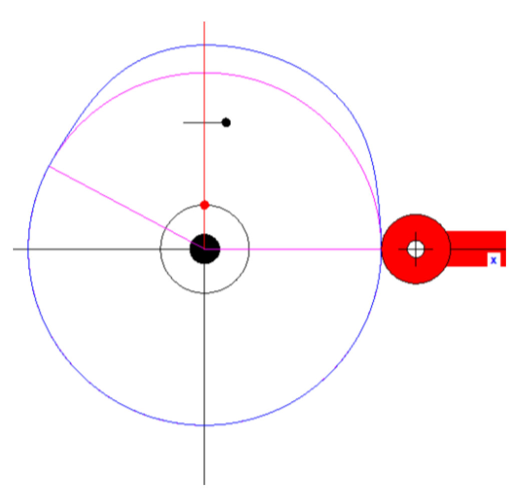
Displacement, Velocity, Acceleration, and Jerk Graph for the Cam with MATLAB.

- Maximum Pressure angle: 11.87° at cam angle of 25°
- Minimum pressure angle: -11.87° at cam angle of 127°. Well below the maximum 30 degrees
- Smallest positive radius of curvature: 322.532 mm at cam angle 9°
- Smallest negative radius of curvature: none
- Largest negative radius of curvature: none
- Smallest Rho: 59.127 mm. The largest allowed roller radius is just under 30 mm

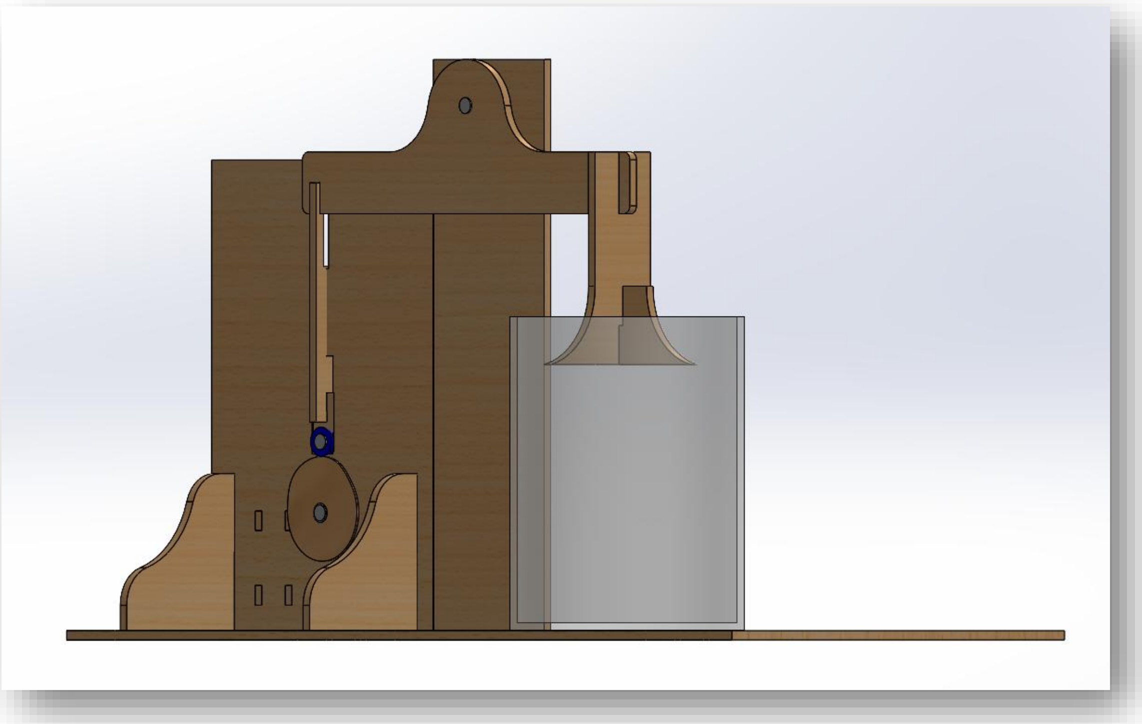
Design Constraints and Task Specifications

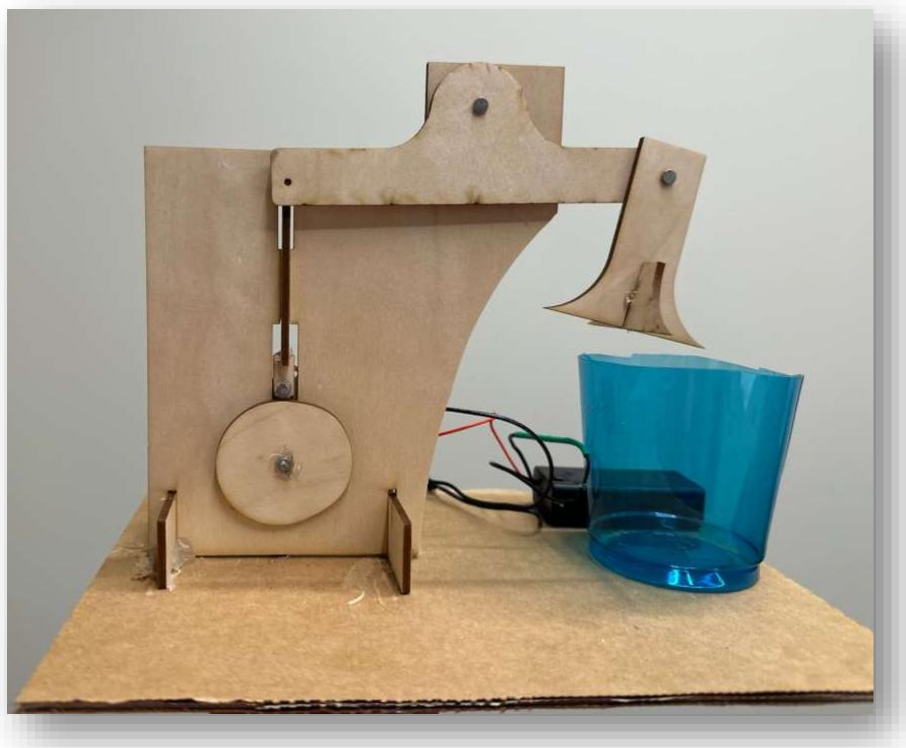
- It can lift 10 mm over 132°
- It has a dwell for 228°
- It has a small size and weight.
- It can rotate continually
- The prototype can be powered by a small motor and a 2 double 1.5 V batteries
- For each time the cam completes one cycle, the valve opens and closes once





Final Design





Results

- ✓ The cam rotates continually, and the rotation cycle is completed in 1.28 seconds
- ✓ On each cycle, the valve opens and closes

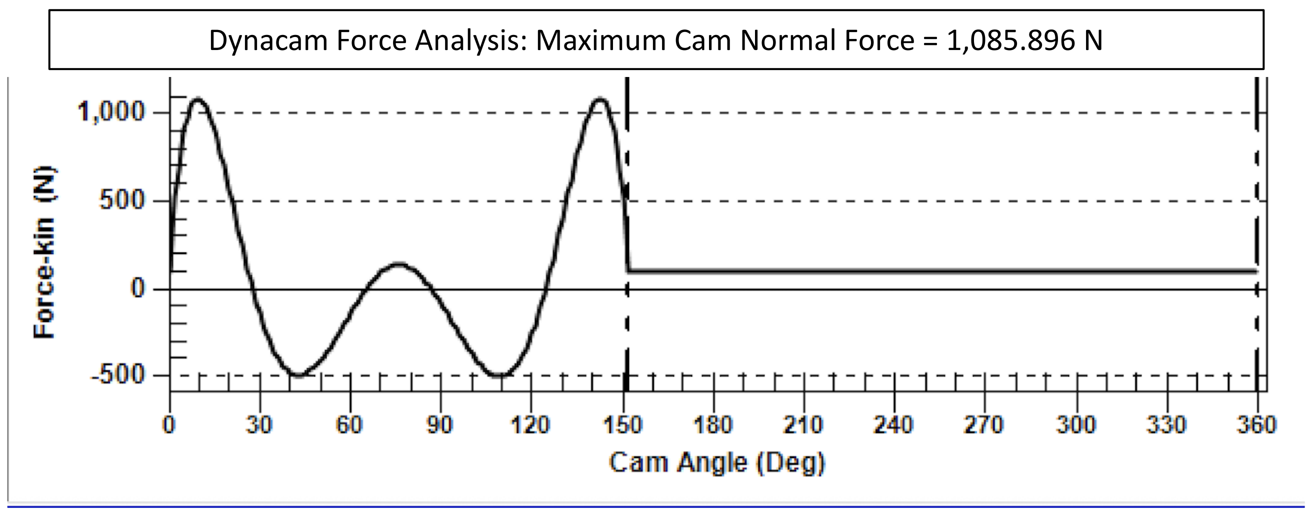
Failure Analysis with Safety Factors

Theoretical Specifications

Theoretical Material: AISI 4130 Steel Alloy

Normal Yield Strength: 435 MPa – Shear Yield Strength: 340 MPa

Theoretical Speed: 287.98 rad/s | Theoretical Cam Mass: 0.2 kg



Rocker Arm Safety Factor Analysis

$$I = \frac{bh^3}{12} = \frac{0.00305m \cdot 0.02m^3}{12} = 2.03 \cdot 10^{-9}\ m^4$$

$$Q = \bar{y}A = 0.005m \cdot 0.01m \cdot 0.00305m = 1.525 \cdot 10^{-7} m^3$$

$$V_{max} = -1{,}629\ N$$

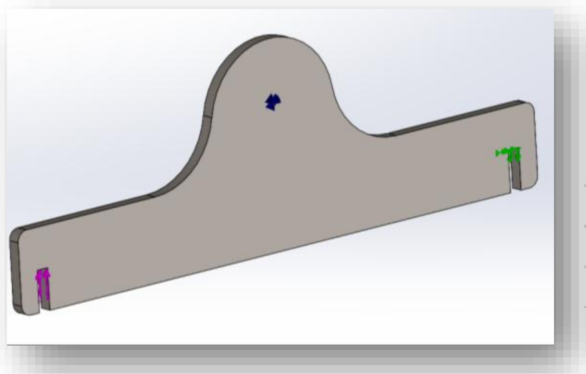
$$\tau_{max} = \frac{V_{max}Q}{It} = \frac{1{,}629N \cdot 1.525 \cdot 10^{-7}m^3}{2.03 \cdot 10^{-9}\ m^4 \cdot 0.00305m} = 40MPa$$

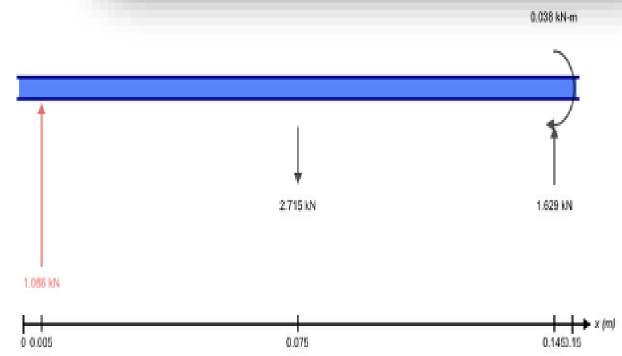
$$SF = \frac{\tau_{yield}}{\tau_{max}} = \frac{340\ MPa}{40\ MPa} = 8.5$$

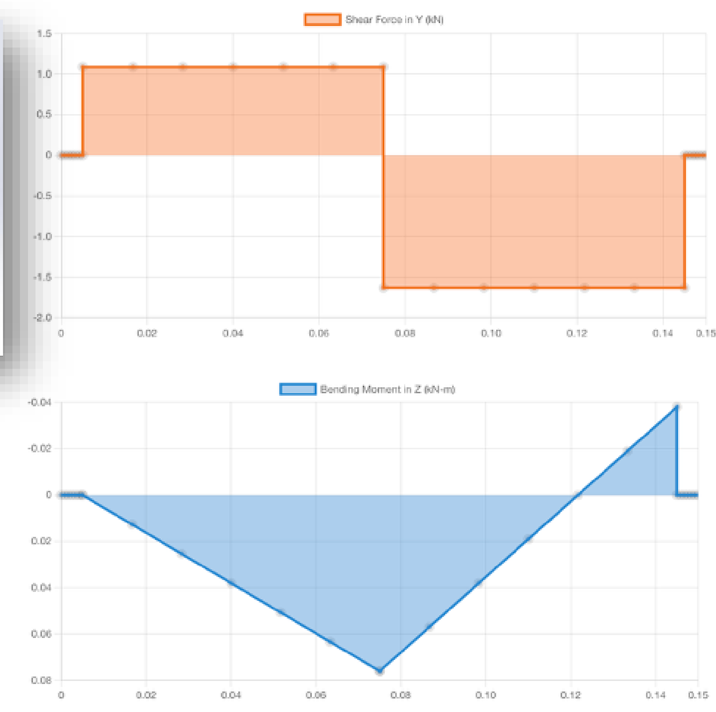
$$M_{max} = 76\ Nm$$

$$\sigma_{max} = \frac{M_{max}c}{I} = \frac{76Nm \cdot 0.01m}{2.03 \cdot 10^{-9}\ m^4} = 373\ MPa$$

$$SF = \frac{\sigma_{yield}}{\sigma_{max}} = \frac{435\ MPa}{340\ MPa} = 1.28$$







Pin Joint Safety Factor Analysis

Solid Works Analysis

Type	Resultant
Shear Force (N)	2,329.5
Axial Force (N)	0.0018819
Bending Moment (N.m)	0
Torque (N.m)	0
Safety Factor	1.52

Hand Calculations

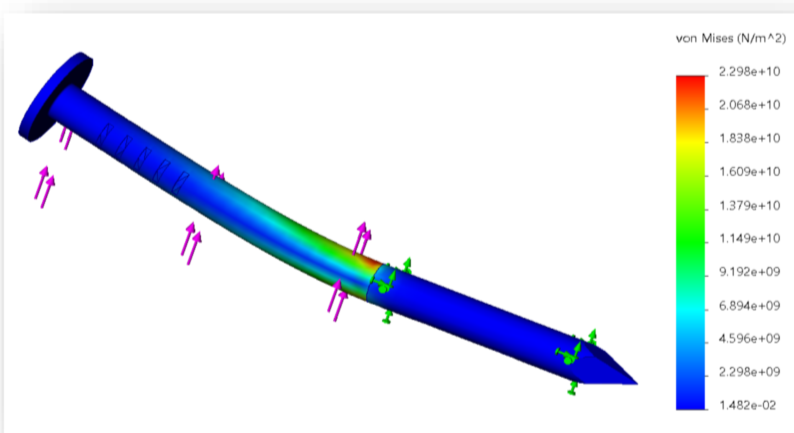
$$V_{max} = 2{,}715\ N$$

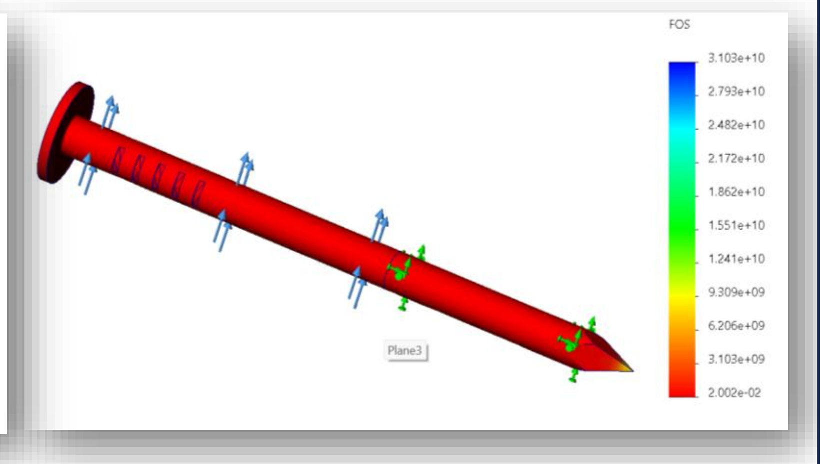
$$A = \frac{\pi}{4}(0.003)m^2 = 7.07 \cdot 10^{-6}m^2$$

$$\tau_{max} = \frac{4V_{max}}{3A} = \frac{4 \cdot 2{,}715\ N}{3 \cdot 7.07 \cdot 10^{-6}m^2} = 256\ MPa$$

$$SF = \frac{\tau_{yield}}{\tau_{max}} = \frac{340\ MPa}{256\ MPa} = 1.33$$

The SolidWorks static study shows that the point with the Maximum von Mises stress occurs at the point halfway through the pin joint used to hold the rocker arm.





Push Rod Safety Factor Analysis

Maximum Normal Force from Cam: 1085.897 N

Push Rod Area: $3.87 \cdot 10^{-5}\ m^2$

$$\sigma_{Follower\ Shaft} = \frac{F_{max}}{A} = \frac{1085.897\ N}{3.87 \cdot 10^{-5}\ m^2} = 28\ MPa$$

$$SF = \frac{\sigma_y}{\sigma_{Follower\ Shaft}} = \frac{435\ MPa}{28\ MPa} = 16$$