EFFICIENT, COMPACT, AND SMOOTH VARIABLE PROPULSION MOTOR

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Project Overview

- Develop variable displacement linkage motor (VDLM) for propulsion of off-highway vehicles
- 36 month timeline

Objectives:

- Efficiency >90% above 15% displacement
- Torque ripple <5% of the mean torque
- Reduce fuel consumption 30%
- Power density >5 kW/kg
- Cost <$4/kW

MEPS Mechanical Energy & Power Systems Laboratory

Project Team

- University of Minnesota
  - Jim Van de Ven, PI
  - Tom Chase, co-PI
  - Perry Li, co-PI
  - Mike Gust, Project Manager
  - Grey Boyce-Erickson, GRA
  - Nate Fulbright, GRA
  - Justinus Hartoyo, GRA
  - John Voth, GRA
  - Shawn Wilhelm, Consultant
- Milwaukee School of Engineering
  - Paul Michael, PI
  - Ninaad Gajghate, GRA
  - Pawan Panwar, GRA
  - Jordan Saikia, GRA
- Eaton Corporation
- Bobcat Doosan

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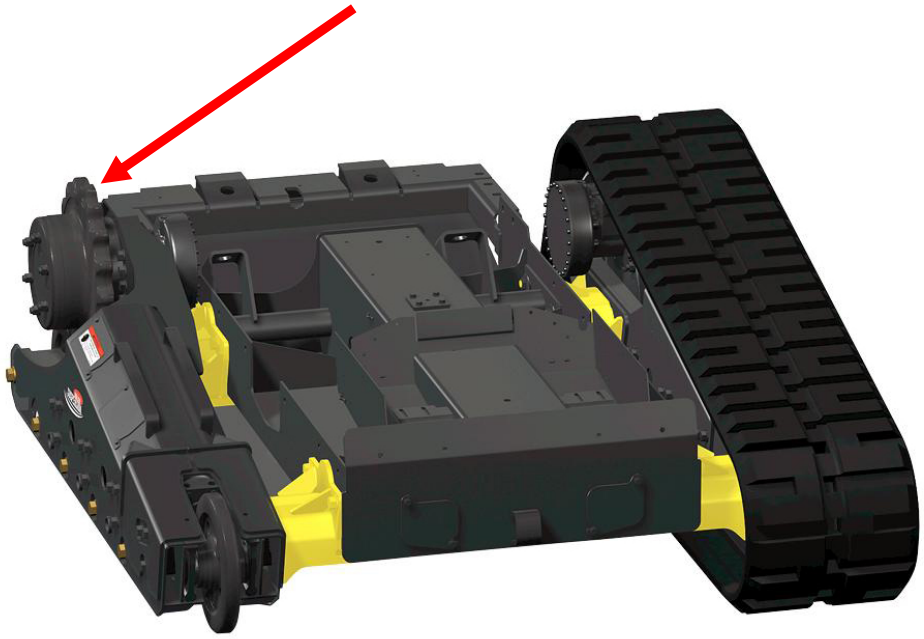
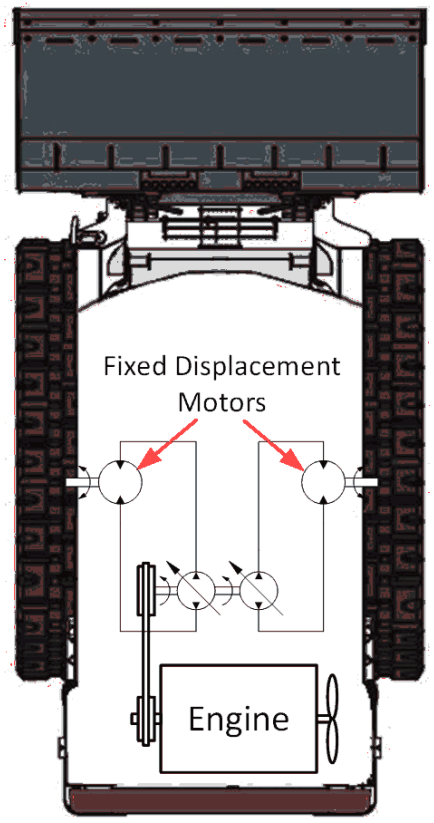
Track Drive Hydraulic Motor

Low Speed High Torque (LSHT) direct drive hydraulic motor with track drive sprocket





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VLDM Value Propositions

- **Motor Efficiency:** Saves fuel, increases power
- **Low Torque Ripple:** Improves control and productivity

- **Variable Displacement Motor:** Increases transport speed and higher system efficiency
- **High Displacement Motor:** eliminates gearbox
- **Scalable Motor:** Applicable to wide variety of off-highway vehicles

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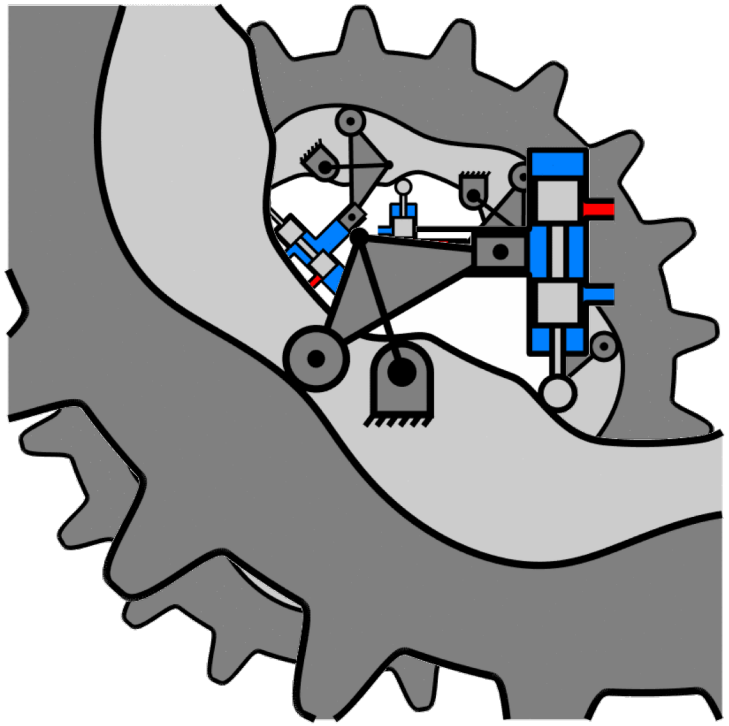
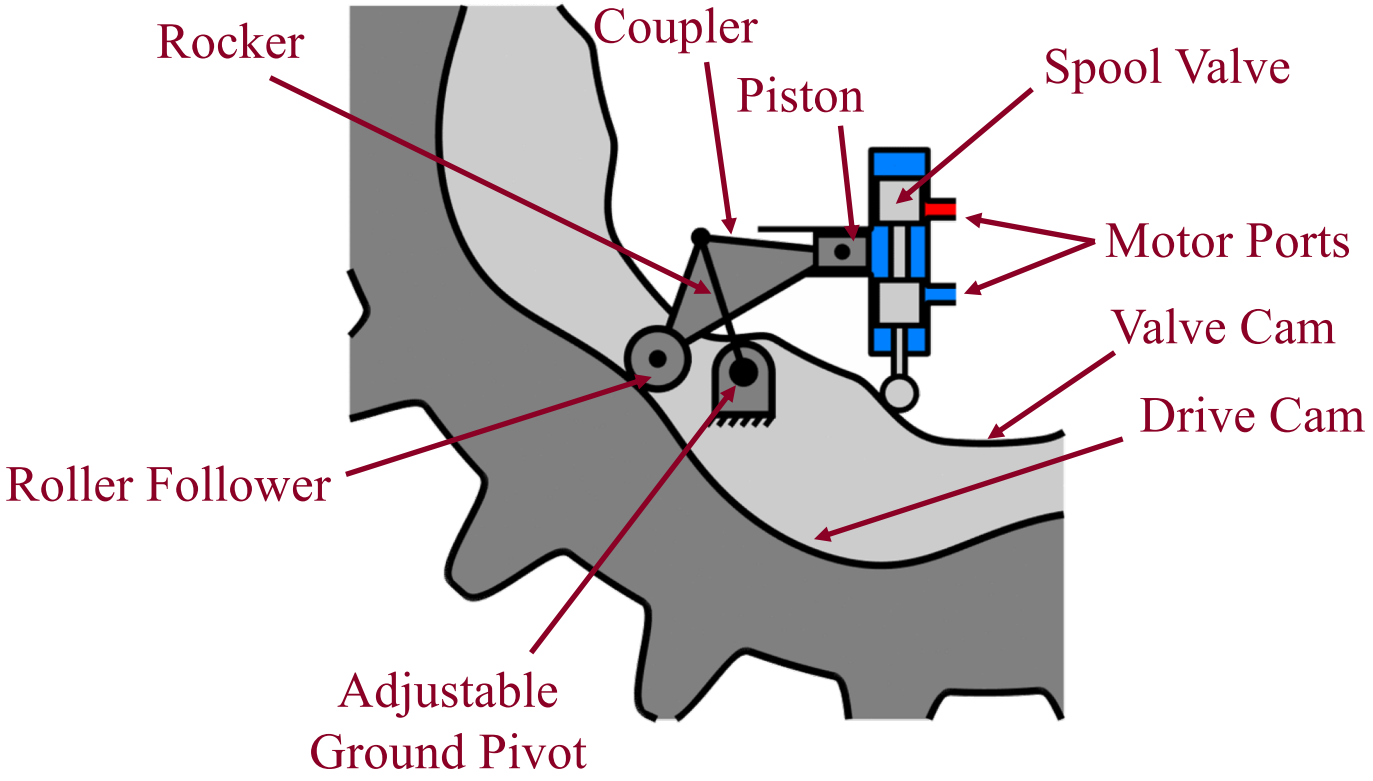
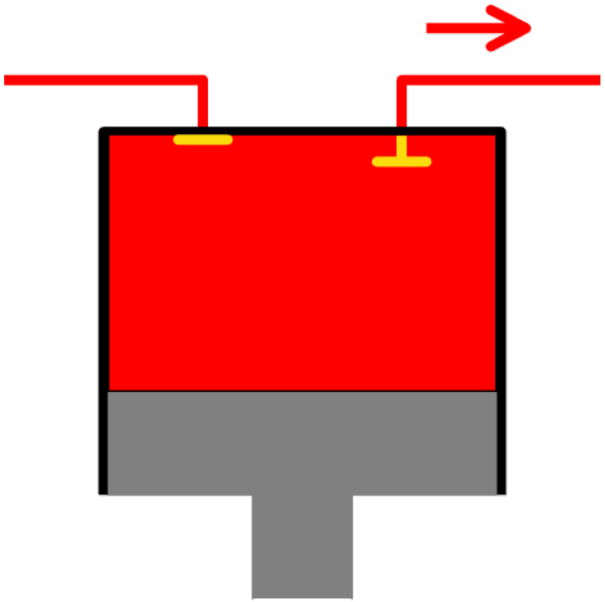
How it Works: VDLM



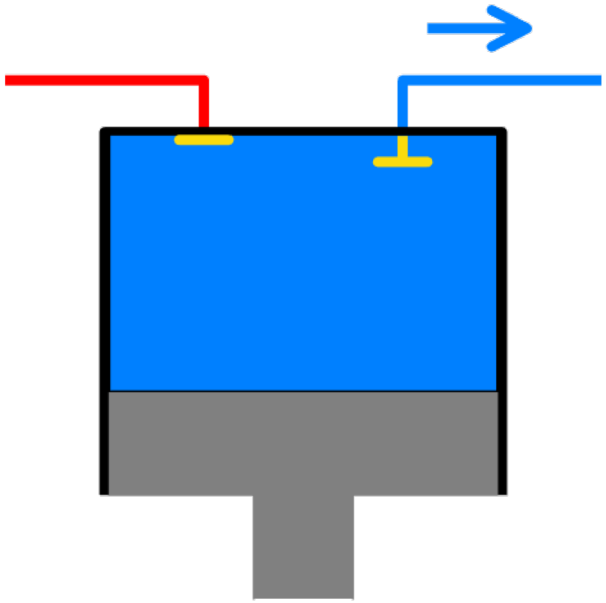
How it Works: VDLM



Importance of Valve Timing

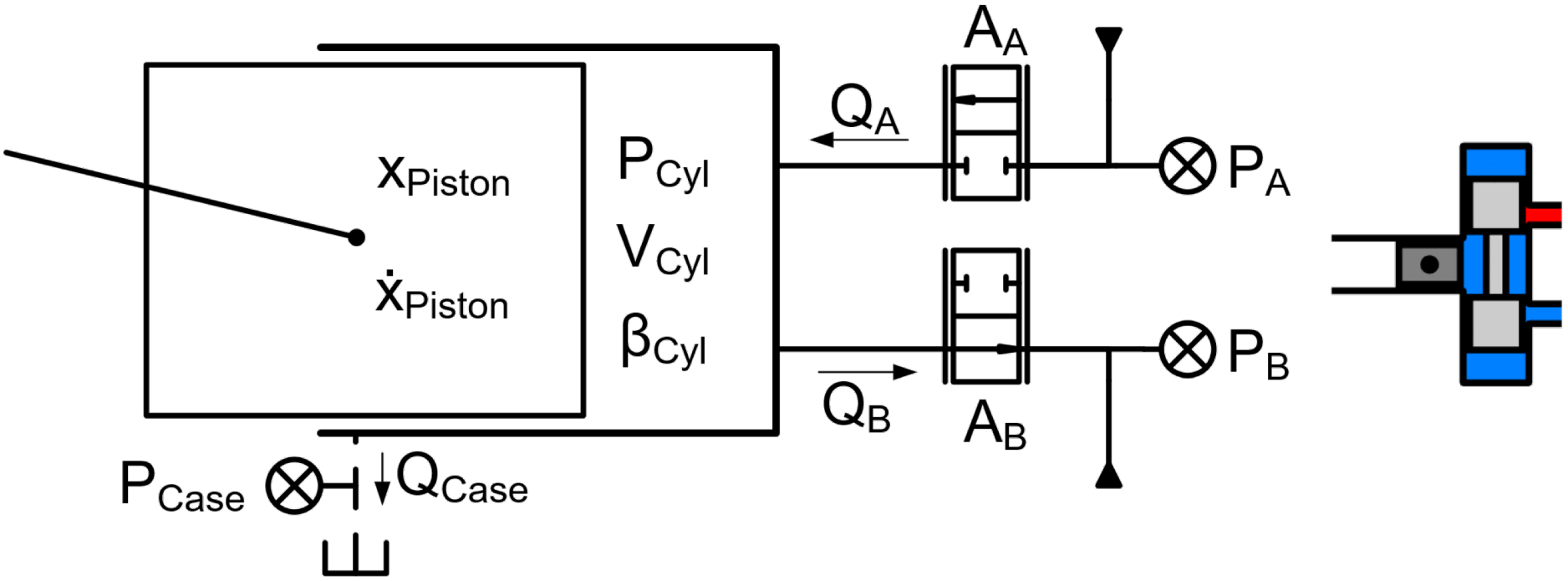


Maximum Power

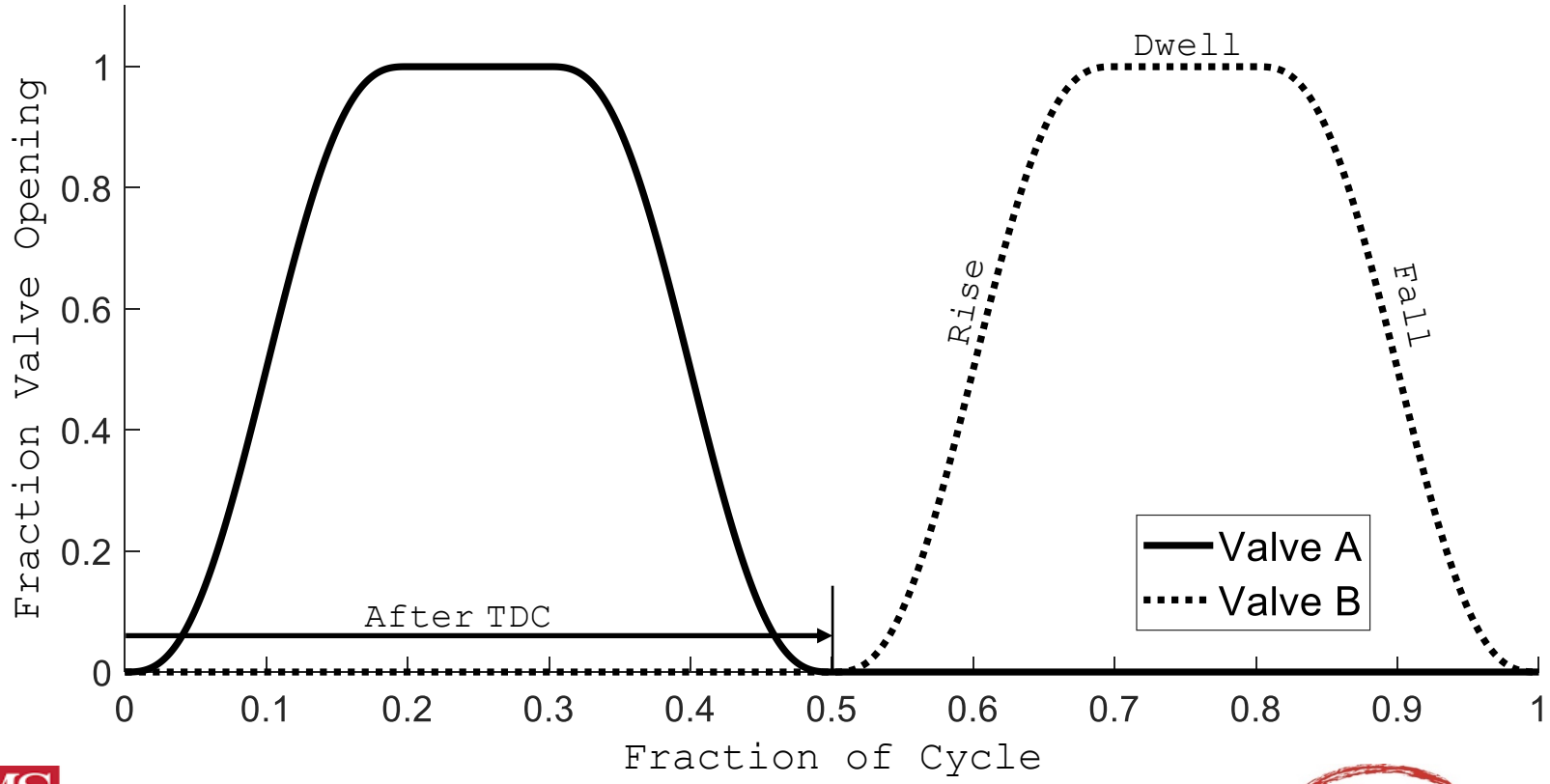


Maximum Efficiency
(Pre-Compression &
Decompression)

Cylinder Model



Valve Timing



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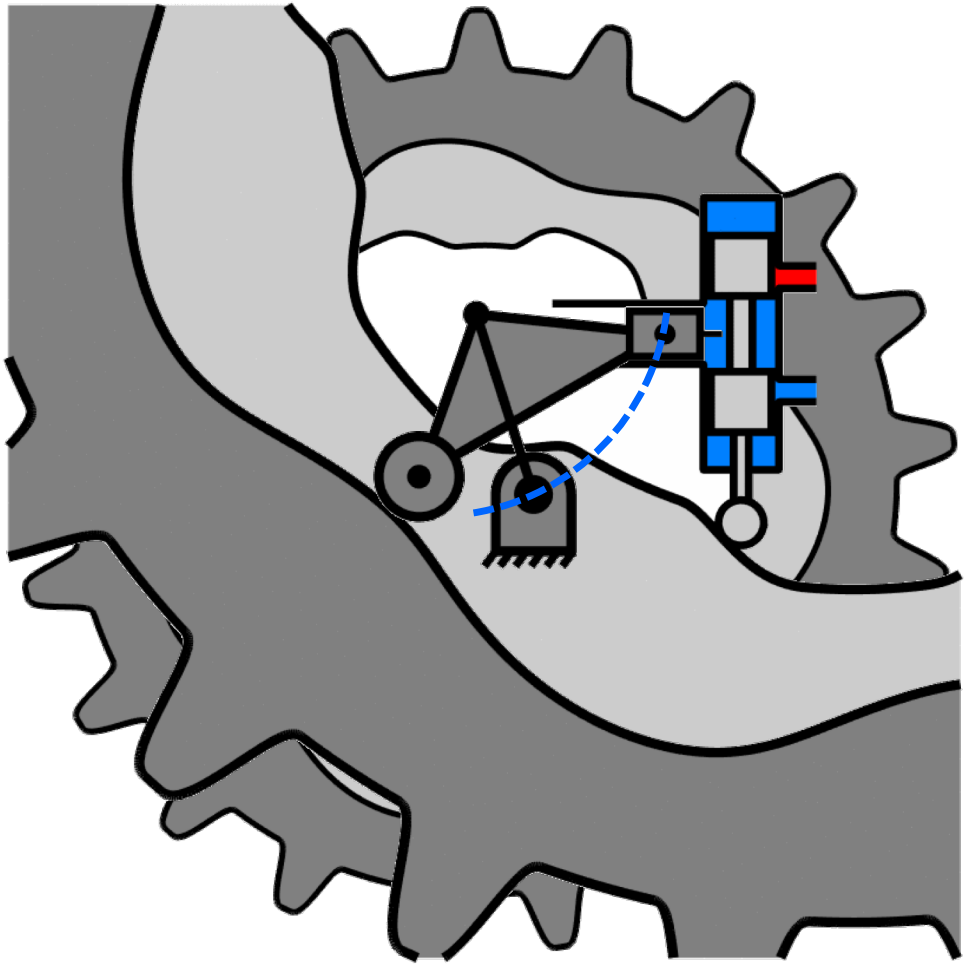
Model Based Design Studies

- Is fixed valve timing sufficient, or is variable valve timing necessary?
- Which is preferred, cam or hydraulic driven valve actuation?
- Spool or poppet valve?



Generating Cam

- Method 1 (conventional)
  - Create cam with desired properties
  - Analyze motion of linkage driven by cam
  - Observe piston trajectory
- Method 2 (our method)
  - Create piston trajectory
  - Analyze motion of linkage
  - Calculate cam that moves linkage as desired

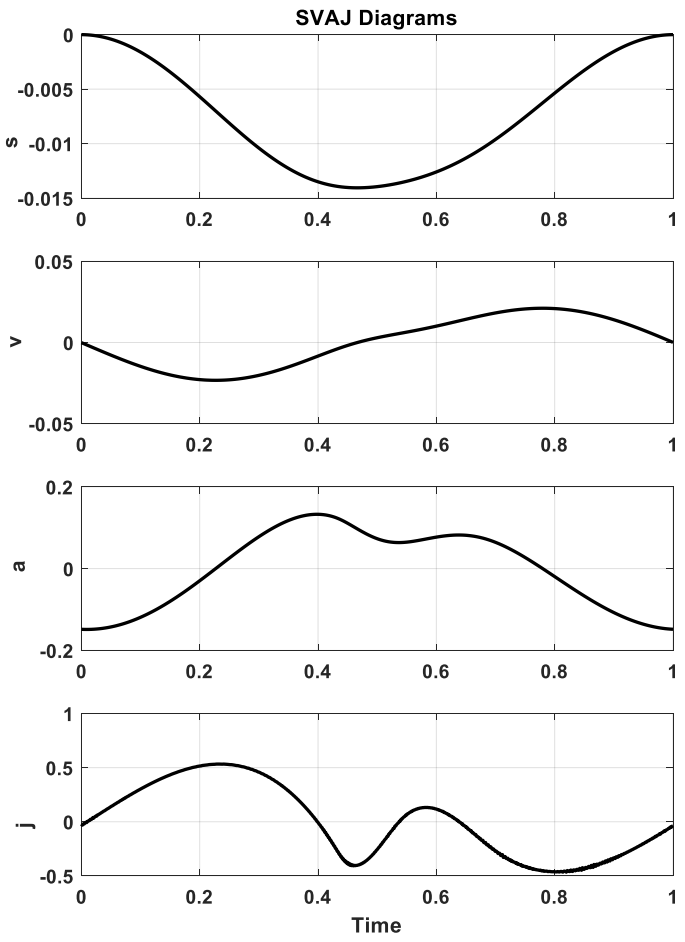
Piston Trajectory – Generation

Importance

- Controls torque ripple

Generation

- Periodic B-spline
- Continuous through (at least) acceleration



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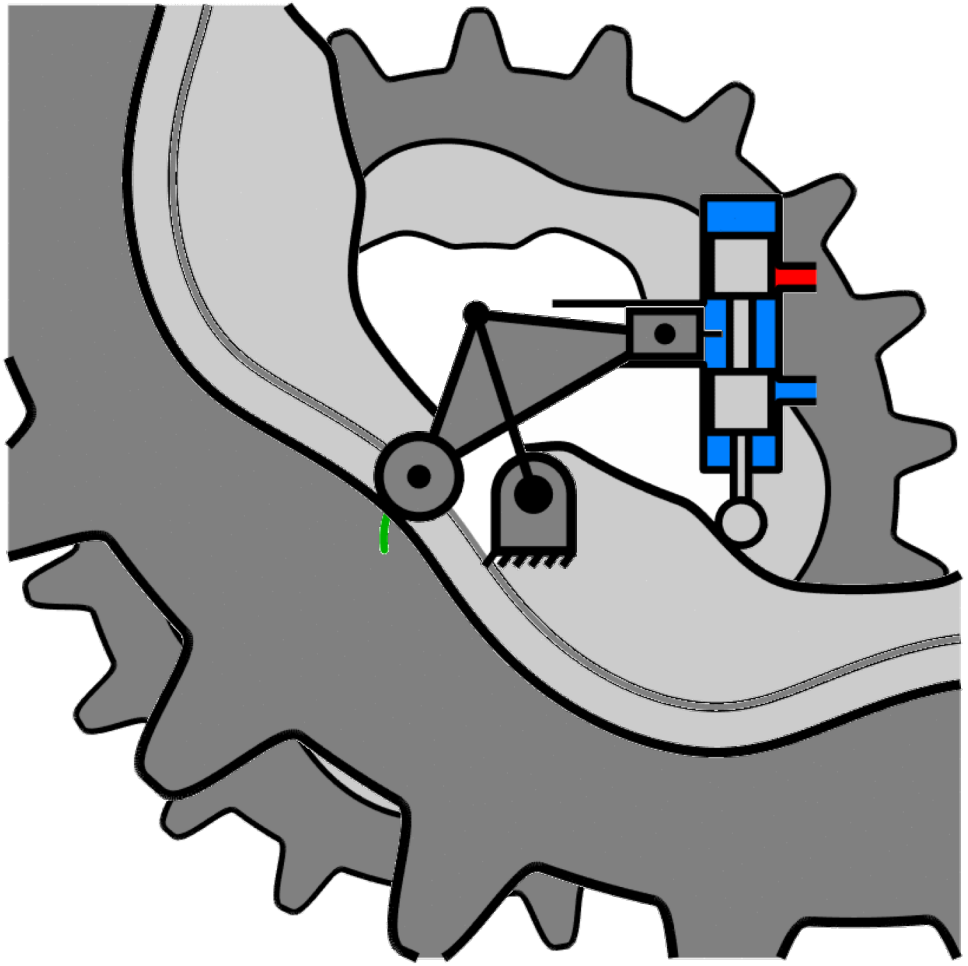


Cam Analysis

- Radius of curvature
- Center of curvature
- Normal vector
- Pressure angle

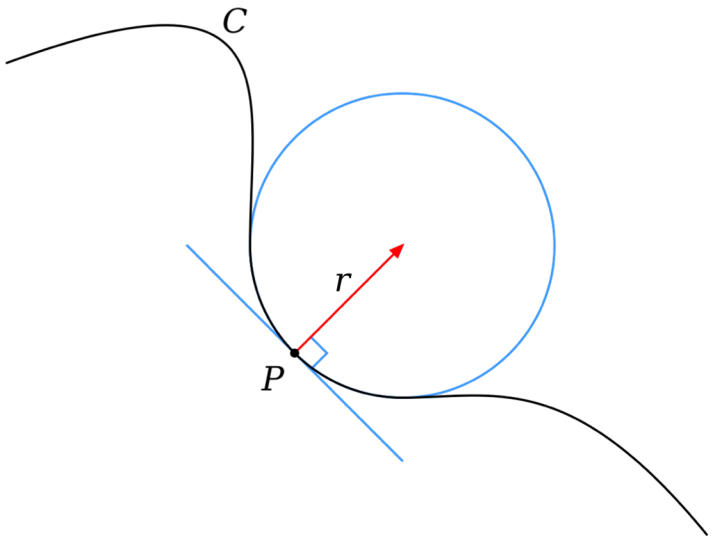
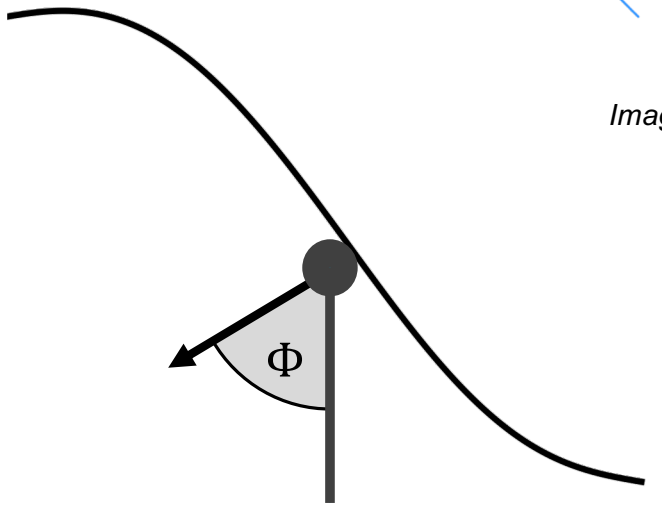
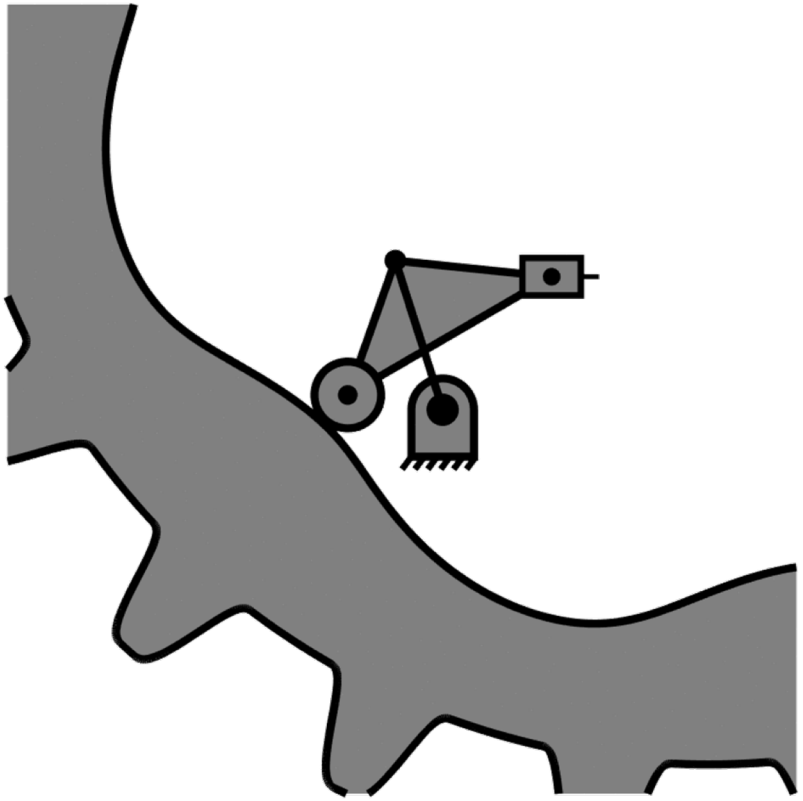


Image from Wikipedia.com



Kinetics

- Force balance
- Torque ripple
- Bearing sizing
- Interference detection



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