Class #19

Hydraulic Hybrid Power Trains

• Reading Questions
• Debate: Hydraulic hybrid architectures
• Hybrid component sizing: comparison to hydrostat
Reading Questions

• Videos: Introduction to Hydraulic hybrids, Hybrid vehicle architectures
• Reading: EPA Hydraulic hybrid research
Debate: Hybrid Architectures

Hybridize a utility vehicle
• Used for mix of work & pleasure

Parallel

Series

Power-Split
Debate Teams

♦ *Diamond*: Parallel Hybrid
♥ *Heart*: Series Hybrid
♠ *Spade*: Hydromechanical Hybrid
♣ *Club*: Moderators / Question Panel
Debate: Hybrid Architectures

• Debate preparation 5 min
  – Prepare strong arguments for your architecture

• Round 1: Opening statements 3 min each
  – Convince panel that your architecture is best choice

• Question preparation 3 min
  – Prepare for moderator questions

• Round 2: Question / Response 1 min/Q
  – Moderators ask questions and teams respond

• Debrief
Debriefing

• Most convincing team?

• Best arguments?

• What did you learn? New points of view?
Series Hydraulic Hybrid Refuse Truck

1. Accumulator sizing
2. Traction motor sizing
3. Pump sizing
4. System weight
5. Control strategy

Source: green.autoblog.com

Mass = 20,000 kg
Frontal Area = 7 m²
Drag Coeff = 0.7
Tire Radius = 0.5 m
Rolling Resist Coeff = 0.01
Component Sizing: Accumulator

- Store all energy from 20 m/s braking

Assumptions:
- Isothermal
- 2:1 Pressure ratio
- \( P_{\text{max}} = 35 \text{ MPa} \)
- Neglect inefficiency

\[
E_{\text{kinetic}} = E_{\text{accumulator}}
\]

\[
\frac{1}{2}mv^2 = P_{\text{charge}}V_{\text{accum}} \ln(r), \quad P_{\text{charge}} = \frac{P_{\text{max}}}{2}
\]

\[
V_{\text{accum}} = \frac{mv^2}{P_{\text{max}}\ln(r)} = 0.33 \text{ m}^3
\]
Component Sizing: Traction Pump/Motor

- Size for peak acceleration (1.5 m/s²)

Assumptions:
- Neglect inefficiency
- Neglect road loads
- 4:1 Axle ratio
- Peak power at minimum pressure

\[ F_{\text{accel}} = \frac{T}{r} = ma \Rightarrow T_{\text{axle}} = 15 \text{ kN} \times \text{m} \]

\[ T_{\text{motor}} = \frac{PD}{2\pi} \Rightarrow D_{\text{motor}} = \frac{2\pi T_{\text{motor}}}{P_{\text{min}}} = 1,346 \text{ cm}^3/\text{rev} \]
Component Sizing: Engine - Pump

- Size for road loads at max speed (30 m/s)
- Use on-off control based on accumulator pressure

Assumptions:
- Simulate w/ on-off flow source
- Neglect inertial force
- Neglect inefficiency

Specs:
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Simulation
UDDS Simulation
Compare to Hydrostatic Sizing

Mass = 20,000 kg
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Rolling Resist Coeff = 0.01
Hybrid Drive Train Architecture

Parallel

Series

Power-Split
Power Split Couplings

Input Coupled:

Output Coupled: