Focused Application, Data Needs, Standardized Testing etc.

Lonnie Love, ORNL
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Fluid Power R&D Opportunities

Lonnie Love, Ph.D.
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2010 DOE/ORNL/NFPA Energy Study

• Fluid power is defined as the application of pumped or compressed fluid (liquid or gas) to provide force and motion to mechanisms

• In 2010, DOE ITP contracted ORNL to conduct a fluid power study
  – Objective was to establish a ballpark estimate on market size, energy consumed, emissions generated and existing efficiency levels
  – ORNL teamed with NFPA and 31 industrial partners spanning all major application areas
  – Industrial partners provided proprietary data on systems, energy consumption, duty cycles and efficiencies
Results of Study

- Segmented industry into 4 areas
  - Mobile hydraulics, industrial hydraulics, pneumatics and aerospace

- Results
  - Industry is a huge manufacturer as well as supporter of manufacturing
    - $17.7B in component sales, > $226B in systems sales
  - 2 to 3 Quads of energy is consumed driving fluid powered systems
    - Mobile hydraulics between 0.4 and 1.3 Quads/yr
    - Industrial hydraulics 1.1 Quads/yr
    - Pneumatics 0.5 Quads/yr
    - Aerospace 0.02 Quads/yr
  - Average efficiency is under 22%

Opportunities for high profile industry wide demonstrations

• CONEXPO/AGG
  – Massive consolidation of fluid power industry every 3 years
  – 120,000 world-wide attendees
  – Target high level of emerging technologies through demonstrations
Private/Public Example: Project AME “Additive Manufacturing Excavator”

Project AME consists of three demonstrations of additive manufacturing in one large-scale application:
1. The heat exchanger will be printed using the Concept Laser
2. The cab will be printed on the Big Area Additive Manufacturing system out of polymer composite material
3. The stick, a large hydraulically articulated arm, will be printed on the Wolf Robotics metal system

Project included CNH, NFPA, CCEFP, Lincoln Electric, Cincinnati Inc...
METHODOLOGIES FROM DUTY CYCLE
DNA COLLECTION & ANALYSIS

Ken Kelly
Team Leader – Commercial Vehicle Technologies, NREL
Focused Applications

Duty Cycle

Ken Kelly
Team Leader – Commercial Vehicle Technologies

Fluid Power Systems Workshop
September 12, 2017
**Kinetic Intensity** is a measure of drive cycle kinetics to define how much *stop and go* is in the cycle.

- Derived from ratio of aerodynamic speed and characteristic acceleration.
- **Characteristic acceleration**: Measures the inertial work to accelerate and/or raise the vehicle per unit mass per unit distance over the cycle.
- **Aerodynamic speed**: Measures the ratio of the overall average cubic speed to the average speed.

![Kinetic Intensity vs Average Driving Speed](image-url)

Duty Cycle Characterization and Evaluation Towards Heavy Hybrid Vehicle Applications

Importance of Duty Cycle for Commercial Vehicles

More Regen Potential

Increased Energy Storage Required
Understanding Modes of Operation

Characteristic Acceleration vs Aerodynamic Speed

Aerodynamic Speed (ft/s)

Cluster 1: Creep/Queue Drive Cycle

Speed (mph)

Cluster 2: Port/Near Dock Drive Cycle

Speed (mph)

Cluster 3: Local Drive Cycle

Speed (mph)

Cluster 4: Metro Highway Drive Cycle

Speed (mph)
Engine-based Drive Cycles

Vehicle-Based Duty Cycle Metrics
- Aerodynamic Speed (ft/s)
- Characteristic Acceleration (ft/s²)
- Percent (%) of total cycle distance below 55 mph
- Percent (%) of total cycle duration at 0 mph
- Number of stops per mile
- Mean (nonzero) driving speed (mph)
- Maximum driving speed (mph)
- Standard Deviation of nonzero driving speed (mph)

Example Engine-based Cycle Metrics:
- average engine load
- maximum engine load
- median load
- standard deviation of engine load
- number of engine loading events per mile traveled (or hour of operation)
- loading ratio (ratio of increasing to decreasing loading rate time)
Idle & PTO Operations

1) Distribution of Engine RPM

2) Distribution of Engine RPM with vehicle speed = 0 (idle + PTO)

3) Time Spent – Driving / Idle / PTO

4) Fuel Consumption
**Commercial Vehicle Electrification**

**Duty Cycle Statistics:**

- **Driving Days**: 17,447
- **Kinetic Intensity (1/mi)**: 3.85
- **Stops per mile**: 5.85
- **Avg Acceleration (ft/s²)**: 0.52
- **Average Speed (mph)**: 15.6

**Motor Continuous Rating**: 55 kW
Applying Drive Cycle Data – NREL DriveCAT

Objectives:

- Provide a common, publically available, easy to use site for standard and custom drive cycles for medium- and heavy-duty vehicles
- Capture, quantify and compare drive cycle variation across the spectrum of medium- and heavy-duty vocations
- Allows users to download raw time series data of drive cycles for their own use
NREL Medium and Heavy-Duty Commercial Vehicle Technologies

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- NREL Fleet Evaluations Website
  http://www.nrel.gov/transportation/fleettest.html
- Fleet DNA Website
  www.nrel.gov/fleetdna
- DriveCAT
  www.nrel.gov/transportation/drive-cycle-tool
- Publications Available at:
  http://www.nrel.gov/transportation/fleettest_publications.html
DISCUSSION 1

• Opportunities in Market Segments
  o Construction
    – Excavators
    – Skid-Steer
    – Compact Track Loader
    – Dozer
    – Wheel Loader
  o Agriculture
    – Tractor
    – Combine/Forage Harvester
  o Material Handling
  o Oil & Gas
  o Mining

• Pre-Competitive Development Needs
• Pre-Competitive Research Needs
  o Energy Consumption Study
  o Baseline System Efficiency
  o Common Duty Cycle(s)
  o Bench Testing
  o Real World Application Testing
• Standardized testing
• Etc.