Improved Efficiency of Off-Road Material Handling Equipment through Electrification

Project ID: ace162

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Michigan Tech

Overview

Timeline

- Project Start: October 2019
- Project End: September 2023
- Percent Complete: 15%

Budget

- Total Project Value: $3.6M
  - Federal: $2.5M
  - Cost Share: $1.1M

Partners

- Michigan Tech (APS LABS)
  - Project Lead
- Pettibone
  - Manufacturer
- Dana
  - Key Vendor

Barriers

- Off-Road equipment has significant diversity of system architecture and end use
- Measuring baseline & incremental system level changes is difficult due to a lack of standardized operating cycles and in-use data
- Additional electrification components may drive initial cost up to the point of sacrificing customer acceptance

Relevance

- Material handling is a critical application at shipping ports, truck and rail yards, timber processing plants, construction sites, etc.
- Intermittent power demand (propulsion & material engagement) combined with material potential energy when in a raised position, make this machine type well suited for electrification

Project Goal & Objectives

Align with DOE VTO goals by demonstrating a >20% reduction in fuel consumption while maintaining emissions compliance, all performance requirements, minimizing increases in cost, and maximizing customer acceptance

1. Evaluate baseline and improvements over representative operating cycles
2. Identify optimal electrification architecture through modeling & experimentation
3. Build a prototype electrified Pettibone CarryLift 204i that demonstrates program goals

Year 1 and 2 Milestones

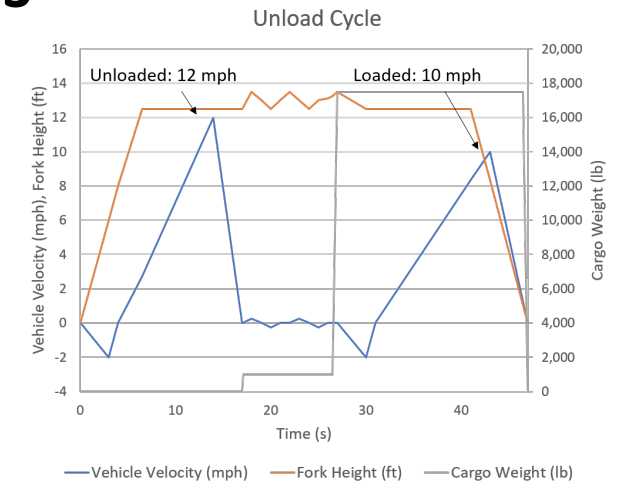
Milestone	Description	Status
M1.1	SOPO Finalized	Complete
M1.2	Sub-Contracts Finalized	In-Process; Behind Schedule
M1.3	Component Selection For Analysis	In-Process
M1.4	Machine Baselining Complete	In-Process; Behind Schedule
M1.5	Vehicle Model Complete w/ Electrification Components Integrated	In-Process; Behind Schedule
M2.1	Model Validated	Not Started; machine / data not available yet
M2.2	Simulation for multiple architectures	Not Started; baseline model to be validated first
M2.3	Electrification Architecture Determined	Not Started; electrification architectures must be simulated first

Approach

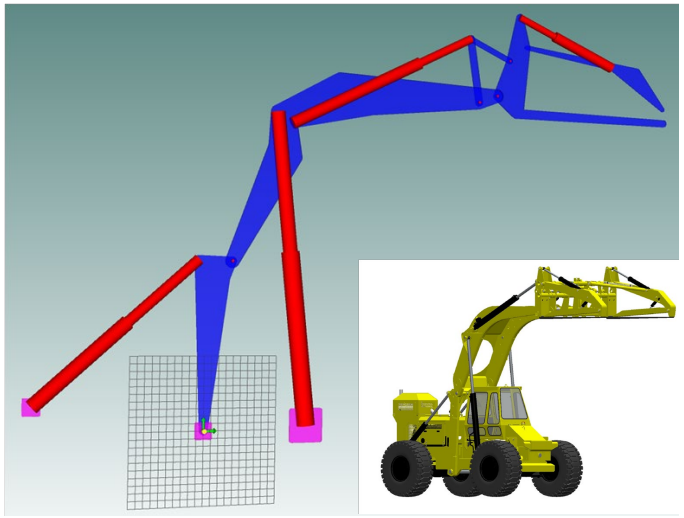
- Baseline performance assessment while developing operating cycles representative of real-world utilization (supports M1.4 & M1.5)
- Develop and calibrate a unified model representative of the baseline propulsion and fluid power systems (supports M1.5 & M2.1)
- Synthesize & Analyze multiple architectures based on commercially available electrification components (supports M1.3 & M2.2 & Year 1 Go/No-Go), and determine optimal architecture to overcome barriers and meet project goals (supports M2.3 & Year 2 Go/No-Go)
- Develop a supervisory controls architecture based on the chosen electrification strategy (supports M3.3)
- Build & real-world demonstration of the electrified machine (supports M3.1 & M3.2)

Technical Accomplishments and Progress

- Simplified sub-modules were developed to represent operating cycles (supports M1.4 & M1.5
- Baseline propulsion system model complete (supports M1.5)
- Baseline fluid-power model in-process (supports M1.5)
- Baseline vehicle build nearly complete (supports M1.4)

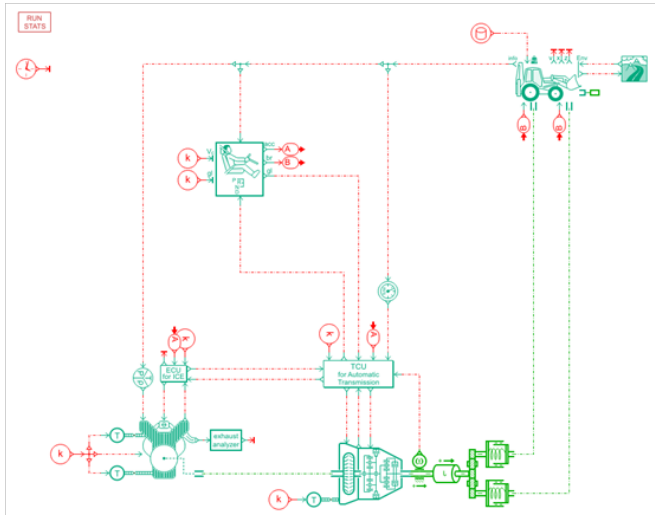


Operating cycles developed by viewing video of a working machine



Kinematics of material engagement components complete, fluid power modeling underway now

Machine being built at Pettibone, May 2021



Propulsion model fully developed and parameterized

Responses to Previous Year Reviewer Comments

- NA; This is the first year for this project to be reviewed

Collaboration & Coordination

- Michigan Tech APS LABS: Project Prime / Lead
- Pettibone: OEM Sub / Partner
  - Engineering Expertise, Machine Technical Specifications, Machine Performance Requirements
  - Since beginning the technical work, MTU & Pettibone have been meeting regularly to exchange technical information, co-develop operating cycles, review modeling results, etc. The success to-date is a direct result of the high-quality working relationship.
- Dana: Key Vendor
  - Detailed technical specifications for electrification components
  - MTU & Dana have an existing strong relationship, which will be critical as the project moves into modeling of electrified architectures
- Cummins, Parker, Funk, Axle Tech / Meritor
  - Sub-System technical specifications

Remaining Challenges & Barriers

- Obtaining real-world data at the onset of the project proved more difficult than expected (COVID & end-user reluctance)
  - Slowing development & calibration of models
  - Delaying development of standard operating cycles
  - First time data will be available will be after the project machine is produced and instrumented
- Accurately modeling the fluid power system is complex, and co-simulation of the hydraulic and propulsion models will be difficult
- Material potential energy recover will be difficult due to safety measures that must be included in the production machine

Proposed Future Research

- Experimental
  - Complete the build of the baseline machine & transport machine from Pettibone to APS LABS
  - Instrument the machine to acquire key propulsion system and fluid power system parameters
  - Transport instrumented machine to end-users for real-world field testing
  - Develop ‘standard’ operating cycles & baseline characterizations
- Modeling
  - Finish the fluid power model
  - Integrate the propulsion model and fluid power model to enable co-simulation
  - Calibrate models with baseline machine data
  - Exercise the model to identify optimal electrification architecture & control strategy

Any proposed future work is subject to change based on funding levels

Summary

- A machine propulsion model and fluid power model are developed
- In the absence of experimental data, representative operating cycles were developed based on video of a working machine
- The machine that will serve as the baseline & prototype is being built and an instrumentation & test plan is being developed
- By October 2021 the project machine will be instrumented, baseline data will have been collected, real-world operating cycles will be finalized, models will be calibrated, and work toward identifying the optimal electrification architecture will be underway

Technical Back-Up Slides

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To avoid the potential of publication of confidential information, no technical back-up slides are provided at this time