Powertrain System
Dynamic Model Development:
M1A1 Abrams Main Battle Tank

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Presentation Topics

- Description of the M1A1 Abrams main battle tank powertrain system hardware
- Modular M1A1 powertrain system models
  - Engine, torque converter, transmission, gearbox, planetaries, driveshafts, hydrostatic steering
  - Functionalities captured in the dynamic models
- Case studies: Using the dynamic powertrain models to understand system performance
  - Focus on the influence of grades & steering input
  - Description of tests conducted and results
- Summary and Conclusions
Overall vehicle
- Prime Contractor: General Dynamics (Land Syst.)
- Combat weight: 67.7 tons (61.4 metric tons)
- Power/weight ratio: 22 hp/ton
- 4 person crew; driver, commander, gunner, loader

Engine
- Textron-Lycoming AGT-1500 gas turbine
- 1500 hp @ 22,500 rpm (power turbine speed)
- High & low pressure compressors, turbines, and spools
- Recuperator, output power turbine and spool
M1A1 Abrams Powertrain System Hardware

Transmission Module
- 7.5:1 speed reduction into transmission module (22,500 rpm to 3,000 rpm, rated speed)
- Allison X1100-3B automatic transmission module
- X110-1C Hydrokinetic torque converter
- 4 forward speeds, 2 reverse speeds
- Hydrostatic steering unit; variable displacement, 9-piston radial hanging ring pump
- Hydraulic brakes at each drive sprocket
- Planetary gear reduction and final drive at each drive sprocket
AGT-1500 Gas Turbine Engine Thermodynamic Cycle

1. Intake System
2. LPC
3. HPC
4. Comb
5. Recuperator
6. HPT
7. LPT
8. PT
9. Load Torque
10. Gas Generator

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M1A1 Abrams
Modular Powertrain System Models

- Mean-value modular engine model (AGT-1500)
  - Data from the torque-speed maps
- Full dynamic modular engine model (AGT-1500)
  - Low pressure spool rotational dynamics
  - High pressure spool rotational dynamics
  - Drive turbine dynamics
  - 5 compressor and turbine maps
  - Gas generator and recuperator
- Full dynamic drivetrain model
  - X1100-3B transmission module, torque converter
  - Hydrostatic steering pump/motor and gearing
  - Final drive planetary gear reductions
Partial Modular Format
for the AGT-1500
Gas Turbine
Dynamic Model

1. Packaged Engine
2. Gas Turbine Engine
3. Gas Generator
4. Compressors
5. Recuperator

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1.头上rpm
1.头上

2.头上
2.头上

1.头上
1.头上

X110-1C
Torque Converter Model

X1110-3B Transmission
Shift Control Logic

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Case studies to examine powertrain system and overall vehicle performance

- Slope and steering response in 3 case studies
  - 1. Response to slope changes w/o steering ($v_0 = 40$ mph)
  - 2. Response to steering w/o slope changes (vehicle launched from 0 mph)
  - 3. Combined slope and steering changes (vehicle launch)

- Vehicle speed control algorithm implemented
  - Driver inputs desired speed (used for demonstration)
  - Removes driver’s influence during comparative testing

- Hydrostatic steering pump control algorithm
  - Comparison w/ current configuration (driver has direct control of steering pump displacement)
8 Slope Scenarios

Scen._1
Scen._2
Scen._3
Scen._4
Scen._5
Scen._6
Scen._7
Scen._8

Time [seconds]

Percent Road Slope [%]
M1A1 Velocity with Varying Slope Input

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Sinusoidal Driver Steering Input

- In the top graph, the Hydraulic Pump Displacement is depicted (in m³/°rad) over time (in seconds). The graph compares the performance with and without compensation. The 2-3 shift is indicated at around 3 seconds.

- In the bottom graph, the Hydraulic Pump Flow (in m³/sec) is shown over time. This graph also compares with and without compensation, showing a 1-2 shift around 2 seconds and a 2-3 shift around 3 seconds.
Sinusoidal Driver Steering Input

Solid lines—Left, Dashed lines—Right

Planetary Sun Relative Velocities [rpm]

-600 −400 −200 0 200 400 600

Time [seconds]

Vehicle and Track Speeds [mph]

10 15 20 25 30 35 40 45

Time [seconds]

Upshift understeer perturbation (eliminated w/ compensation)

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Combined Steering & Slope Commands

Baseline

Combined loading

Time (seconds)

Steering command

% Road Slope

Baseline

Combined loading

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Track Speeds & Transmission I/O Speeds

M1A1 steering maneuver

4-3 downshift

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Summary and Conclusions: Case Studies

- Powertrain system dynamic response
  - Steering coupled to engine speed (upshift = understeer perturbation, downshift = oversteer)
  - Grade/slope changes predict shifting patterns and vehicle performance in uneven terrain

- Utility of M1A1 powertrain system simulation
  - Can be used to gain a deeper understanding of overall system vehicle performance
  - Optimize components, controls, and system for specific applications and duty cycles
    - battlefield environment, respond to enemy capability ...
  - More examples: environment, loading, thermal ...

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Summary and Conclusions: Overall Models

- Dynamic models of the complete M1A1 Abrams powertrain system have been developed by the University of Wisconsin-Madison Quad. New attributes to be added.
- Powertrain system models can be used for optimization or overall system performance.
- Examples were presented showing how the component and system level performance can be simulated and analyzed.
- See - http://www.erc.wisc.edu/powertrain/