Powertrain Systems in
ADAMS/Car

Makarand V Datar
4th January 2007
University of Wisconsin, Madison
• ADAMS/Car uses different templates to create subsystems for Steering, Suspension, Brakes, Powertrain et cetera. These subsystems are then assembled to create full vehicle assemblies.

• Powertrain is not essential to create a full vehicle assembly.

• Then when would a Powertrain system be required?
Topology of the powertrain System

- Engine
- Clutch
- Transmission
- Differential
Simplified Topology of the Elements in Powertrain System
• The dynamics of the Powertrain subsystem are not modeled with parts and joints but by a set of Differential Equations and State variables (Algebraic Equations)

• Output communicators of the Powertrain system communicate with the input communicators of the _MDI_SD1_TESTRIG
<table>
<thead>
<tr>
<th>Variables represented by Differential Equations</th>
<th>Variables represented by Algebraic Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. clutch_slip</td>
<td>3. analysis_type</td>
</tr>
<tr>
<td>2. engine_omega</td>
<td>4. clutch_displacement_ic</td>
</tr>
<tr>
<td></td>
<td>5. clutch_torque</td>
</tr>
<tr>
<td></td>
<td>6. differential_torque</td>
</tr>
<tr>
<td></td>
<td>7. engine_rpm</td>
</tr>
<tr>
<td></td>
<td>8. engine_speed</td>
</tr>
<tr>
<td></td>
<td>9. engine_torque</td>
</tr>
<tr>
<td></td>
<td>10. halfshaft_omega_left</td>
</tr>
<tr>
<td></td>
<td>11. halfshaft_omega_right</td>
</tr>
<tr>
<td></td>
<td>12. max_braking_torque</td>
</tr>
<tr>
<td></td>
<td>13. max_driving_torque</td>
</tr>
<tr>
<td></td>
<td>14. throttle_position_emis</td>
</tr>
<tr>
<td></td>
<td>15. total_axle_torque</td>
</tr>
<tr>
<td></td>
<td>16. transmission_input_omega</td>
</tr>
</tbody>
</table>
Type of Simulations in the ADAMS Car powertrain system

• Dynamic Simulation

• Quasi-Static Simulation
Engine Details
Dynamic Simulation

Contains a single part ges_engine which represents all the mass and inertia properties of engine block, clutch housing, transmission

- A differential equation "engine_omega" is integrated to calculate the angular speed of the engine

\[
\frac{dw}{dt} = \frac{\text{(Engine Torque)} - \text{(Clutch Torque)}}{\text{Engine Rotational Inertia}}
\]

- A general spline element (gss_engine_torque) represents the engine's steady-state torque versus engine speed (W) and throttle position. Before any analysis, gss_engine_torque is updated by reading the engine torque versus engine speed and throttle from a powertrain property file
Torque vs Engine Speed and Throttle position
Quasi-Static Simulation

- for a Quasi-Static simulation, $dw/dt = 0$ this means that (Engine Torque = Clutch Torque)

- Engine torque is again calculated by referring to the spline gss_engine_toque. But this time the engine speed is not available. (there is no equation for numerical integration).

- Since Engine Torque = Clutch Torque, this means that there is no slip in the clutch thus Engine Speed = Clutch Speed. This clutch speed can be back calculated from the omega of driven tires and applying all the gear ratios.
• The angular velocity of the driving wheel is calculated by using a VARSUB, variable subroutine.

• This subroutine uses the idea of tire slip to calculate the angular velocity of driving wheels.
Clutch Details
Dynamic Simulation

No parts exist in the clutch model.

- Only differential and algebraic equations
- Clutch demand of 1 and 0
- These demand values could be set by using parameter variables pvs_clutch_closed and pvs_clutch_open
- Closed clutch acts like a torsional spring and damper, but there is a limit on maximum clutch capacity and is set by the variable pvs_clutch_capacity
• Clutch Torque = Clutch Stiffness*Clutch Slip) + Clutch Damping*Clutch Slip Speed

• When the Clutch is Closed (=0),
  Clutch Slip Speed = Engine Omega - Transmission Input Omega

• When the Clutch is Open (=1)
  Clutch Sleep Speed = S/decay period

• neither is true when the clutch demand is between 0 and 1. Hence an equation capturing both these phenomena is used.
In the quasi-static setup, Clutch torque equals Engine torque. So, here, unlike the dynamic setup, the clutch torque is already known. Thus the equation for the clutch torque is used to calculate the initial conditions for clutch slip.
Transmission Details
• Transmission dynamics are simple to capture

• Previously calculated Clutch Torque is scaled by the gear ratio based on the gear demand to calculate the axle torque.

• Transmission input omega is calculated by scaling the rotational omegas of the drive wheel half-shafts.
Differential Details
• Differential Input speed is the average of the left and right output shaft speeds multiplied by the final drive ratio.

• Differential Torque is calculated based on the difference between the speeds of the left and right output shafts. A spline element, gss_differential uses this value to calculate the differential torque.
Thank you!