Vehicle Dynamics
Term Project
Driveline Modelling

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In a motor vehicle, the term vehicle driveline describes the main components that generate torque and deliver it to the wheels, which forms the interface.

In layman language, this is the medium through which you connect the engine with the wheels.
CAD MODEL OF DEIVELINE
Components of Drive Train

- Engine
- Clutch
- Transmission
- Propeller Shaft
- Final Drive
- Drive Shaft
- Wheels

CAD MODEL OF CAR
In vehicle we use Internal combustion engines. These convert the chemical energy present in fuel into mechanical energy.

At around 100 km/hr the passenger cars produce about 7000 rpm.
It transmits engine power to the gearbox, and allows transmission to be interrupted while a gear is selected to move off from a stationary position, or when gears are changed while the car is moving.

Most cars now a days use a friction clutch operated either by fluid (hydraulic).
Engine torque is transmitted through the clutch to the transmission or transaxle. The transmission contains sets of gears that increase or decrease the torque, before it is transmitted to the rest of the drive train. The lower the gear ratio selected, the higher the torque transmitted.
It is used to transmit the torque from the gear box or transmission to the final drive.

Usually around 4 feet for cars to about 9 feet for trucks
The final drive provides a final gear reduction, to multiply the torque before applying it to the driving axles.

Inside the final drive, a differential gear set divides the torque to the axles, and allows for the difference in speed of each wheel when cornering.
It transmits the differential torque to driving wheels. These along with the propeller shafts experience the highest twist.

Material”
Driveline modeling

Model 1: Drive Shaft Flexibility

The clutch and the propeller shafts are assumed to be stiff, and the drive shaft is described as a damped torsional flexibility. The transmission and the final drive are assumed to multiply the torque with the conversion ratio, without losses.

\[ M_w = M_d = k(\theta_f - \theta_w) + c(\dot{\theta}_f - \dot{\theta}_w) \]

\[ M_w = M_d = k\left(\frac{\theta_m}{\tau_f \tau_g} - \theta_w\right) + c\left(\frac{\dot{\theta}_m}{\tau_f \tau_g} - \dot{\theta}_w\right) \]

\[ (J_{f} + J_{t} \tau_f^2) \ddot{\theta}_m = M_c \tau_g^2 \tau_f^2 - b_t \dot{\theta}_m \tau_f^2 - b_f \dot{\theta}_m - k(\theta_m - \theta_w \tau_f \tau_g) - c(\dot{\theta}_m - \dot{\theta}_w \tau_f \tau_g) \]
This forms a state space form.

\[
\dot{x} = Ax + BU + Hl
\]

Where

\[
A = \begin{pmatrix}
0 & \frac{1}{\tau} & -1 \\
-k \frac{1}{\tau J_1} & -(B_1 + \frac{c}{\tau^2}) \frac{1}{J_1} & c \frac{1}{\tau J_1} \\
k \frac{1}{J_2} & c \frac{1}{\tau J_2} & -(c + b_2) \frac{1}{J_2}
\end{pmatrix}
\]

\[
l = r_m (c_{r1} + g \sin \alpha)
\]

\[
b_1 = b_w + \frac{b_f}{\tau_g^2} + \frac{b_f}{\tau_f^2}
\]

\[
J_2 = J_w + m r_w^2
\]

\[
B = \begin{pmatrix}
1 \\
J_1 \\
0
\end{pmatrix}
\]

\[
H = \begin{pmatrix}
0 \\
J_1 & -1 \\
0
\end{pmatrix}
\]

\[
x_1 = \frac{\theta_m}{\tau_f \tau_g} - \theta_w
\]

\[
x_2 = \dot{\theta}_m
\]

\[
x_3 = \dot{\theta}_w
\]

\[
b_2 = b_w + mc r_w^2
\]

\[
J_1 = J_m + \frac{J_f}{\tau_g^2} + \frac{J_f}{\tau_f \tau_g}
\]

\[
\tau = \tau_f = \tau_g
\]
Model 2: Flexible Clutch and Drive Shafts

A model with a linear clutch and one torsional flexibility (the drive shaft) is derived by repeating the procedure for Model 1 with the difference that the model for the clutch is a flexibility with stiffness $k_c$ and internal damping $c_c$.

\[
(J_t + J_f/i_f^2)\ddot{\theta}_t = i_t \left( k_c (\theta_m - \dot{\theta}_t i_t) + c_c (\theta_m - \dot{\theta}_t i_t) \right) - (b_t + b_f/i_f^2)\dot{\theta}_t - M_d/i_f
\]

Model 3: Flexible Propeller Shaft

A model with a flexible propeller and drive shaft, is derived by repeating the procedure for Model 1 with the difference that the model for the propeller shaft is a flexibility with stiffness $k_p$ and internal damping $c_p$.

\[
(J_w + m r_w^2)\ddot{\theta}_w = k_d (\theta_p/i_f - \theta_w) + c_d (\dot{\theta}_p/i_f - \dot{\theta}_w)
- b_w \dot{\theta}_w - \frac{1}{2} c_w A_o p_o r_w^2 \dot{\theta}_w^2 - m c_r r_w^2 \dot{\theta}_w - r_w m (c_{r1} + g \sin(\alpha))
\]
Parameters and Assumptions

- Engine type: spark engine
- Maximum power: 45000W
- Speed at maximum power: 3800rpm
- Maximum speed: 6000rpm
- Stall speed: 350 rpm
- Engine inertia: 0.2 kg-m²
- Fuel consumption per revolution: 25mg/rev
- Inertia of shaft 1: 0.2 kg-m²
- Inertia of shaft 2: 1kg-m²
- Single Gear, No meshing and viscous losses
- Single Custom clutch
- Throttle 100% open for the engine
- No flexibility assumed for any component
(A) SIMULINK MODEL OF REAR WHEEL DRIVE
1. INPUT OF CLUTCH
Normalized pressure vs time (sec)
2. POWER OUTPUT OF ENGINE

Power output (in Watt) vs time (in sec)
3. VELOCITY OF VEHICLE

Velocity (in km/hr) vs time (in sec)
4. SLIP OF THE WHEEL
Tire slip vs time (in sec)
(B) SIMULINK MODEL OF FOUR WHEEL DRIVE
(Using same parameters and assumptions)
Clutch pressure vs time (in sec)

Engine power (Watt) vs Time (in sec)

Vehicle velocity (km/hr) vs time (in sec)

Tire slip (10^-3) vs time (in sec)
Four wheel and Two wheel drive

Four wheel drive (4WD) is a form of all-wheel drive powertrain capable of providing power to all wheels of a four wheeled vehicle simultaneously. The car has a way to send engine power to both the front and rear tires. Four Wheel drive means all four wheels are motorized, and that gives better traction in extreme conditions.

Two-wheel drive (FWD) is a form of engine and transmission layout used in motor vehicles, where the engine drives the front wheels only. The direct connection between engine and transaxle reduces the mass and mechanical inertia of the drivetrain.
COMPARISON OF TWO WHEEL AND FOUR WHEEL DRIVE USING CARSIM
Parameters for four wheel drive
The drive shaft applies a roll moment between the engine mass and differential. Most drivelines cause positive roll of the engine mass during acceleration. (When viewed from the front of the vehicle, the drive shaft rotation is clockwise.)
Parameters for front wheel drive

Vehicle Body
- Sprung mass: Rigid Sprung Mass
- A-Class, Hatchback Sprung Mass

Aerodynamics
- A-Class, Hatchback Aero

Animator Data
- Vehicle animation data: Vehicle Shape
- A-Class, Subcompact

Systems
- Powertrain: Front-wheel drive
  - 150 kW, 6-spdr., 4:1 Ratio
- Brake system: 4-wheel system
  - B-Class, Hatchback w/ ABS
- Steering system: 4-wheel steer
  - A-Class, Hatchback, Manual, R&P

Front
- Suspension type: Independent
  - Front kinematics: Independent
    - A-Class, Hatchback - Front Suspension
  - Front compliance: Independent
    - A-Class, Hatchback - Front Comp.
  - Right-front tire: Tire
    - 175/65 R14
  - Left-front tire: Tire
    - 175/65 R14

Rear
- Suspension type: Independent
  - Rear kinematics: Independent
    - A-Class, Hatchback - Rear Suspension
  - Rear compliance: Independent
    - A-Class, Hatchback - Rear Comp.
  - Right-rear tire: Tire
    - 175/65 R14
  - Left-rear tire: Tire
    - 175/65 R14
Driveline Torsional Flexibility

This flexibility involves all driveline parts (incl. transmission, differentials, and all drive wheels, but not engine).

Drive shaft roll effect:

The drive shaft applies a roll moment between the engine mass and differential. Most drivelines cause positive roll of the engine mass during acceleration. (When viewed from the front of the vehicle, the drive shaft rotation is clockwise.)

Check this box if the engine body has a pitch effect from: 

- Drive torque pitch effect to engine body
1. Slip vs time
2. Acceleration vs distance.
3. Longitudinal velocity vs distance-
4. Transmission clutch control vs time-
REFERENCES-

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