# CONTROL STRATEGY OPTIMIZATION FOR A DUAL CLUTCH TRANSMISSION DOWNSHIFT

GROUP 2
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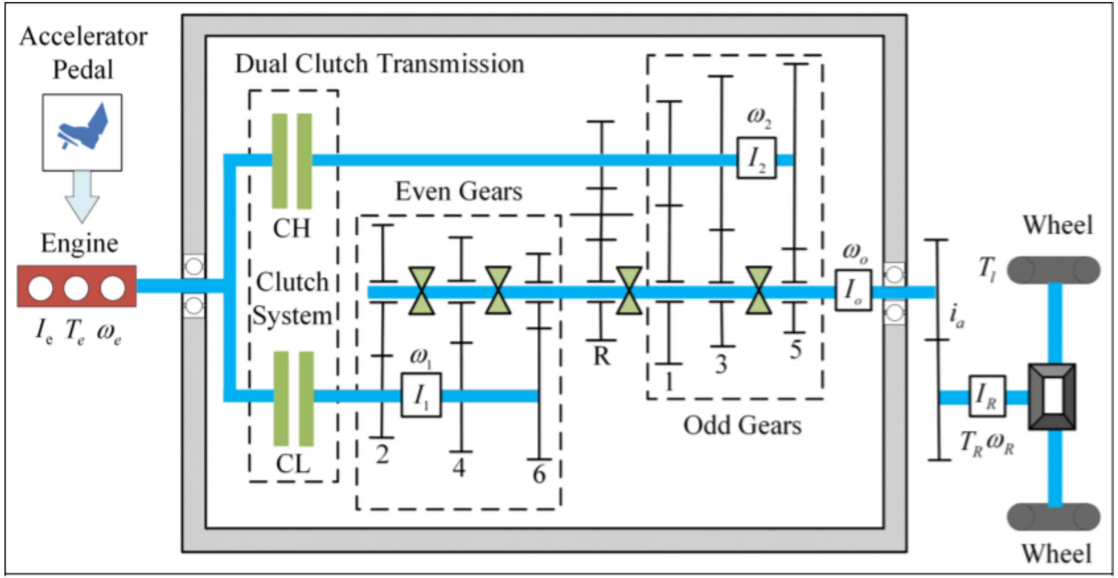
# Problem Statement

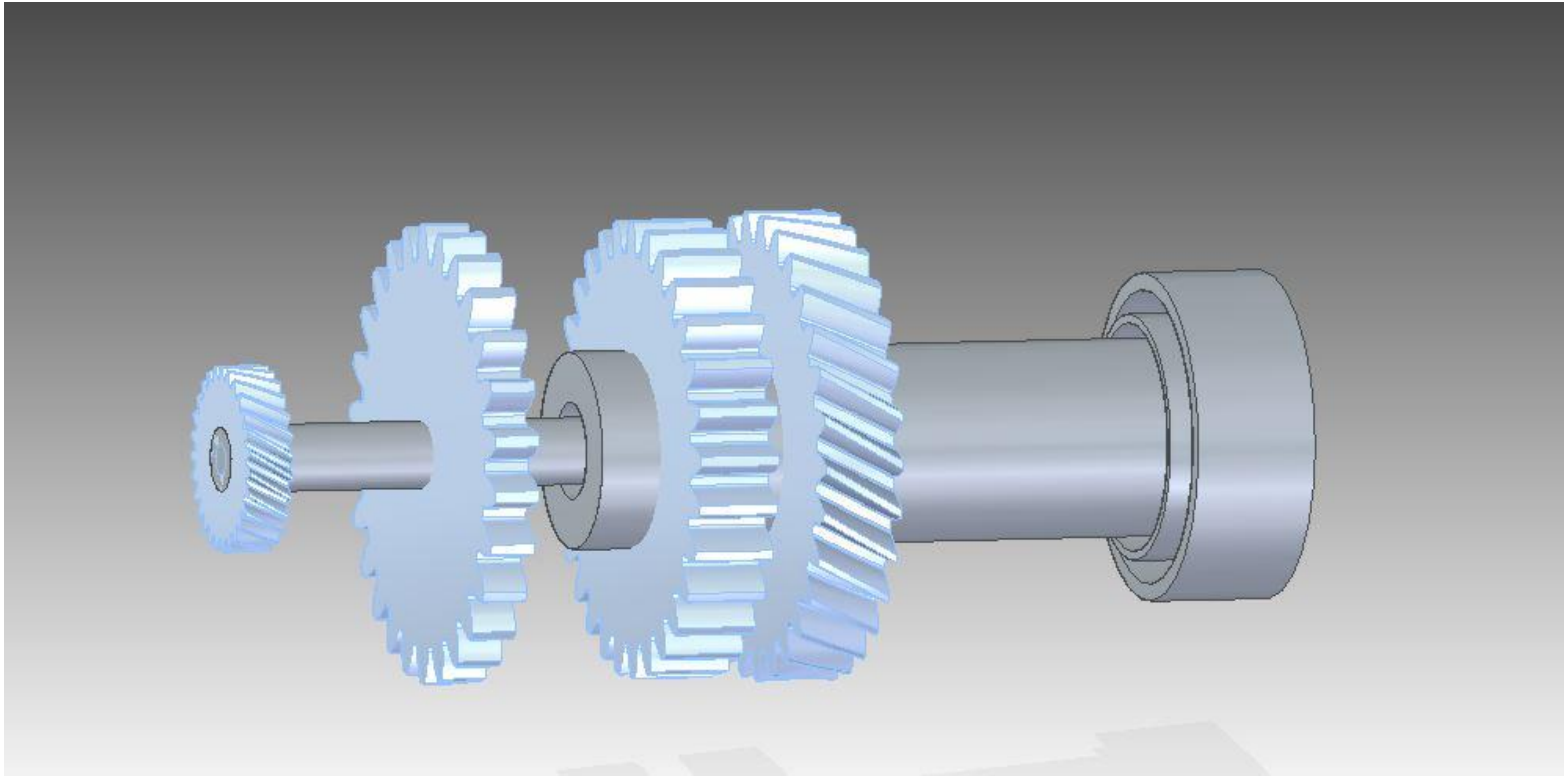
- Timing of engagement and disengagement of the two clutches without power interruption or power circulation.
- Need to balance the frictional energy loss and the level of jerk during the inertia phase.
- Along with only one slipping clutch in the Torque phase

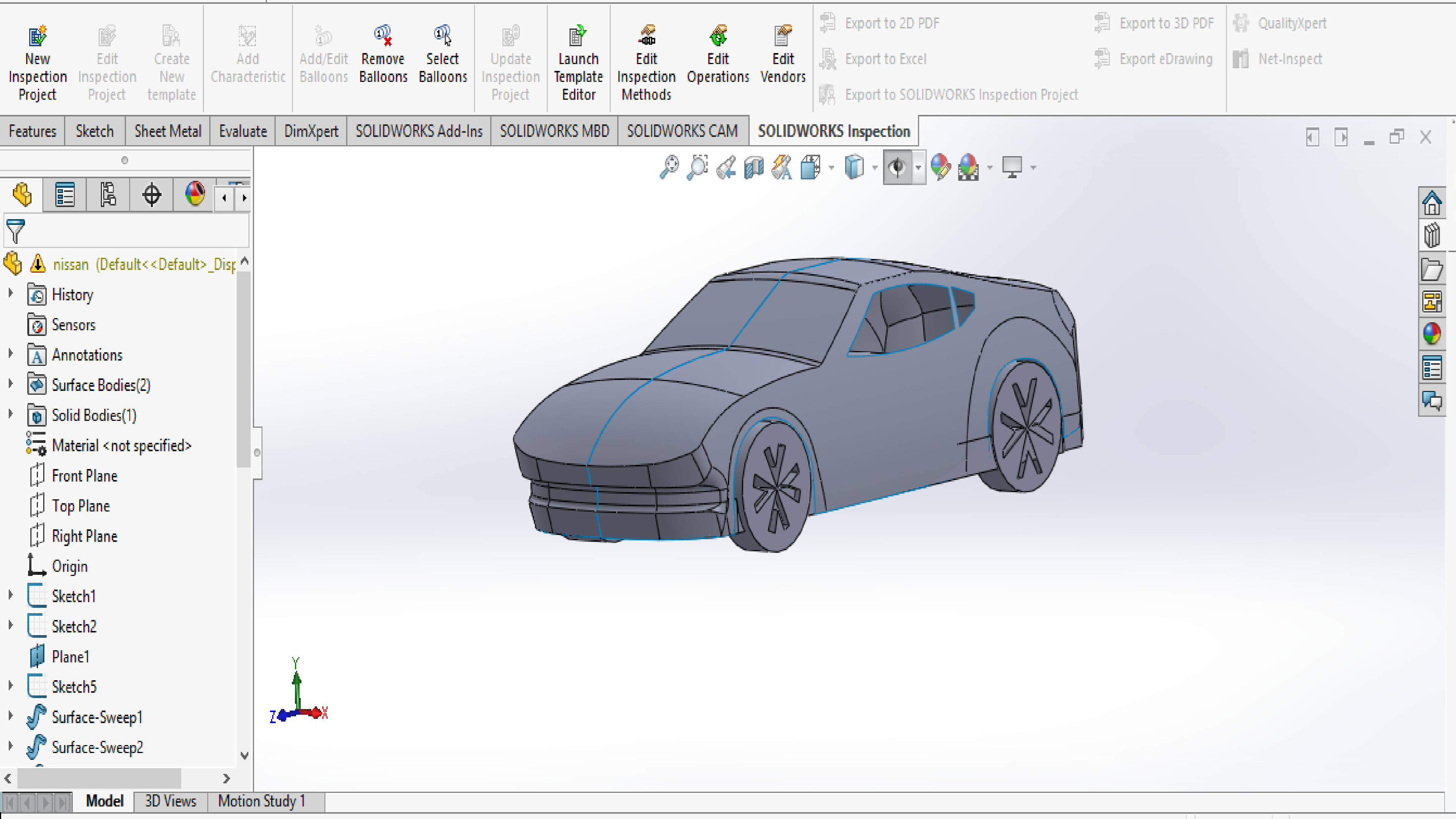
# Introduction

What is DCT?

- 

# CAD Models





New Inspection Project
Edit Inspection Project
Create New template
Add Characteristic
Add/Edit Balloons
Remove Balloons
Select Balloons
Update Inspection Project
Launch Template Editor
Edit Inspection Methods
Edit Operations
Edit Vendors
Export to 2D PDF
Export to Excel
Export to SOLIDWORKS Inspection Project
Export to 3D PDF
Export eDrawing
QualityXpert
Net-Inspect
Features
Sketch
Sheet Metal
Evaluate
DimXpert
SOLIDWORKS Add-Ins
SOLIDWORKS MBD
SOLIDWORKS CAM
SOLIDWORKS Inspection
nissan (Default<<Default>_Disp
History
Sensors
Annotations
Surface Bodies(2)
Solid Bodies(1)
Material <not specified>
Front Plane
Top Plane
Right Plane
Origin
Sketch1
Sketch2
Plane1
Sketch5
Surface-Sweep1
Surface-Sweep2
Model
3D Views
Motion Study 1

# Inertia Phase(High gear)

- DCT gear shifts consist of three phases.
- Inertia phase is first one.
- the releasing pressure is reduced gradually, resulting in a decrease in the torque capacity of the CH

$$I_e \frac{d\omega_e}{dt} = T_e - T_{CHi} - c_e\omega_e$$

$$I_2 \frac{d\omega_2}{dt} = T_{CHi} - \frac{T_o}{i_5} - c_2\omega_2$$

$$I_e \frac{d\omega_e}{dt} = T_e - T_{CH} - c_e\omega_e$$

$$I_2 \frac{d\omega_2}{dt} = T_{CH} - \frac{T_o}{i_5} - c_2\omega_2$$

- By uniform wear theory of clutches:

$$T_{CH} = \mu K_n P_{CH}$$

$$K_n = A_f n \frac{2}{3}\left(\frac{R_o^3 - R_i^3}{R_o^2 - R_i^2}\right)$$

- Also we assume the change in the vehicle speed and the change in the road grade are small. and the rolling resistance as constant..

# Torque Phase

- In this phase pressure need to be applied on CL and pressure on CH should be released to 0.
- Also uniform wear theory is applied to CL clutch.

$$I_e \frac{d\omega_e}{dt} = T_e - T_{CH} - T_{CL} - c_e\omega_e$$

$$I_1 \frac{d\omega_1}{dt} = T_{CL} - \frac{T_{CLo}}{i_4} - c_1\omega_1$$

$$I_2 \frac{d\omega_2}{dt} = T_{CH} - \frac{T_{CHo}}{i_5} - c_2\omega_2$$

$$T_{CL} = \mu K_n P_{CL}$$

# Inertia Phase(Low gear)

- This phase only occurs when pressure to CH drops to zero.
- Usually, this phase is avoided.
- When the CL engages, the DCT shifts to the fourth gear. Then, the pressure applied to the CL increases rapidly to the line pressure, and the downshift process ends.

# Shift Quality

- With disengagement of the offgoing clutch, not only the transferred torque but also the rotational speed vary strongly, and so the shift quality, including the shift time, the friction losses, and the jerk intensity, are closely related to inertia phase.
- Performance Evaluation Index: Jerk<10m/s^3

$$j = \frac{r_w}{I_R} \frac{\mathrm{d}T_R}{\mathrm{d}t}$$

# Controller Design

- All the previous stated torque equations are combined to give two equations:
- From these equations, shift time has impact

  Of various effects like coeff. Of friction..

  Hence a state space equation is considered.

$$I_e \frac{\mathrm{d}\omega_e}{\mathrm{d}t} = T_e - \mu K_n P_{CH} - c_e \omega_e$$

$$I_2' \frac{\mathrm{d}\omega_2}{\mathrm{d}t} = \mu K_n P_{CH} - \frac{T_l}{i_a i_5} - c_2 \omega_2$$

$$I_2' = I_2 + \frac{I_o}{i_5^2} + \frac{I_R}{i_a^2 i_5^2}$$

$$\mathbf{A} = \begin{bmatrix} -\frac{c_e}{I_e} & 0 & -\frac{K_n\mu_{nom}}{I_e} \\ -\frac{c_e}{I_e} + \frac{c_2}{I'_2} & -\frac{c_2}{I'_2} & -\frac{K_n\mu_{nom}}{I_e} - \frac{K_n\mu_{nom}}{I'_2} \\ 0 & 0 & 0 \end{bmatrix}$$

$$\Delta\mathbf{A} = \begin{bmatrix} 0 & 0 & -\frac{K_n\,\Delta\mu\,\delta}{I_e} \\ 0 & 0 & -\frac{K_n\,\Delta\mu\,\delta}{I_e} - \frac{K_n\,\Delta\mu\,\delta}{I'_2} \\ 0 & 0 & 0 \end{bmatrix}$$

$$\boldsymbol{x} = \begin{Bmatrix} \omega_e \\ \omega_e - \omega_2 \\ P_{CH} \end{Bmatrix}$$

$$\mathbf{B}_1 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u = \frac{\mathrm{d}P_{CH}}{\mathrm{d}t}$$

$$\mathbf{B}_2 = \begin{bmatrix} \frac{1}{I_e} & 0 \\ \frac{1}{I_e} & \frac{1}{I'_2 i_a i_5} \\ 0 & 0 \end{bmatrix}$$

$$\boldsymbol{w} = \begin{Bmatrix} T_e \\ T_l \end{Bmatrix}$$

$$\dot{\boldsymbol{x}} = (\mathbf{A} + \Delta\mathbf{A})\boldsymbol{x} + \mathbf{B}_1\boldsymbol{u} + \mathbf{B}_2\boldsymbol{w}$$

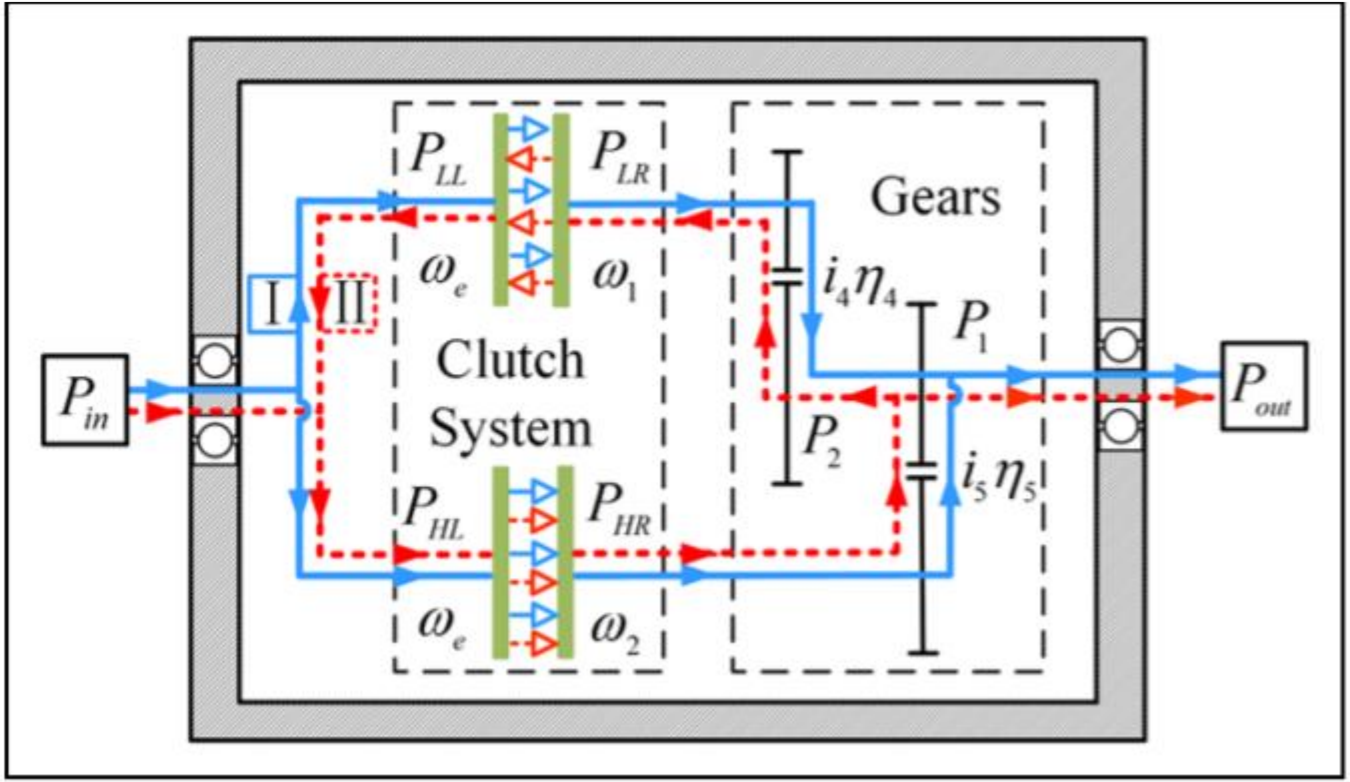
$$\boldsymbol{z} = \mathbf{C}_1\boldsymbol{x} + \mathbf{D}_{12}\boldsymbol{u}$$

$$\boldsymbol{y} = \mathbf{C}\boldsymbol{x}$$

# Torque phase Control strategy

- Late engagement of the CL and early disengagement of the CH results in the occurrence of power interruption and extension of the shift process, whereas early engagement of the CL leads to power circulation.

# Power flow paths



- DCT system efficiency is dependent on the relative angular vel. Between engine and shaft 1.
- Hence signum function is used.
- Case1: $\omega_e - \omega_1 < 0$,

  Power circulation occurs

$$\eta = \eta_L \left[ \eta_4^{\mathrm{sgn}(\omega_{CL})} (1 - \zeta) + \eta_5 \zeta \frac{i_5}{i_4} \right]$$

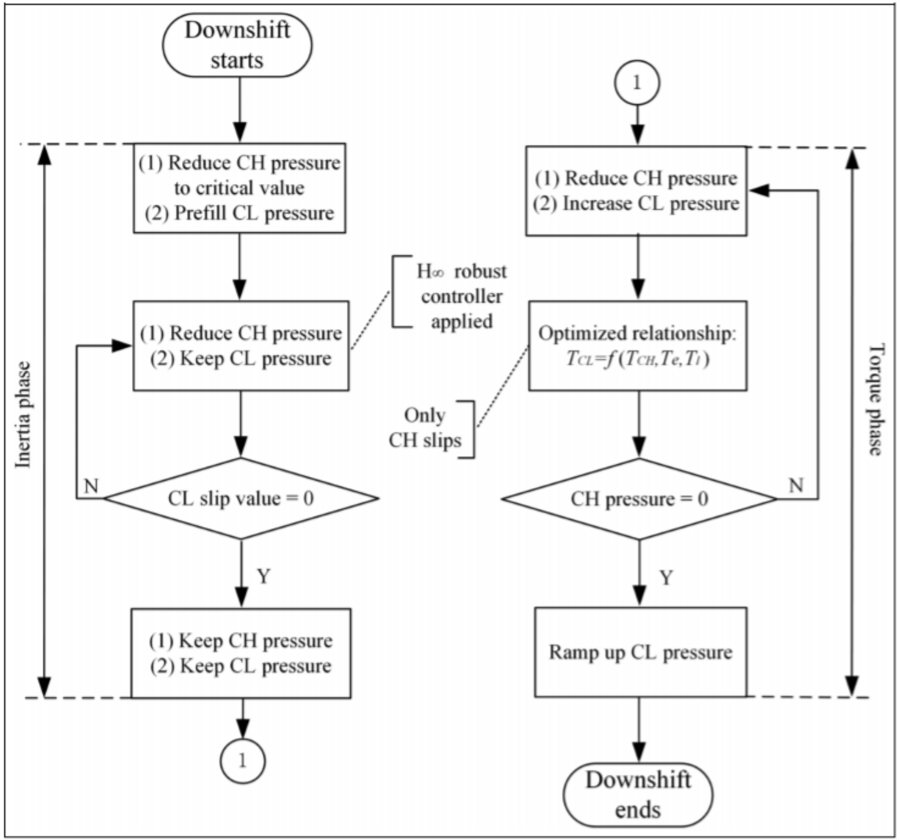
- Case 2: $\omega_e - \omega_1 > 0$,

  Power interruption occurs and friction work increase.

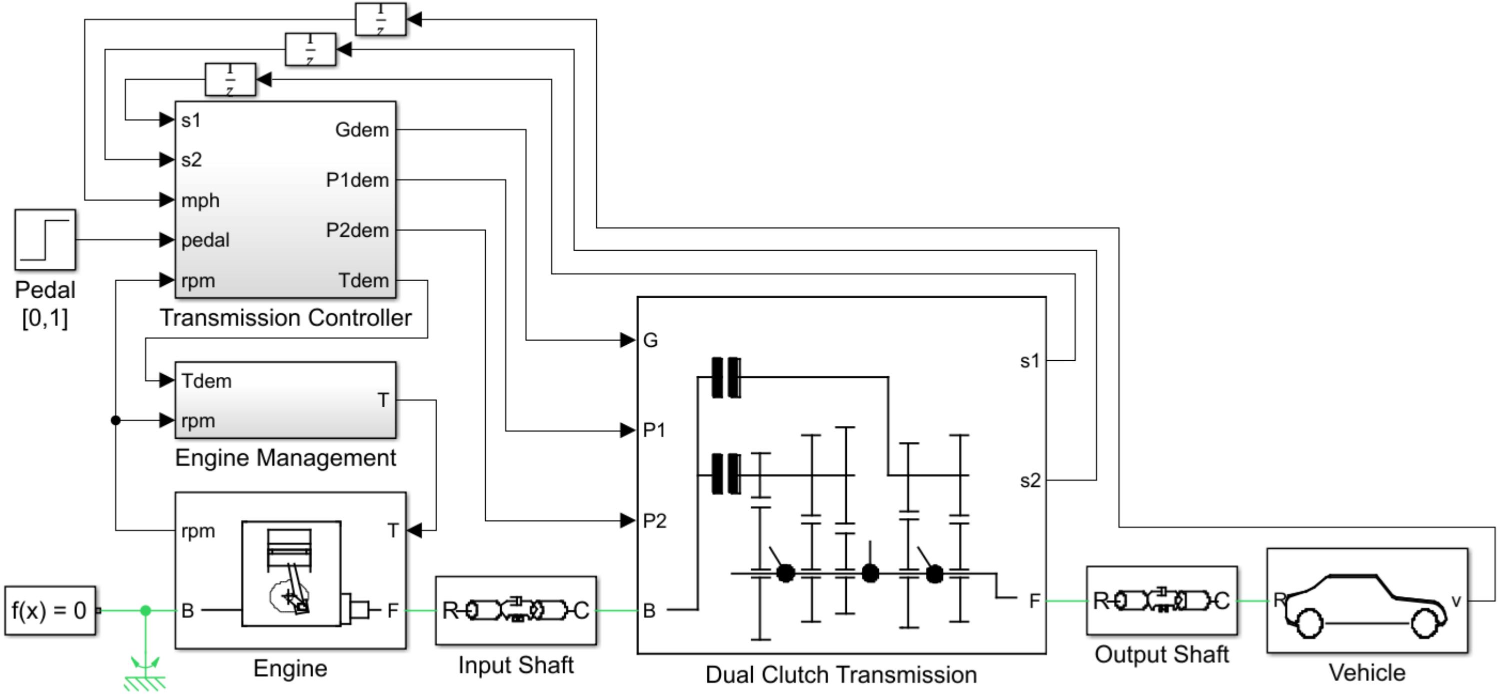
- Hence $\omega_e = \omega_1$.

  Only one clutch slips.

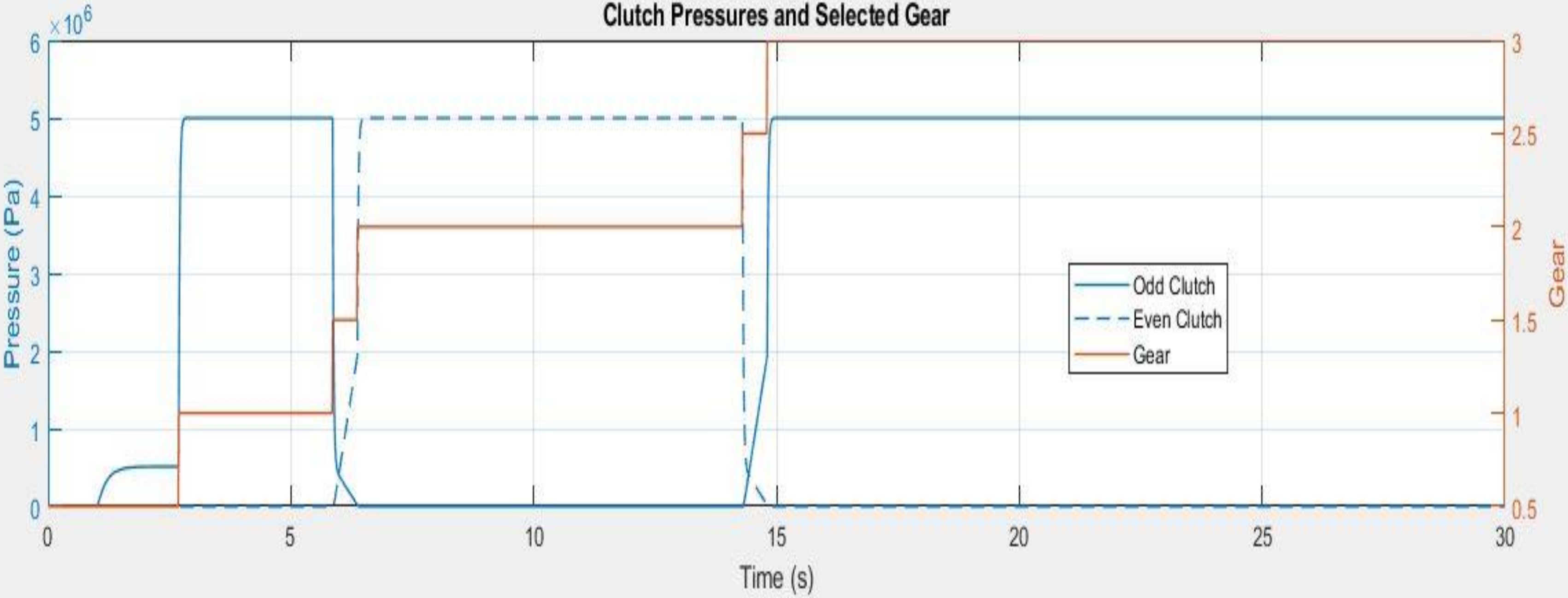
# Overall Control Strategy



# Simulink Simulation



# Graphs



Clutch Pressures and Selected Gear
×10^6
Pressure (Pa)
Gear
Time (s)
0
1
2
3
4
5
6
0
5
10
15
20
25
30
0.5
1
1.5
2
2.5
3
Odd Clutch
Even Clutch
Gear

# Assumptions

- In, simulink, Engine's max. Power is assumed to be 205kW
- Mass of vehicle 1600kg
- During the shift process, the change in the vehicle speed and the change in the road grade are small. and the rolling resistance can be regarded as constant.
- While, according to reference paper the simulations were carried out for engine properties: Power varies with throttle angle and engine speed.

# References


[1]  Control strategy optimization for a dual-clutch transmission downshift with a single slipping clutch during the torque phase by Jikai Liu

[2] Control of a twin clutch transmission for smooth gearshifts by  Behrooz Mashadi.

[3] Gearshift control for dry dual-clutch transmissions by Chunsheng Ni, Tongli Lu, Jianwu Zhang

# Acknowledgement

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# THANK YOU