Development of High Fidelity, Dynamic Model of an Automated Manual Transmission Unit

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Contents of the Presentation

• Need of high fidelity Mathematical Model of AMT

• How Simscape helped us?

• Synchronizer Model Development

• Clutch Model Development

• Five Speed Gearbox Model
AUTOMATED MANUAL TRANSMISSION

Driver Requirements

Vehicle Operating Conditions

Transmission Control Unit

Gear Shift Control

Clutch Control
Why is the Mathematical Model Needed?

Mathematical Model of AMT

- Validation and Testing of Control Strategy through MIL, HIL & CIL Simulations
- Selection of Actuators
- Sensitivity analysis of Transmission Control Unit
- Analysis of effect of change in transmission parameters
- Detailed Synchronizer Model
- Detailed Clutch Model
How Simscape helped us?

- Multi-domain Environment
- Object oriented
- Flexibility
- User Friendly
- Non-linearity Modelling

Simscape
What is Synchronizer?

- Essential part of Gear Shifting Process
- Helps in smooth and noiseless engagement by reducing the rpm difference between the shaft/hub and the gear

Image Source: Ana Pastor Bednar; Master Thesis; Synchronization processes and synchronizer mechanisms in manual transmissions
The Synchronization Process

1. Neutral Position
2. First Free Fly
3. Synchronization
4. Second Free Fly
5. Ring Separation
6. Gear Turning
7. Final Engagement
Factors Taken into consideration

• Exact profiles of the sleeve, ring and gear teeth are considered.
• Detailed Friction model for synchronization process is considered.
• Thermal expansion of ring due to frictional heat between cone surface is taken into account.
• Second bump has been modeled as a double bump: separate ring separation and gear turning is considered.

Assumptions/ Factors Ignored

• Process of Pre-Synchronisation is ignored
• Effect of lubricating oil between cone surfaces and teeth has been neglected
• During process of synchronisation ring heats up due to friction between cone surfaces. It is assumed that it cools to its original temperature before start of second bump.
• Occurrence of Second bump is a random phenomenon. For the model the worst case scenario has been taken into account.
• During disengagement effect of rotational inertia is not considered.
• Rotational damping due to lubricating oil has been ignored.
Modelling Approach

Synchroniser Mathematical Model

Feasibility study for HIL Simulation & fidelity level of existing SimDriveline model

Preparing stepwise Individual Model for each step

Select particular Simscape and Simulink Blocks for development of model

First Free Fly
First Bump
Synchronization
Second Free Fly
Second Bump
Turning the gear and separating the ring
Final free fly
(Positive Locking)

Friction model
Clashing between sleeve and ring teeth
Cone Clutch model
Teeth sliding friction model
Interaction of sleeve and gear tooth
Thermal and Inertia model
Friction model

Development of logic according to flow

Integration of individual models to build synchroniser
Challenges in Modelling the Synchronizer

- Simulating the 7 step Process in the right order
- Calculation of Second Bump Forces
- Double Sided Synchronizer
- Running the Model at the time step accepted by the HIL Setup
Simscape Dual Sided Synchronizer Model

Calculation of First and Second Bump Forces

Synchronization Process

Strut-Detent System
The simulations of the Synchronizer Model give the desired results as shown in the graphs.
Dual Sided Synchronizer (Engagement & Disengagement)
DIAPHRAGM CLUTCH

Flywheel

Clutch Disc

Diaphragm Spring

Pressure Plate

Hub

Bearing Sleeve

Friction pad

Cushion Spring

Force Vs. Deformation of Cushion Spring

Force Vs. Deformation of Diaphragm Spring
CLUTCH MODEL
Results

![Graph showing vehicle speed and engine speed over time with labeled phases: Speed Equalization, Complete Engagement, Engaged Phase, Start of Disengagement, Complete Disengagement.](image)
5 Speed Gear Box Model
Five Speed Gearbox MIL SETUP
Gear Change Test Results for Five Speed Gearbox

- Gear Engagement
- Clutch Engagement
- Engaged Condition
- Clutch Disengagement

Graph showing the speed and time for gear change and clutch engagement.
Thank You
Q & A