Estimation of steering effort at parking condition using MATLAB

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Introduction

- At the parking condition, the driver has to overcome the static friction developed due to tire-rod contact.

- The static steering effort to the driver at the steering wheel is function of tire-road contact friction and efficiency of mechanical linkages.

- The initial design of steering system and component sizing is function of maximum steering torque observed at parking condition.

Source: en.Wikipedia.org
Introduction

Objective:

- To develop parametric model for the prediction of the steering effort, tie-rod forces and rack forces at parking condition
- To estimate the required motor torque relative to the driver torque for PAS (Park Assisted Steering)
- To develop GUI for better visualisation with multiple options as per steering type
Input parameters

Below details of the steering geometry used in the calculation of the steering effort:

- **Suspension parameters**
  - Kingpin axis direction & location (coordinates of upper and lower point on kingpin axis)

- **Steering parameters**
  - IBJ & OBJ coordinates on tie rod
  - Rack gain/c-factor
  - Max. steering wheel angle

- **Tire patch parameters**
  - Coordinates of patch center
  - Dimensions of patch
  - Front axle load
  - Friction coefficient
Calculation methodology

**Calculation of effort at steering wheel**
- Effort at wheel can be represented as sum of static steering torque and gravity aligning torque
- Gravity aligning torque which is induced due to resistance from vertical tire force is the function of:
  - Kingpin inclination angle
  - Kingpin caster angle
  - Tire angle
  - Kingpin offset
- Tire-patch friction torque can be given as integral function of:
  - Pressure distribution across the tire-road contact patch
  - Length of arm
  - Coefficient of friction
- The final Steering effort is obtained by the relation:
  
  \[ M_{steering} = (M_{friction} + M_{gravity}) \cdot \eta_{mech} \cdot (d\theta_{sw} / d\theta_{tyre}) \]

Where,
- \( \eta_{mech} \) = Mechanical efficiency of linkages
- \( d\theta_{sw} \) = Change in angle of steering wheel
- \( d\theta_{tyre} \) = Change in angle of tyre
- \( M_{gravity} \) = Gravity aligning torque
- \( M_{friction} \) = Tire-patch friction torque
Use of MATLAB appdesigner tool

- The converted mathematical of steering effort calculation is embedded in MATLAB application.
- The embedded application GUI is created in app designer and compiled using MATLAB compiler to generate the .EXE for sharing with designers.

GUI modelling

GUI after compilation
GUI features

- Steering geometry and tire details are taken as input from a standard EXCEL template.

Option for EXCEL template import

Input template
GUI features

- The pressure distribution selection for the modelling of the tire-patch parameters
- The user can select the dimensions across
  - Length & Width
- Pressure distribution type
  - Uniform
  - Linear
  - Square

Pressure distribution selection across length and width
GUI features

- Selection of the rack gear type based on the steering ratio (c-factor) i.e.
  - Constant & variable
  - The status of the sheet name provided for each of the selection

Rack gear type selection & name of the sheet name
GUI features

- Selection of the steering type:
  - Normal
  - Park assisted

Steering gear type selection
GUI features

Visualisation for the analysis of the results

- The results plotted in quick response time at the click
- The results plotted in “uixes” against the steering angles for:
  - Steering effort
  - Rack force
  - Motor torque

- **Steering effort vs Steering angle**
- **Rack force vs Steering angle**
- **Motor torque vs Steering angle**
GUI features

Additional features

- Facility to export output excel file in form of excel standard template file

- The status bar to display the status of the calculation to the user
Results

- The Maximum tie-rod force is correlated with the mathematical results formulated in Matlab and found in good agreement with the test results.

- From the below figure, the estimation of maximum steering effort and Rack force can be performed.
Conclusions

- This tool is useful for the concept level calculation for the maximum steering effort
- Gives the initial estimate at the design stage of steering system
- Useful for multiple projects
QUESTIONS?
Thank you

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