

Estimation of steering effort at parking condition using MATLAB

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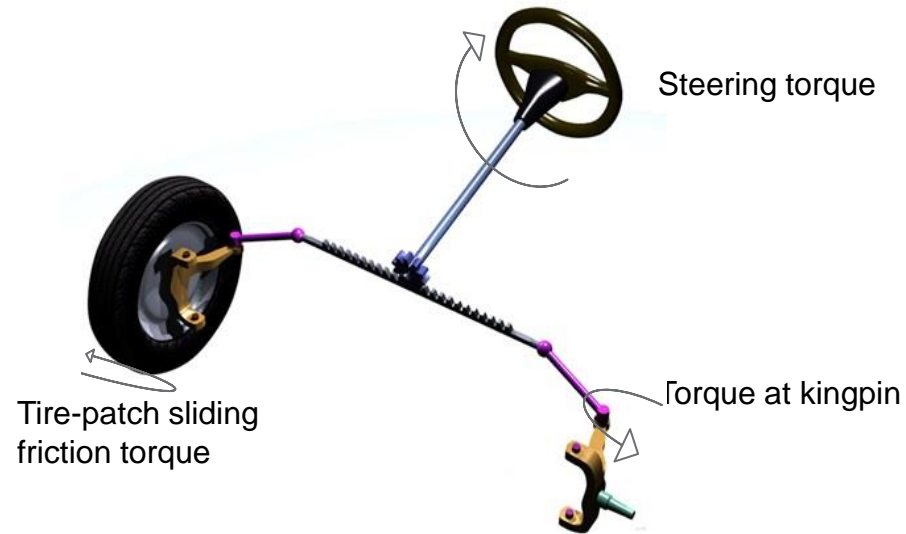
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Introduction

- 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:

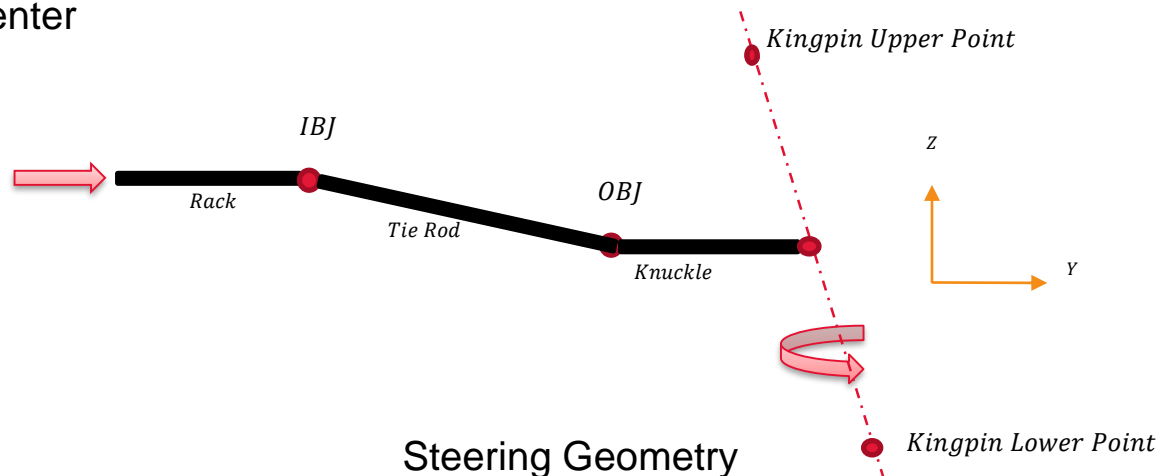
- To develop parametric model for the prediction of the steering effort, tie-rod forces and rack forces at parking condition
- To estimate the required motor torque relative to the driver torque for PAS(Park Assisted Steering)
- To develop GUI for better visualisation with multiple options as per steering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



Steering Geometry

Calculation methodology

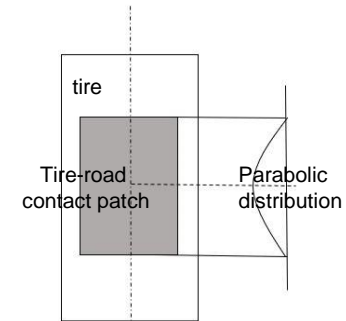
■ Calculation of effort at steering wheel

- 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:

$$M_{\text{steering}} = (M_{\text{Friction}} + M_{\text{gravity}}) \cdot \eta_{\text{mech}} \cdot (d\theta_{\text{sw}} / d\theta_{\text{tyre}})$$

Where,

- η_{mech} = Mechanical efficiency of linkages
- $d\theta_{\text{sw}}$ = Change in angle of steering wheel
- $d\theta_{\text{tyre}}$ = Change in angle of tyre
- M_{gravity} = Gravity aligning torque
- M_{friction} = Tire-patch friction torque



Pressure distribution across contact patch

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.

The screenshot shows a GUI titled "INPUT" with the following elements:

- Select Input Excel File:** A text field with a blue "Click Here" button next to it.
- Sheet Name:** A text field containing the value "input".
- Pressure Distribution:** A section containing two dropdown menus, both set to "Uniform".
- Choose Rack Gear Type:** Radio buttons for "Constant" (selected) and "Variable".
- C-factor Sheet Name:** A text field containing the value "C-factor".
- Steering Type:** Radio buttons for "Normal" (selected) and "Park Assisted".

GUI modelling



The screenshot shows the same GUI titled "INPUT" after compilation, with the following elements:

- Select Input Excel File:** A blue button labeled "Standard Input Template_4:".
- Sheet Name:** A text field containing the value "input".
- Pressure Distribution:** A section containing two dropdown menus, both set to "Uniform".
- Choose Rack Gear Type:** Radio buttons for "Constant" (selected) and "Variable".
- C-factor Sheet Name:** A text field containing the value "C-factor".
- Steering Type:** Radio buttons for "Normal" and "Park Assisted" (selected).
- Td vs Tm Sheet Name:** A text field containing the value "Td_Tm".

GUI after compilation

GUI features

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

INPUT

Select Input Excel File

Sheet Name

Pressure Distribution

Option for EXCEL template import

Kingpin Parameters			
	Right		
Hard Points	X (mm)	Y (mm)	Z (mm)
Lower Point			
Upper Point			

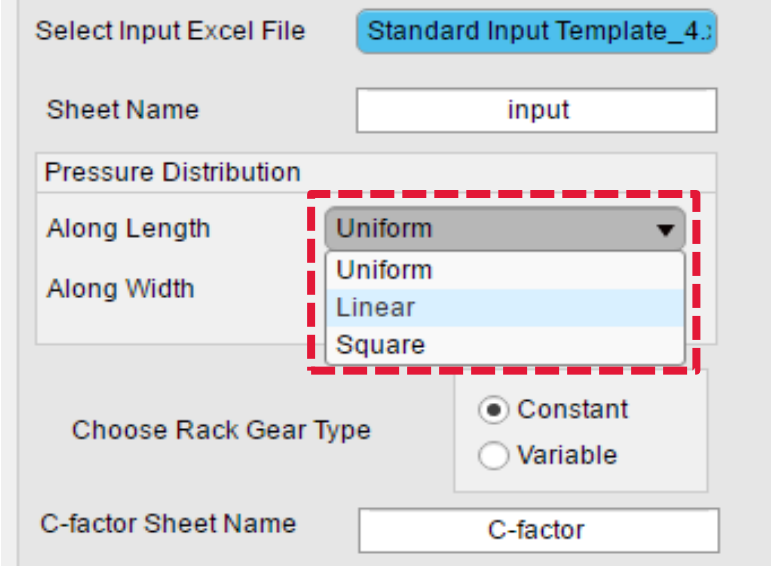
Tyre Parameters						
Hard Points	X (mm)	Y (mm)	Z (mm)	Parameters	Dimension	Unit
Wheel Center				Distance b/w Wheel Center to Tire Patch Center (SLR)		mm
Tyre Patch Center				Width of Tire Patch		mm
				Length of Tire Patch		mm
				Friction Coefficient		null
				Single Tyre Vertical Force		N

Steering System Parameters						
Hard Points	X (mm)	Y (mm)	Z (mm)	Parameters	Dimension	Unit
OBJ				Gear Reduction ratio		null
IBJ				Rack Gain/C-Factor		mm/rev
				Maximum Steering Wheel Angle		deg
				Rack Efficiency		null
				thresholdAngle		deg
				Lh side		deg

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

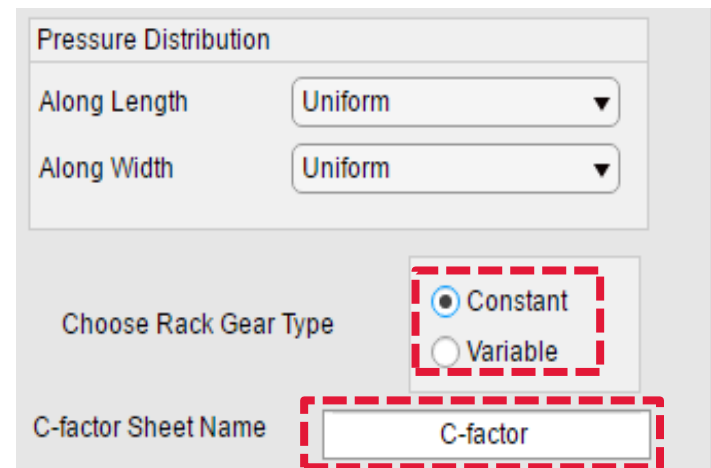


The screenshot displays a software interface for configuring input files and pressure distribution parameters. The 'Select Input Excel File' field is set to 'Standard Input Template_4.'. The 'Sheet Name' field is 'input'. Under the 'Pressure Distribution' section, there are two dropdown menus: 'Along Length' and 'Along Width'. The 'Along Length' dropdown is currently set to 'Uniform', and the 'Along Width' dropdown is open, showing options for 'Uniform', 'Linear', and 'Square'. The 'Linear' option is highlighted. Below these, the 'Choose Rack Gear Type' section has two radio buttons: 'Constant' (selected) and 'Variable'. The 'C-factor Sheet Name' field is 'C-factor'.

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



The screenshot displays a software interface with the following elements:

- Pressure Distribution** section:
 - Along Length:** A dropdown menu set to "Uniform".
 - Along Width:** A dropdown menu set to "Uniform".
- Choose Rack Gear Type:** A radio button selection area where the **Constant** option is selected (indicated by a blue dot), and the **Variable** option is unselected (indicated by an empty circle).
- C-factor Sheet Name:** A text input field containing the value "C-factor".

Red dashed boxes highlight the "Constant" radio button and the "C-factor" text field.

Rack gear type selection & name of the sheet name

GUI features

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

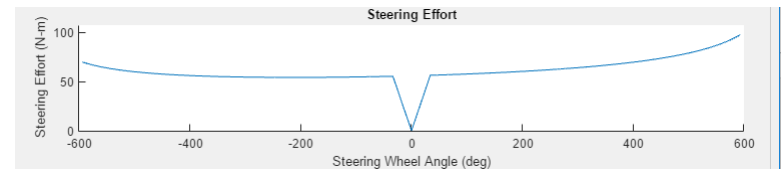
The screenshot displays the 'INPUT' configuration panel. It includes fields for 'Select Input Excel File' (Standard Input Template_4.), 'Sheet Name' (input), 'Pressure Distribution' (Along Length: Uniform, Along Width: Uniform), 'Choose Rack Gear Type' (Constant selected, Variable unselected), 'C-factor Sheet Name' (C-factor), 'Steering Type' (Normal unselected, Park Assisted selected), and 'Td vs Tm Sheet Name' (Td_Tm).

Steering gear type selection

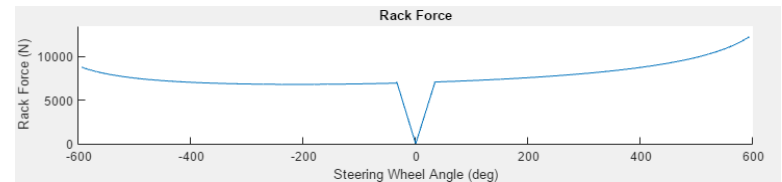
GUI features

Visualisation for the analysis of the results

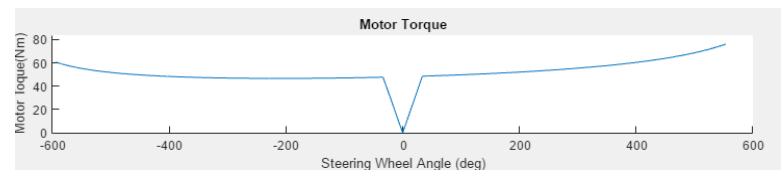
- The results plotted in quick response time at the click
- The results plotted in “uixes” against the steering angles for:
 - Steering effort
 - Rack force
 - Motor torque



Steering effort vs Steering angle



Rack force vs Steering angle

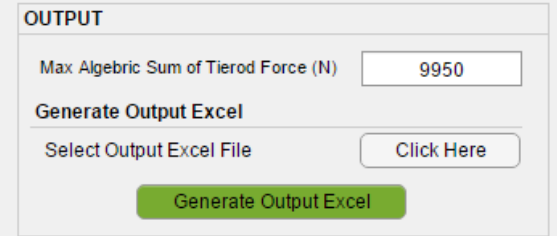


Motor torque vs Steering angle

GUI features

Additional features

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



OUTPUT

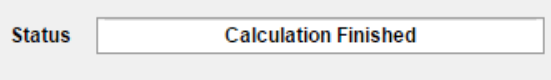
Max Algebraic Sum of Tierod Force (N)

Generate Output Excel

Select Output Excel File

Export output results

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

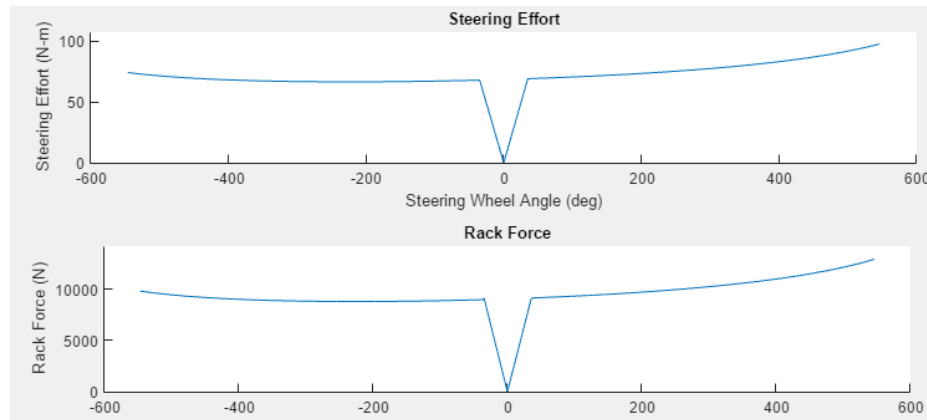


Status

Calculation status

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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