Estimation of steering effort at parking condition using MATLAB

Aliakbar Saifee, Masurkar Kaustubh,
Barde Vishal P

Mahindra Research Valley,
Mahindra & Mahindra Ltd.,
Chennai

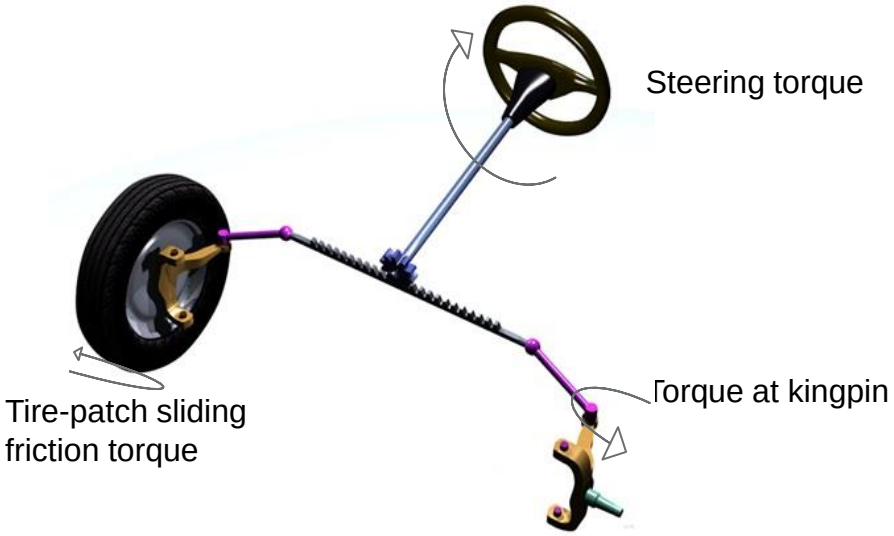
saifee.aliakbar@mahindra.com


Mahindra
Rise.
Mahindra 605 DI-i
ARJUN
SCORPIO

Contents

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

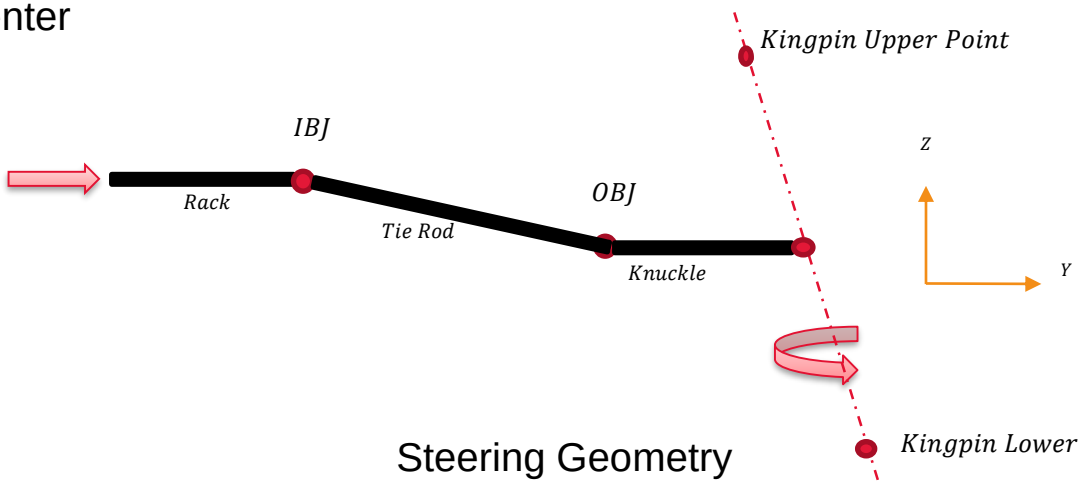
Objective:

- 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

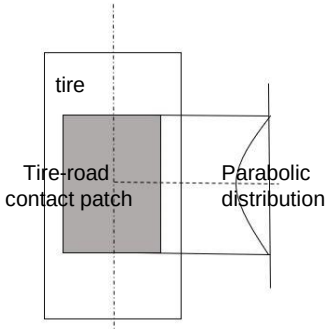
Calculation methodology

- **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:

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

Where,

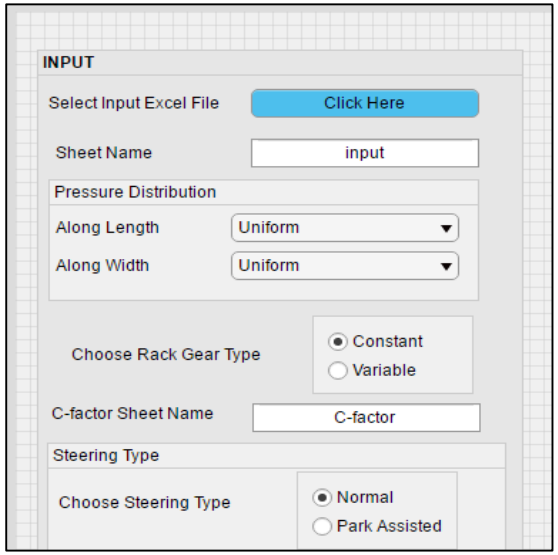
η_{mech} = Mechanical efficiency of linkages
$d\theta_{sw}$ = Change in angle of steering wheel
$d\theta_{tyre}$ = Change in angle of tyre
$M_{gravity}$ = Gravity aligning torque
$M_{friction}$ = Tire-patch friction torque



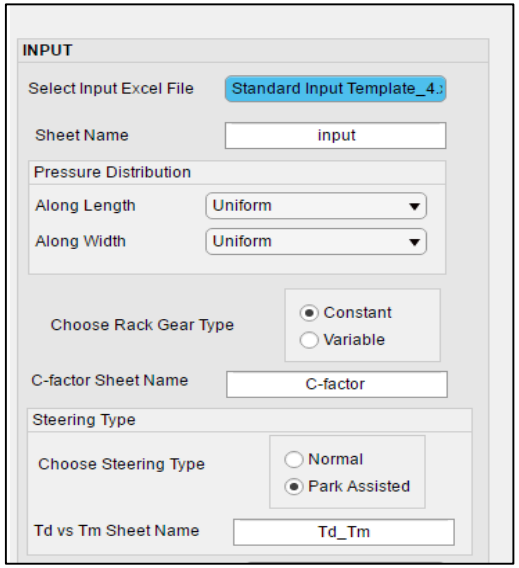
Pressure distribution across contact patch

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.



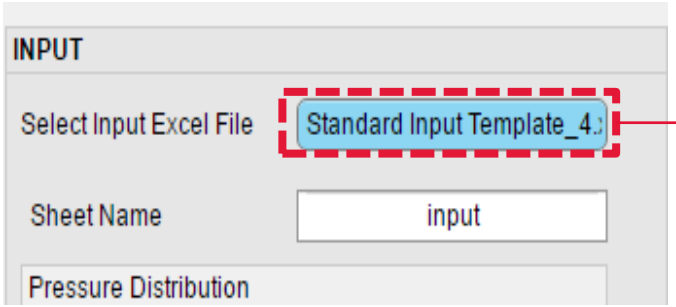
GUI modelling



GUI after compilation

GUI features

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



Option for EXCEL template import

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

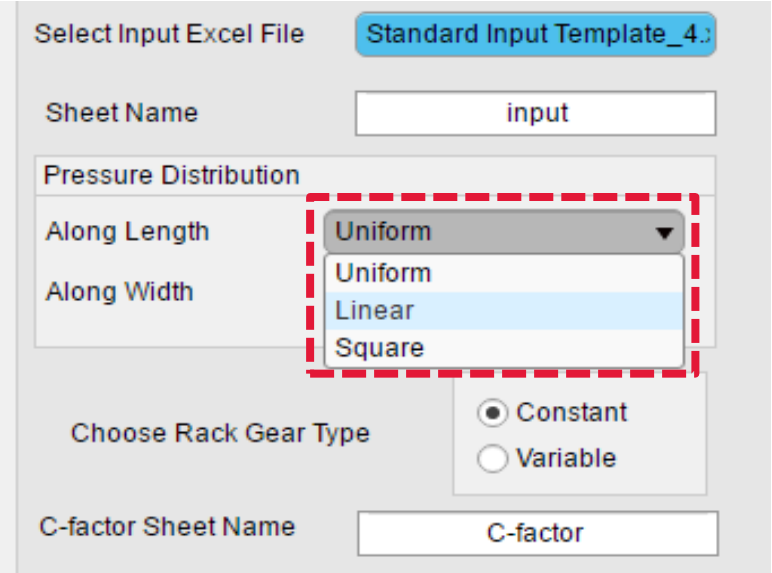
Tyre Parameters						
Hard Points	*X (mm)*	*Y (mm)*	*Z(mm)*	*Parameters*	*Dimension*	*Unit*
Wheel Center				**Distance b/w Wheel Center to Tire Patch Center (SLR)**		mm
Tyre Patch Center				**Width of Tire Patch**		mm
				Length of Tire Patch		mm
				Friction Cofficient		null
				Single Tyre Vertical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

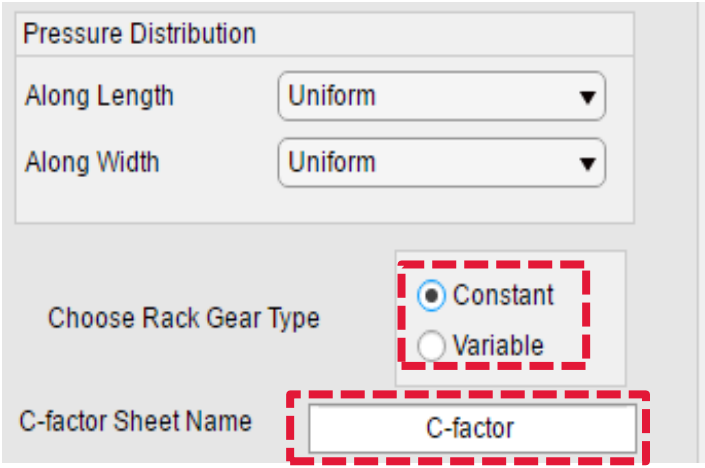
- The pressure distribution selection for the modelling of the tire-patch parameters
- The user can select the dimensions across
  - Length & Width
- Pressure distribution type
  - Uniform
  - Linear
  - Square



Pressure distribution selection across length and width

GUI features

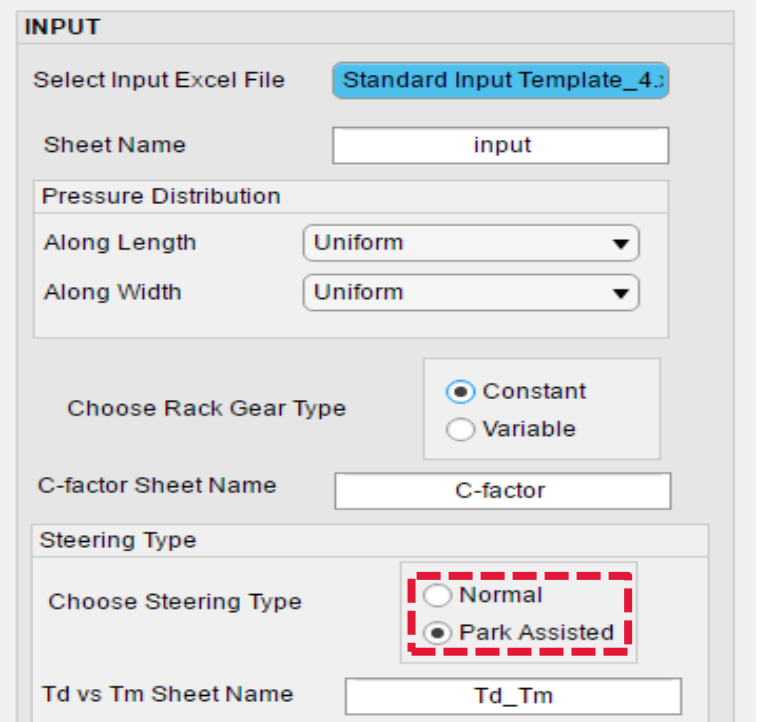
- Selection of the rack gear type based on the steering ratio(c-factor) i.e.
  - Constant & variable
  - The status of the sheet name provided for each of the selection



Rack gear type selection & name of the sheet name

GUI features

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

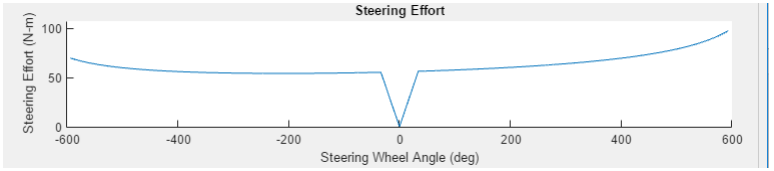


Steering gear type selection

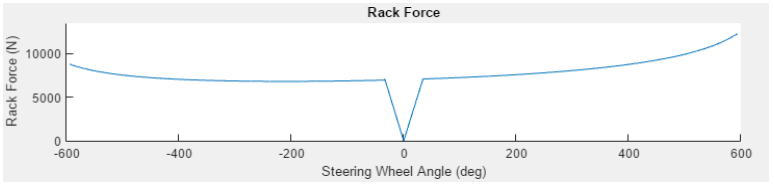
GUI features

Visualisation for the analysis of the results

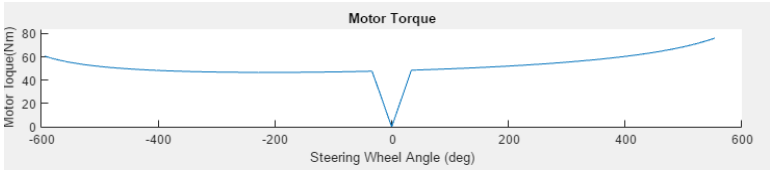
- The results plotted in quick response time at the click
- The results plotted in “uixes” against the steering angles for:
  - Steering effort
  - Rack force
  - Motor torque



Steering effort vs Steering angle



Rack force vs Steering angle

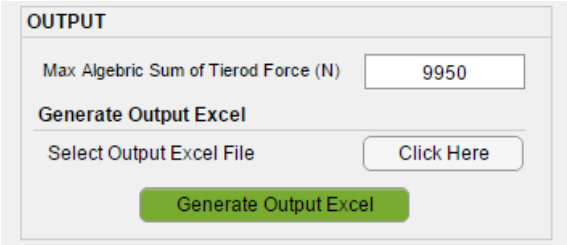


Motor torque vs Steering angle

GUI features

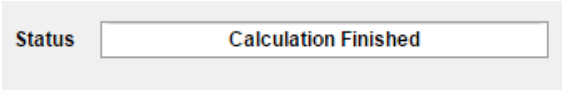
Additional features

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



Export output results

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

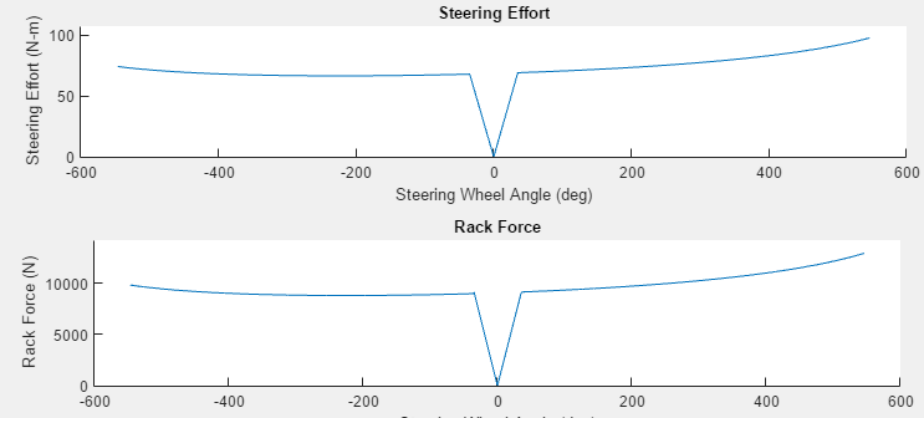


Calculation status

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 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

Mahindra Rise.

QUESTIONS?

MathWorks®

Thank you

Disclaimer

Mahindra & Mahindra herein referred to as M&M, and its subsidiary companies provide a wide array of presentations and reports, with the contributions of various professionals. These presentations and reports are for informational purposes and private circulation only and do not constitute an offer to buy or sell any securities mentioned therein. They do not purport to be a complete description of the markets conditions or developments referred to in the material. While utmost care has been taken in preparing the above, we claim no responsibility for their accuracy. We shall not be liable for any direct or indirect losses arising from the use thereof and the viewers are requested to use the information contained herein at their own risk. These presentations and reports should not be reproduced, re-circulated, published in any media, website or otherwise, in any form or manner, in part or as a whole, without the express consent in writing of M&M or its subsidiaries. Any unauthorized use, disclosure or public dissemination of information contained herein is prohibited. Unless specifically noted, M&M or any of its subsidiary companies is not responsible for the content of these presentations and/or the opinions of the presenters. Individual situations and local practices and standards may vary, so viewers and others utilizing information contained within a presentation are free to adopt differing standards and approaches as they see fit. You may not repackage or sell the presentation. Products and names mentioned in materials or presentations are the property of their respective owners and the mention of them does not constitute an endorsement by M&M or its subsidiary companies. Information contained in a presentation hosted or promoted by M&M is provided “as is” without warranty of any kind, either expressed or implied, including any warranty of merchantability or fitness for a particular purpose. M&M or its subsidiary companies assume no liability or responsibility for the contents of a presentation or the opinions expressed by the presenters. All expressions of opinion are subject to change without notice.


Mahindra
Rise.