Tyre Dynamics: Analysis and Testing

BY

VIVEK AK

PRASHANT CHOUDHARI

MUHAMAMD SHUAIB

SAGAR TAYADE

AJAY KUMAR

concept by prashant choudhary —

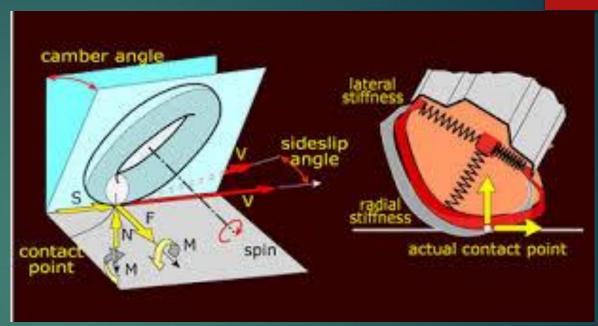




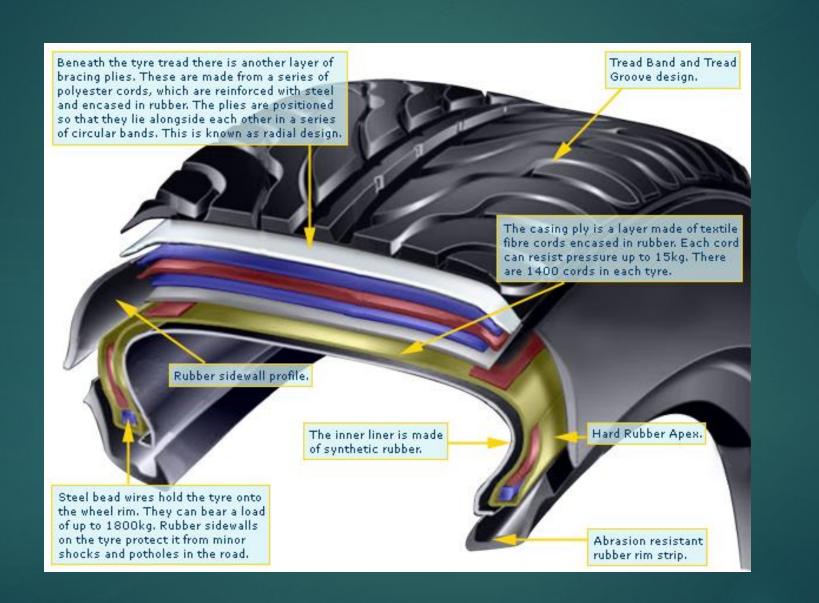
Introduction:

Tyre Dynamics





Nomenclature



Various tyre models used

- PAC2002 Tire Model
- PAC-TIME Tire Model
- '89 and '94 Pacejka Tire Models (older pac models)
- 521-Tire Model
- UA-Gim-Tire Model
- FTire Model

► PAC2002 Tire Model

The PAC2002 Tire Model is the industry standard when it comes to computational tire/force interaction. During the solving process, each tire is characterized by 15-20 different coefficients that represent different forces exerted on the tire's contact patch

PAC-TIME Tire Model

The PAC-TIME model is a new version of the PAC2002 model. The only modification made is in the equations for the aligning moment Mz and side force Fy.

▶ 521-Tire Model

The 521-Tire Model is one of the more simple models in Adams.

Older model

UA-Gim-Tire Model

The University of Arizona Tire Model, abbreviated UA-Gim tire model,

It limits the total friction achieved by the wheel/ground interface but allows for different values of the longitudinal and lateral friction.

FTire Model

The FTire, or Flexible Ring Tire Model, different from most other models.

No form of the magic formula is used.

This model is made by finite element method.

It relies almost exclusively on analytical means to solve problems using classical mechanical approaches. A Tire Model for Ride & Durability Simulations

MORE DETAILS ABOUT TYRES IS IN REPORT.

Simulation and analysis of different tire models

- To test which tire model is best suited.
- Testing done on different tire models using different simulation events available in Adams/car 2012 software

Events used

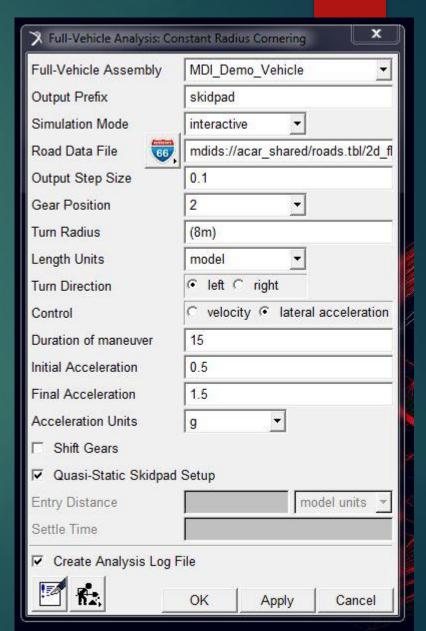
- 1. Computational model testing: Skid pad
- 2. Computational model testing: Fish hook maneuver
- 3. Computational model testing: Step steer maneuver
- 4. Computational model testing: Longitudinal acceleration

Vehicle Description

- ▶ A larger 205/55R16 tire was fitted. This tire size was chosen because it could be used consistently across all the tire models.
- ▶ The vehicle choosed: MDI Demo Vehicle from Adams Car software.

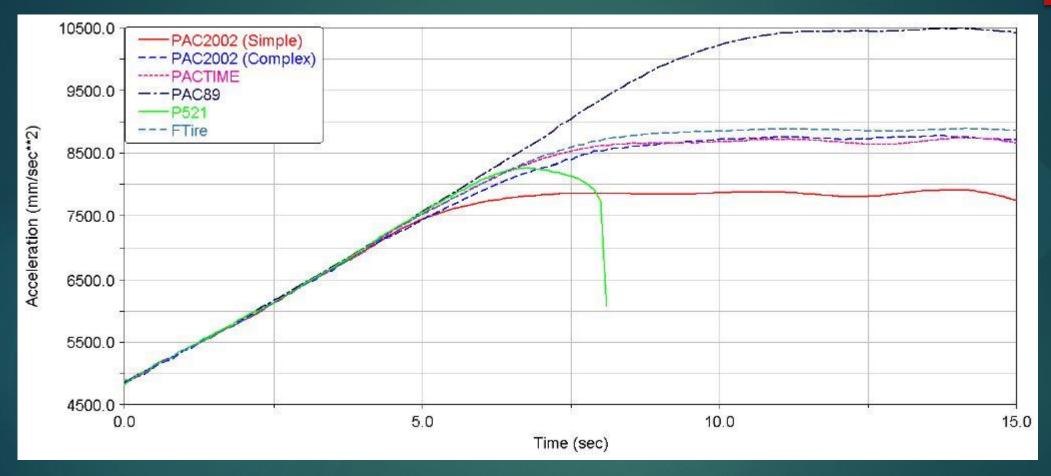
Computational model testing: Skidpad

- Constant Radius Cornering commonly referred to as a Skidpad.
 - Linearly increasing acceleration
 - > Turn radius: 8m
 - Single gear through out (to prevent any jerking movement caused by shifting)
 - Test was conducted over a 15 second duration.
 - Initial acceleration: 0.5g
 - Final acceleration of 1.5g



ADAMS plots

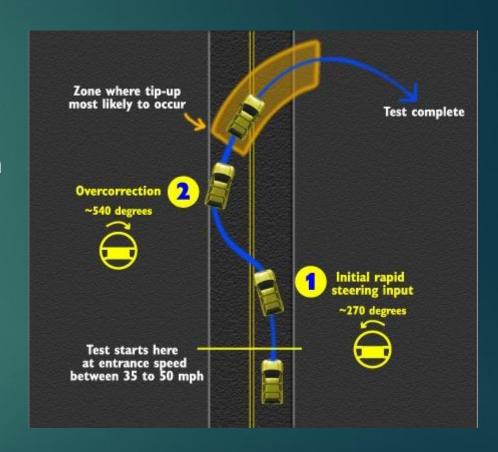
Lateral Acceleration vs. Time for the Skidpad Maneuver



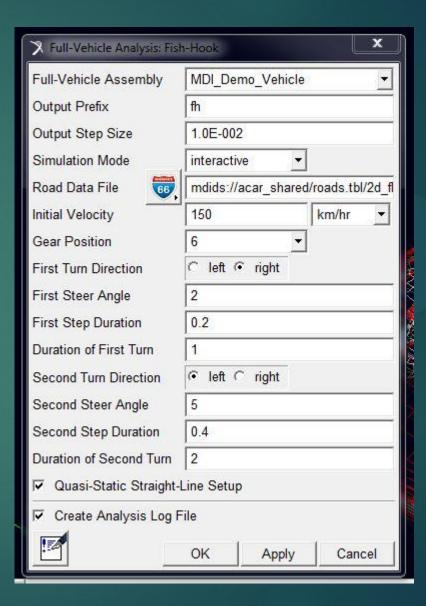
- UA-Gim tire didn't work due to compatibility issues.
- P521 Lost control at 8m/s^2 due to loss of traction.
- Ftire, PAC2002, PACTIME are close to mean values.
- PAC89, 521, and simple PAC2002 are known inaccurate.

Computational model testing: Fish hook maneuver

- maneuver consists of turning slightly to the right and then quickly back to the left.
- This will cause the vehicle to over steer in that direction and spin out.
- Significance: it shows how the tire models cope with sudden motions.

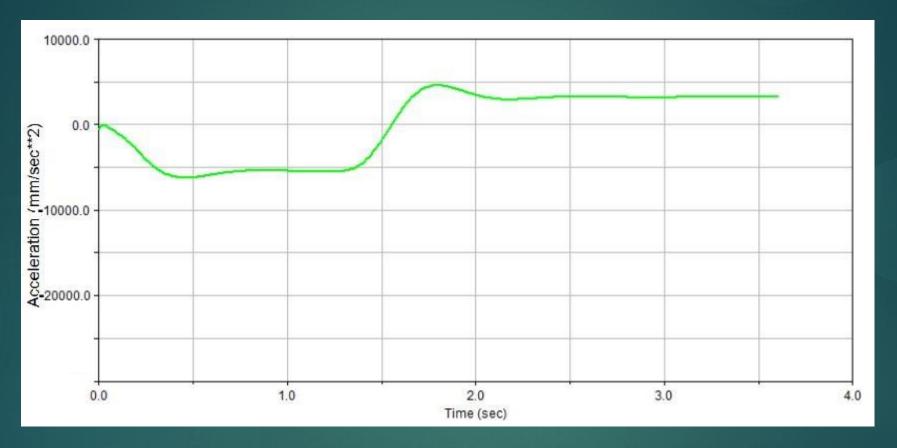


- Initial velocity of 150 km/hr in 6th gear.
- initially turn right to an angle of 2 degrees over a time of 0.2s and continue in this direction for 1 second.
- Then it would turn left at an angle of 5 degrees over a 0.4s and it would try to continue in this direction for 2s.



ADAMS plots

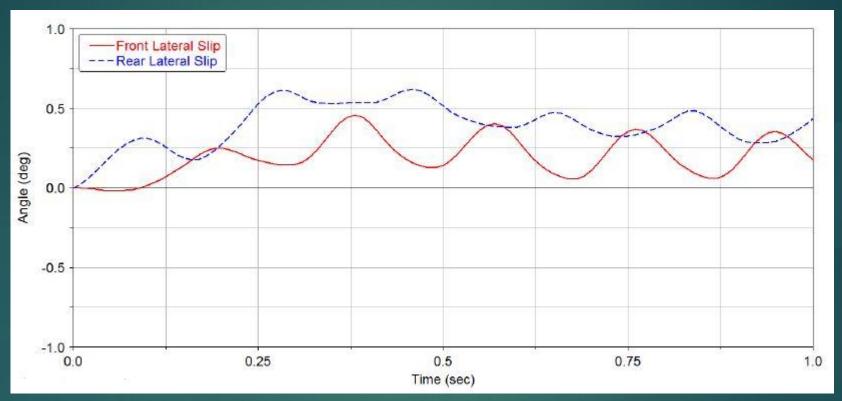
Vehicle Acceleration vs. Time for the Fish Hook Maneuver



- Ua tyre model or university of Arizona tyre model.
- First 1.5 seconds of the maneuver consist of negative acceleration (lateral and towards the right of the vehicle).
- Acceleration turns positive.
- end up losing control almost immediately after the second turn.

Over steer

Vehicle Side-Slip Angles



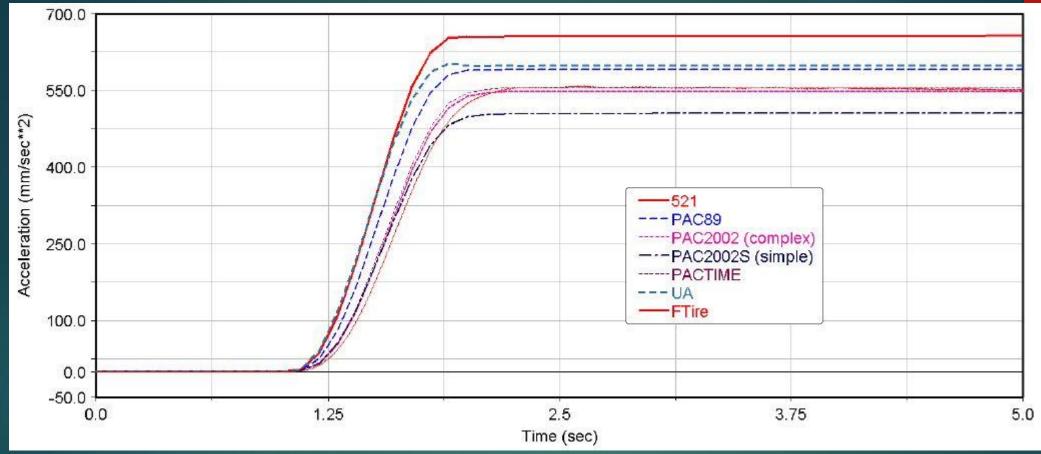
- Slight lateral slip (because of the high speed and turn angles)
- > Rear tire had a slightly larger slip angle than the front.
- > Implies that the vehicle was experiencing over steer.

Computational model testing: Step steer maneuver

- ► The test consists of turning in one direction at high speed.
- typically used to measure the reaction time of the car to that of steering input.
- ▶ It can also be used to measure the tire's characteristics during the duration of the maneuver.
- ► Test was set to last 8 seconds with a starting speed of 60 km/hr.
- After 1 second the vehicle would turn right to 2 degrees in a linear fashion over a 1 second interval.



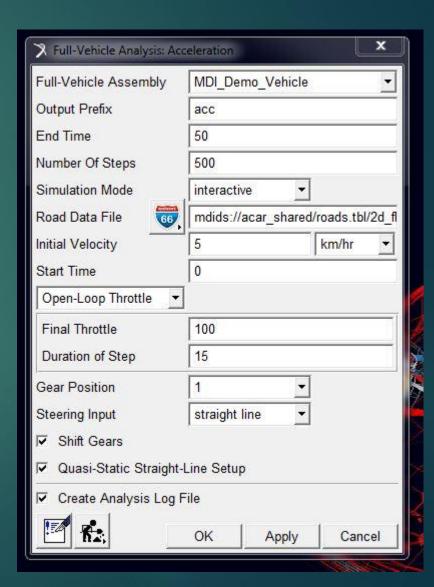
ADAMS plots

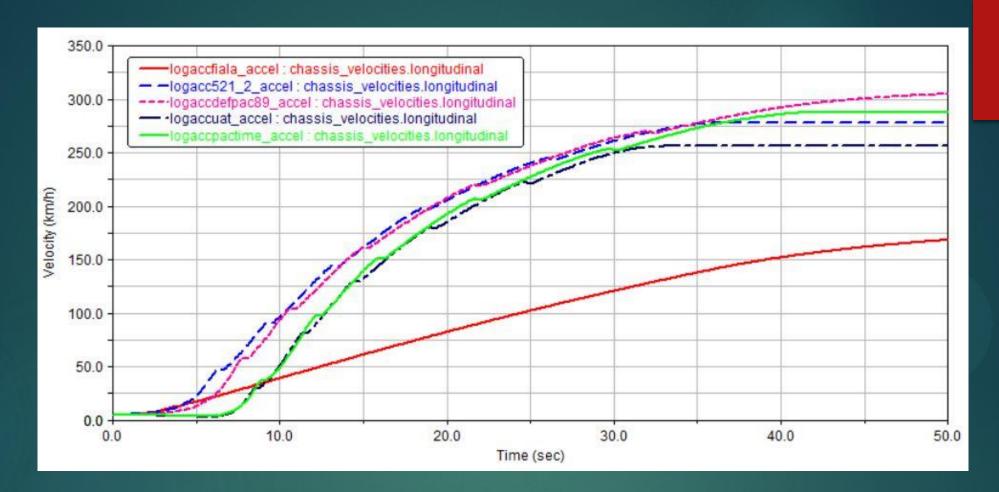


- > percent difference of approximately 35% between the 521 and simple PAC2002 models
- > Hard to reasonably justify which is correct (almost equal dispersion of all the results).
- ➤ Close proximity of the PACTIME, FTire, and complex PAC2002 models (most reasonably the actual result).
- > 521 model showed a relatively high amount of error.
- > Other models showed only about a 7 or 8% deviation from the assumed correct error.

Computational Model Testing: Longitudinal Acceleration

- ► the throttle would linearly increase until full throttle was reached.
- At which point the throttle position would immediately return to zero.
- ▶ Test duration: 50 sec
- Initial vel: 5km/hr
- All 5 gears are used an gear shifting is done automatically



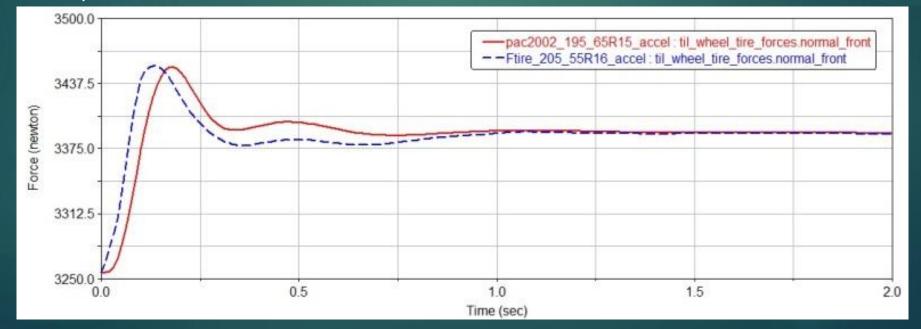


- The peaks are due to shifting of the gear
- ► The 521 model shows smooth curve maybe due to simplicity of the model

- ▶ Fiala doesn't show variation
- Next better curve is pac 89
- Which model was able to make the vehicle accelerate the quickest.
- ► PACTIME is similar to pac2002 and is giving results closer to mean value

Ftire vs pac2002

- Acceleration generates forces in the tire which can make the handling of the vehicle haywire.
- It's important this forces stabilizes as fast as possible
- The transient response off the tires normal force is compared to underdamped second order differential equation
- Comparison is done on the basis that how fast the normal force



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Transient Response

Peak time

$$t_p = \frac{\pi}{\omega_n (1 - \zeta)^{-1/2}}$$

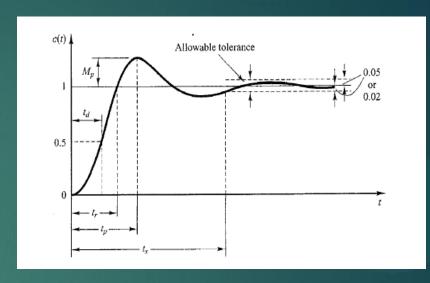
Max. overshoot

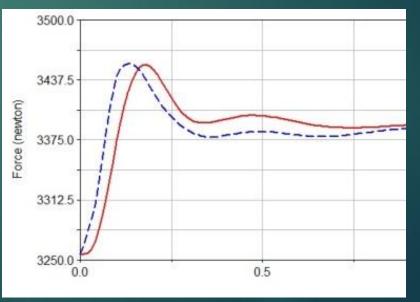
$$M_p = e^{-\frac{n_s}{(1-\zeta)^{-1/2}}}$$

Settling time

$$t_S = \frac{4}{\omega_n \zeta}$$

- Settling time for ftire = 0.248 s
- Settling time for pac2002 =0.352 s





Conclusion

- Adams software is a guide to help decide which tire model would be most appropriate for particular applications
- ▶ Tire performance is dependent on the structure of tire
- Ftire was found to be better in almost all conditions.
- Surprisingly for Fishhook Maneuver ua tyre was found to be effective.

References

- MSC Software. Adams 2012.1.3. Computer Program. MSC Software, 2012.
- Statistical modeling and comparison with experimental data of tiresoil interaction for combined longitudinal and lateral slip by <u>Jonah</u> <u>H. Lee</u>
- ▶ Pacejka '94 H.B Pacejka and E. Bakker. The Magic Formula Tire Model. Proceedings of the 1st International Colloquium on Tire Models for Vehicle Dynamics Analysis, Swets & Zeitlinger B.V., Amsterdam/Lisse, 1993.
- Adams tutorials: http://web.mscsoftware.com/Academia/Learn/Learn-AdamsCar.aspx

THANK YOU