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CONTROLLING TIRE SWAY

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***Abstract*:** The paper presents different solutions for reducing Vehicle / Tire sway. The study is a part of a larger campaign aimed to increase people awareness on driving safety by avoiding vehicle run-over.
Keywords: *Tire, Sway, Anti-Sway bar, Anti-Roll, High Performance, Low series*

1. INTRODUCTION

Modern vehicles are becoming more and more performing. There is an obvious reduction in overall body mass and increasing capabilities for higher and higher speeds even on moderate driving (touring) class of vehicles. 20 years ago most of the passenger vehicles were using “S” or “T” speed rated tires (for 180 or 190 Km/h, respectively). Today there are lots of vehicle using “V”, “W” or “Y” speed rating tires (240, 270 or 300 km/h).

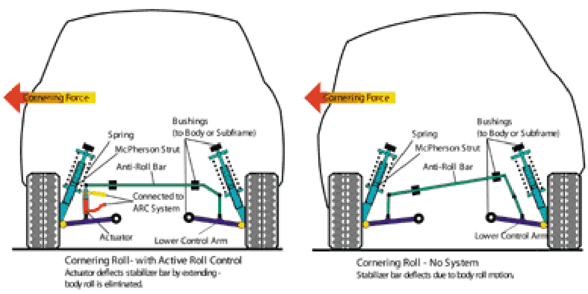

Fig. 1. Tendency to lift up and away from the inside wheels

2. VEHICLE SWAY

Driving at higher speeds and sharp cornering with a lighter vehicle induces a stability problem: Vehicle Sway, or Vehicle Rolling Tendency. As a car goes around a turn, the body leans toward the outside wheels and has a tendency to lift up and away from the inside wheels (Fig. 1.).

Relatively to the chassis itself, it appears that the outside suspension compresses and the inside extends. Therefore the inside wheel has the tendency to lose contact with the road. This is an important safety hazard since the driver can lose control of the vehicle.

3. ANTI-SWAY BAR

A very effective solution to keep the vehicle stable on the road is the Anti-Sway Bar (Fig. 2). A sway bar or anti-roll bar or stabilizer bar is a part of an automobile suspension that helps reduce the body roll of a vehicle during fast cornering or over road irregularities. It connects opposite (left/right) wheels together through short lever arms linked by a torsion spring.

Fig. 2. Anti-Sway Bar

A sway bar increases the suspension's roll stiffness—its resistance to roll in turns, independent of its spring rate in the vertical direction. Although there are many variations in design, a common function is to force the opposite wheel's shock absorber, spring or suspension rod to lower, or rise, to a similar level as the other wheel. In a fast turn, a vehicle tends to drop closer onto the outer wheels, and the sway bar will soon force the opposite wheel to also get closer to the vehicle. As a result, the vehicle tends to "hug" the road, closer in a fast turn, where all wheels are closer to the body. After the fast turn, then the downward pressure is reduced, and the paired wheels can return to their normal height against the vehicle, kept at similar levels by the connecting sway bar.

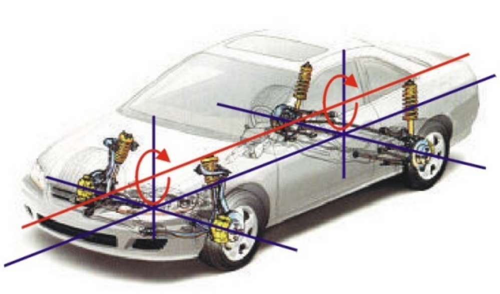
Fig. 3. Cross-Connected Bar

Because each pair of wheels is cross-connected by a bar (Fig. 3.), then the combined operation causes all wheels to generally offset the separate tilting of the others, and the vehicle tends to remain level against the general slope of the terrain. A negative side-effect, of connecting pairs of wheels, is that a jarring or bump to one wheel tends to also jar the opposite wheel, causing a larger impact applied across the whole width of the vehicle. If there are several potholes scattered in the road, then a vehicle will tend to rock, side-to-side, or waddle, due to the action of the bar at each pair of wheels.



a. b.
Fig 4. a. Understeering; b. Oversteering

The other function of anti-roll bars is to tune the handling balance of a car. Understeer (Fig. 4. A.) or oversteer (Fig. 4. B.) behavior can be tuned out by changing the proportion of the total roll stiffness that comes from the front and rear axles. Increasing the proportion of roll stiffness at the front will increase the proportion of the total load transfer that the front axle reacts and decrease the proportion that the rear axle reacts. In general this will cause the outer front wheel to run at a comparatively higher slip angle, and the outer rear wheel to run at a comparatively lower slip angle, which is an understeer effect. Increasing the proportion of roll stiffness at the rear axle will have the opposite effect and decrease understeer.

3.1 Adjustments

Anti-Roll Bar (ARB) or Sway Bar diameter: A powerful tuning tool to affect the overall behavior of the car. A larger diameter bar is stiffer than a small diameter bar, with the stiffness proportional to d^4, thus even small diameter changes have fairly large stiffness effects. The material the bar is made from also effects stiffness, with steel or “Fe” bar being stiffer than a titanium or “Ti” bar of the same diameter.

3.1.1 Sway bar or ARB Arm Length

Changing the arm length fine-tunes the stiffness of the sway bar. A shorter arm will enhance the sway bar’s effect on cornering. This increases the bar’s effective stiffness by reducing the length of the lever-arm through which the wheel acts on the bar. A longer arm will lessen the sway bar’s effects. Sometimes this adjustment is indicated directly as soft, medium, and stiff (or firm), and sometimes it is indicated by a number adjustment. When a number is used, higher values are stiffer. On many race cars this is the only anti-roll bar adjustment, and a generic soft, medium, stiff ARB adjustment normally indicates that the stiffness adjustment is being made by changing the length of the ARB arms or where the ARB mounts attach to the ARB (thus changing the effective length).

3.1.2. Impact of adjusting Anti-Sway bar

3.1.2.1 Front

(1) Stiffer: Will increase overall car stability (reduces roll) and shift the car's balance toward UNDERsteer (push), thus allowing the driver to be more aggressive with the steering. The compromise can be on bumps and/or braking. A stiffer front bar will reduce compliance, so when one tire hits a bump the entire front axle will be affected through a loss of overall grip.

(2) Softer: Allows more roll and will shift the cars balance toward OVERsteer (or less UNDERsteer). The front will improve in compliance, which improves performance in brake zones and over bumps.

3.1.2.2 Rear

(1) Stiffer: As you add throttle through the corner while the steering wheel is still turned, the rear anti-roll bar becomes very effective. Stiffening the bar supports the rear and shifts the balance to less UNDERsteer at corner exit. Again, the compromise is in compliance; a possible SNAP or FLAT OVERsteer may result if rear anti-roll bar is TOO stiff.

(2) Softer: Allows more roll at the back of the car, which will be most evident at corner exit. If the bar is TOO soft, the car will exhibit exit OVERsteer. In this case, compared to a rear bar that is TOO stiff, the exit OVERsteer condition will be more gradual instead of a snap, hence the phrase "roll OVERsteer."

3.2 Vehicle Sway Interactions

The roll control effects of an anti-roll bar or sway bar are similar to the effect of changing spring rate (in effect an ARB is just a special kind of torsion spring), thus the roll stiffness of the ARB is often traded back forth between spring rates to determine the optimum compromise. Stiff front anti-roll bars can also lead to increased front inside front tire lockup under braking.

4. TIRE SWAY

The tire, as part of the suspension, acts like a spring, in contact with the ground. Vertical forces on the tire are affecting the spring ratio and cause tire to compress or extend.

As the compression on the tire sidewall increases, there are several factors influencing tire sway: Driving speed; Sidewall stiffness; Tire Aspect Ratio; Inflation pressure; Proper tire choice.

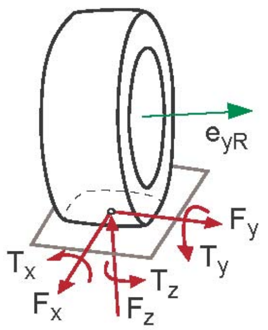

Fig. 5. Content:
Fx longitudinal force
Fy lateral force
Fz vertical force or wheel load
Tx tipping torque
Ty rolling resistance torque
Tz self aligning and bore torque

4.1 Steady State Tire Forces and Torques

The lateral force Fy acting in the contact patch deflects the tire in lateral direction, the first order approximation takes the lateral tire deflection y_e into account (Fig. 6.).

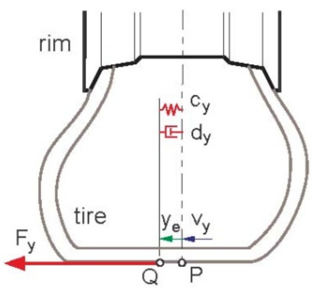

Fig. 6. Lateral tire deflection

$$\frac{F_y(v_y+\dot{y}_e)}{F_y^D} = \frac{F_y(v_y)}{F_y^S} + \frac{\partial F_y}{\partial v_y}\dot{y}_e \qquad (1)$$

In relation (1) v_y describes the sliding velocity of the contact point in lateral direction. y_e is greatly influenced by tire sidewall stiffness in the way that a stiffer tire sidewall will have a lower y_e. The amount of Tire lateral deflection is critical in Tire Sway because it will induce asymetrical sidewall compression. In Figure 6 left sidewall will compress more than right sidewall and will increase the Tipping Torque T_x (Fig. 5). Camber angle γ is the tilting angle of tire about the longitudinal x-axis. Camber angle generates a lateral force Fy called camber trust or camber force. Figure 7 illustrates a front view of a cambered tire and the generated camber force Fy . Camber angle is assumed positive $\gamma > 0$, when it is in the positive direction of the x-axis, measured from the z-axis to the tire.

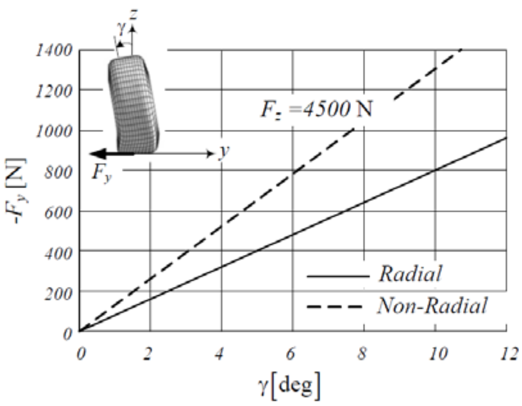

Fig. 7. Cambered tire

5. CONCLUSION

In order to reduce Tipping Torque we have to increase sidewall stiffness.

1) The safest way reduce Tire Sway is to drive at slower speeds. Tipping Torque and Tire Lateral Deflection will be much lower. Ride will be much more confortable and tires will last longer.
2) Choose a tire with a stiffer sidewall construction. High Performance tires have a stiffwer sidewall construction than Touring tires. Therefore is better to install a tire with a Speed Index of “H”, “V” or “W” than “S”, “R”, “T”, etc.
3) Reduce tire aspect ratio. Aspect ratio is defined by tire Section Hight divided by Section Width. A tire with an aspect ratio of 35 will have a much lower sidewall and wider contact patch than a tire with an aspect ratio of 65.

6. REFERENCES

[1] Cars Direct, Aug 17, 2009
[2] iRacing. Com. Anty-Sway Bar tuning, 2012
[3] First Order Tire Dynamics – George Rill, 2006
[4] Transport Canada – Rolling on Air, 2004
[5] Wheels - Winter tires can't take heat of spring and summer, Apr 30, 2010
[6] Pneus Mag - Le roulis: Comment bien le contrôler ?, May 3, 2005
[7] Vehicle Dynamics, Reza N. Jazar, 2008

CONTROLAREA RULARII LATERALE A PNEULUI

Rezumat : Lucrarea prezinta cateva sugestii pentru controlarea rularii laterale a pneului in scopul unui control superior al stabilitatii vehiculului. Subiectul face parte dintr-o campanie mai larga de sensibilizarea conducatorilor auto asupra sigurantei pe drumurile publice.

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