

Homework 0 Solutions ME 106/227 Spring 2001

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Problem 1:

A)

The Ackermann angle is given by L/R where L is the wheelbase of the vehicle and R is the radius of the turn. In this case, $R = 100ft$ and for the Lexus $L = 105.1in = 8.76ft$. The Ackermann angle is

$$\delta = L/R = 8.76ft/100ft = 0.088rad = 5.0deg$$

To figure out how much the driver turns the steering wheel you must use the steering ratio which is 15.7 : 1

$$\delta_{driver} = (5.02deg)(15.7) = 78.8deg$$

B) Under ideal Ackermann geometry the inner and outer wheel angles are given by

$$\delta_{outer} = \frac{L}{R + t/2}$$
$$\delta_{inner} = \frac{L}{R - t/2}$$

where, t is the track width. For the Lexus $t = 58.9in = 4.9ft$

$$\delta_{outer} = \frac{8.76ft}{100ft + (0.5)(4.9ft)}(57.3deg/rad) = 4.9deg$$
$$\delta_{inner} = \frac{8.76ft}{100ft - (0.5)(4.9ft)}(57.3deg/rad) = 5.2deg$$

Ignoring the difference is reasonable. In fact, the bicycle model uses the Ackermann steering angle, which varies from the outer and inner angles by only about 2%.

C)

The lateral acceleration on the skidpad $a_n = 0.91g = 8.93m/s^2$

$$a_n = \frac{v^2}{R}$$

so,

$$R = 100ft = 30.49m$$
$$v = \sqrt{a_n R} = 16.5m/s = 36.9mph$$

To calculate the angular velocity

$$\omega = \frac{v}{R} = \frac{16.5m/s}{30.49m} = 0.54rad/s = 31.0deg/s$$

Problem 2:

A)

The cornering stiffness on the front and rear is taken to be equal with $C_{\alpha f} = C_{\alpha r} = C_{\alpha} = 1800N/deg$
 The understeer gradient,

$$K = \frac{W_f}{C_{\alpha}} - \frac{W_r}{C_{\alpha}}$$

where W_f and W_r is the weight on the front and rear wheels, respectively.

BMW:

$$mass = 3530lb = 1605kg$$

Weight Distribution (f/r): 53/47

$$m_{front} = (1605kg)(0.53) = 851kg$$

$$m_{rear} = (1605kg)(0.47) = 754kg$$

$$K = \frac{(851kg)(9.81m/s^2)}{1800N/deg} - \frac{(754kg)(9.81m/s^2)}{1800N/deg} = 0.52deg/g$$

Lexus:

$$mass = 3520lb = 1600kg$$

Weight Distribution (f/r): 55/45

$$m_{front} = (1600kg)(0.55) = 880kg$$

$$m_{rear} = (1600kg)(0.45) = 720kg$$

$$K = \frac{(880kg)(9.81m/s^2)}{1800N/deg} - \frac{(720kg)(9.81m/s^2)}{1800N/deg} = 0.87deg/g$$

Mercedes:

$$mass = 3630lb = 1650kg$$

Weight Distribution (f/r): 55/45

$$m_{front} = (1650kg)(0.55) = 908kg$$

$$m_{rear} = (1650kg)(0.45) = 742kg$$

$$K = \frac{(908kg)(9.81m/s^2)}{1800N/deg} - \frac{(742kg)(9.81m/s^2)}{1800N/deg} = 0.89deg/g$$

Volvo:

$$mass = 3640lb = 1655kg$$

Weight Distribution (f/r): 61/39

$$m_{front} = (1655kg)(0.61) = 1009kg$$

$$m_{rear} = (1655kg)(0.39) = 646kg$$

$$K = \frac{(1009kg)(9.81m/s^2)}{1800N/deg} - \frac{(646kg)(9.81m/s^2)}{1800N/deg} = 1.98deg/g$$

B)

To get the understeer gradient at the wheel, simply multiply the understeer gradients from part A with the appropriate steering ratio.

BMW

Steering Ratio 15.5:1

$$K_{wheel} = (0.52deg/g)(15.5) = 8.1deg/g$$

Lexus

Steering Ratio 15.7:1

$$K_{wheel} = (0.87deg/g)(15.7) = 13.7deg/g$$

Volvo

Steering Ratio 17.0:1

$$K_{wheel} = (1.98deg/g)(17.0) = 33.7deg/g$$

C)

For all the vehicles, the qualitative rankings from Road and Track are understeering, which is consistent with our analysis. The moderate understeer given for the Mercedes does not match up with the magnitude of the understeer gradients calculated at the road in part A. If the steering ratio is small for the Mercedes, this could give a smaller understeer gradient at the steering wheel making the vehicle feel less understeering to the driver.

Problem 3:

A)

Since the Mercedes and Lexus have the same weight distribution, one way to make the Mercedes understeer less than the Lexus would be to put on tires with higher cornering stiffness. From the understeer gradient equation

$$K = \frac{W_f}{C_{\alpha f}} - \frac{W_r}{C_{\alpha r}}$$

it is clear that this would make the ratios smaller and decrease the understeer gradient.

B)

Lexus Tire Size: P215/45ZR-17

Mercedes Tire Size: P225/50R-16

The Mercedes has the greatest width and the Lexus has the lowest aspect ratio and largest rims. From graph 4 on page 200 of the text, the larger rim size (by about 6%) of the Lexus will give a higher cornering stiffness as will the lower aspect ratio (Lexus sidewall height is about 14% lower than the Mercedes). Although the Mercedes has wider tires, they are only marginally wider (about 5%) making it unlikely that this would outweigh the effects of aspect ratio and rim size. Given this, the tire sizes do not predict that the Mercedes will have stiffer tires, so the performance difference noted by the Road and Track drivers must be caused by some other factors not captured by the understeer gradient.

C)

Not necessarily. The stiffness will depend on the material of the tires but, given the same material, the lower aspect ratio tire will be stiffer.

D)

In order to decrease the understeer in a vehicle, putting stiffer tires on the front will have more impact than stiffer tires all around. To see this look at the understeer gradient equation. Putting stiffer tires on the front decreases the first ratio without decreasing the second.