Anti-dive and Longitudinal Wheel Paths

Formula SAE Vehicle Dynamics and Suspension

Ryan Alexander

10/13/2011

The following paragraphs summarize the implementation of anti-dive front suspension geometry on trophy-winning 2010 UWO Formula Racing car.

ANTI-GEOMETRY DEFINITION

"Anti-geometry dictates the proportion of the weight transfer that acts through the suspension links [geometric] and the weight transfer that acts through the springs and the dampers [elastic]. Thus, anti-geometry can be used to reduce, amplify, or reverse the motion of the chassis during longitudinal accelerations. The total weight transfer is not affected by the anti-geometry, except for its effects on the height of the center of gravity." (OptimumG, 2011)

The amount of anti-geometry in a suspension system depends on the side-view wheel instant center location (SVIC), the wheelbase, the center of gravity height, and the proportion of force that the front and rear tires generate.

In this analysis it is assumed that the front brakes are mounted from the upright.

CALCULATION

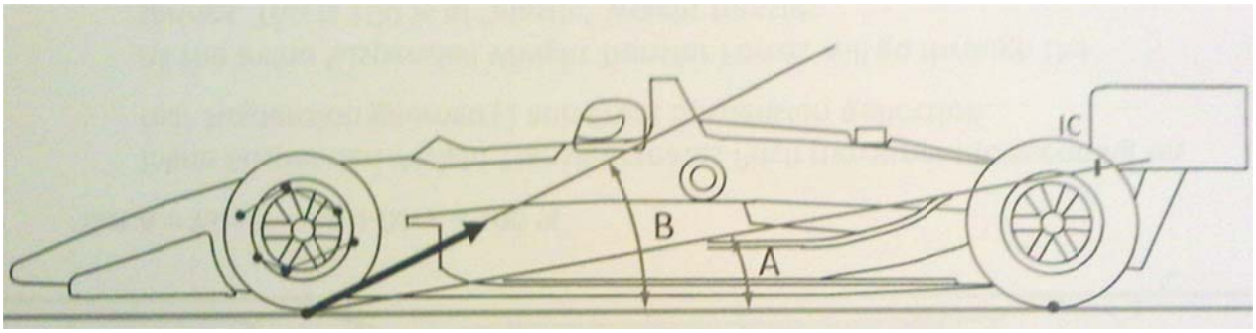

FIGURE 1: ANGLE A AND B DEFINITION (FROM OPTIMUMG 2011 SLIDES)

Anti-dive percentage can be calculated with the following equation.

$$AntiDive\ [\%] = 100 * \frac{Tan(A)}{Tan(B)}$$

Angle A is a function of the instant suspension geometry

$$A = \ \text{atan}\ \ [\![SVICz/(-SVICx)]\!]$$

Angle B is a function of the inline weight transfer and brake

$$B = \ \ atan\ \ [\![longitudinal\ WT\ per\ corner/front\ longtitudinal\ contact\ patch\ force]\!]$$

Another way simplified way of calculating anti-dive is (Milliken):

$$\%Anti\ Dive\ Front = (\%Front\ Braking) * \tan(A) * Wheelbase\ /\ CG\ Height$$

IMPLEMENTED FRONT SUSPENSION SIDE-VIEW GEOMETRY

The images below are screenshots from OptimumK Kinematics simulation software from the side-view. The origin is at the center of the track of the front wheels at ground level. The blue line is the kinematic roll axis, and the red lines are the kinematic swing arms and swing axis of the front wheel. All other axes are hidden for simplicity and shown in Figure 5 on Page 5 for reference.

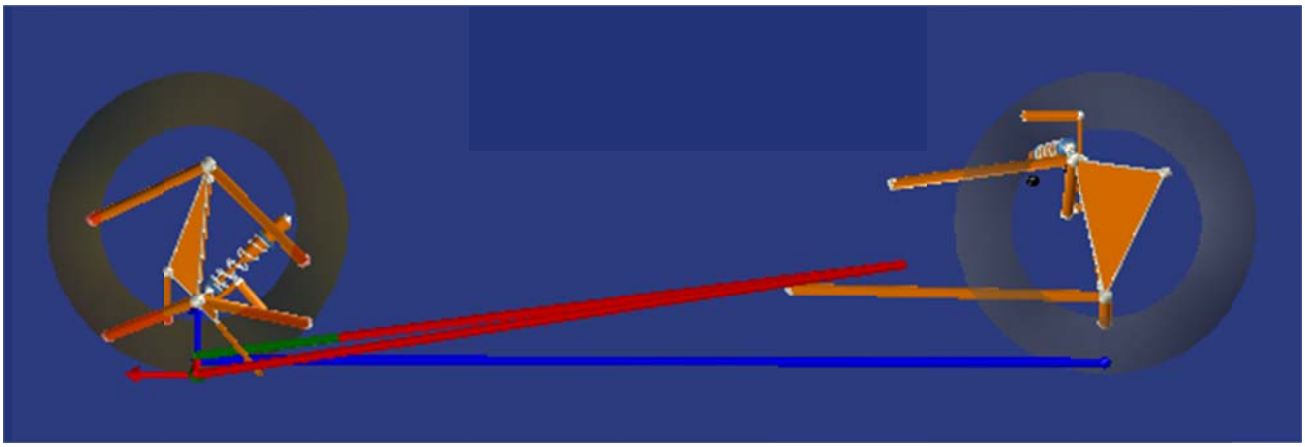

FIGURE 2: SIDE-VIEW IC AFT AND BELOW WHEEL CENTER SVIC(-1183, 184)

IC ANGLE

1.3mm rearward front wheel movement through 25mm downward body heave (Optimum K Simulation)

The following is a sample calculation for the front anti-dive-geometry (for consistency and speed, all calculations were done and checked in Excel and other software simulators)

$$SVIC\ Angle, A = \tan^{-1}\left(\frac{184\ mm}{1183\ mm}\right) = 8.84\ degrees$$

*Note: IC shift at 25mm heave brings A to 7.46 degrees

CONTACT PATCH RESULTANT FORCE VECTOR ANGLE

Constants: 1.5 G deceleration, 278kg GVW, 46.1% Front Static Mass Distribution, 72% Front Brake distribution, Front Tire Cf = 1.47, Rear Tire Cf = 1.58

$$WT\ Resultant\ Vector\ Angle, B = \tan^{-1}\left(\frac{366\ N}{1463\ N}\right)$$

$$B = 14.05\ degrees$$

$$AntiDive\ [\%] = 100 * \frac{Tan(8.84)}{Tan(14.05)}$$

$$Anti\ Dive\ [\%] = 62\ \%$$ (decreases to 52% with 25mm wheel bump)

Or, by Milliken to double check: $\%Anti\ Dive\ Front = (72\%) * \tan(8.84) * \frac{1524mm}{270\ mm} = 62\%$

ALTERNATE GEOMETRIES

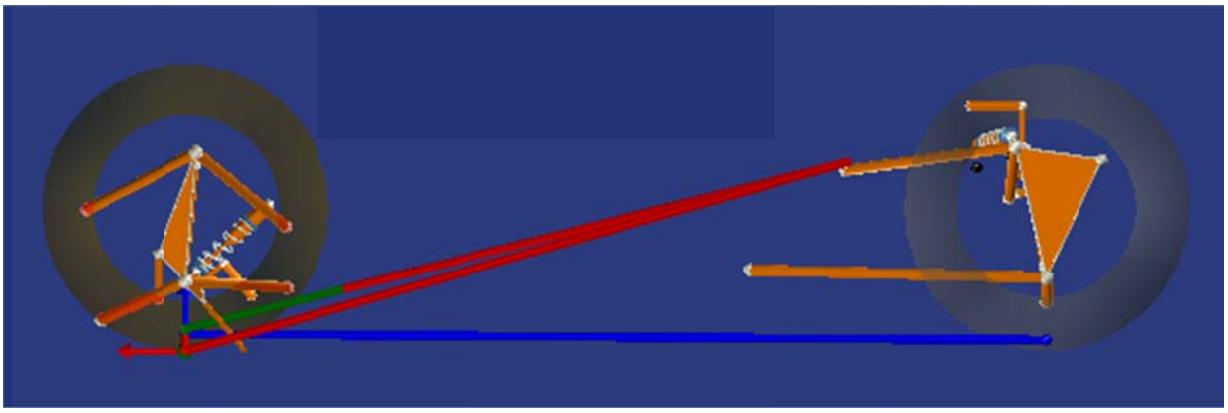

FIGURE 3: SIDE-VIEW IC AFT AND ABOVE WHEEL CENTER SVIC(-1173,335)

100%-110% Anti-dive, 1.8mm forward wheel movement through 25mm downward body heave

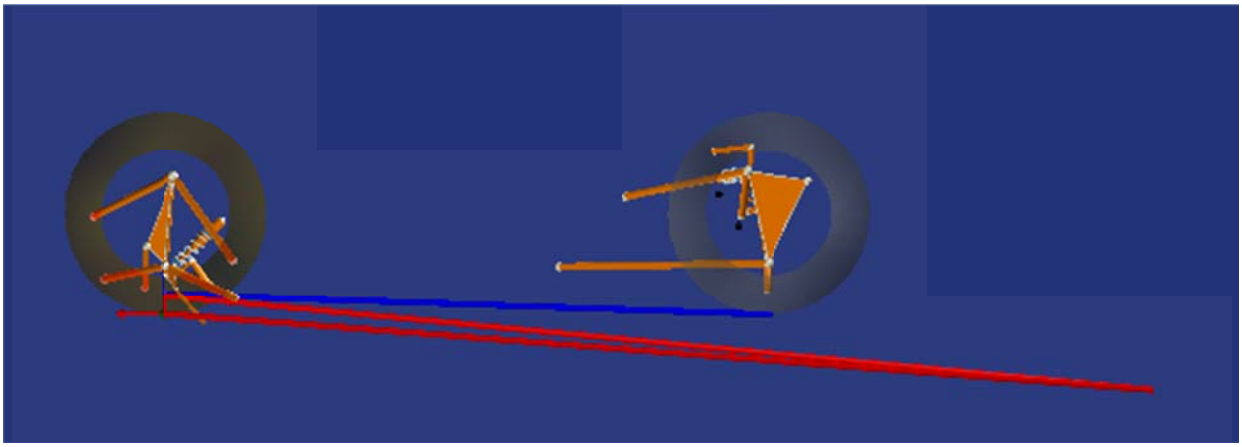

FIGURE 4: SIDE-VIEW IC AFT AND BELOW GROUND SVIC(-2141,-111)

-21% to -30% Anti dive, 4mm rearward wheel movement through 25mm downward body heave

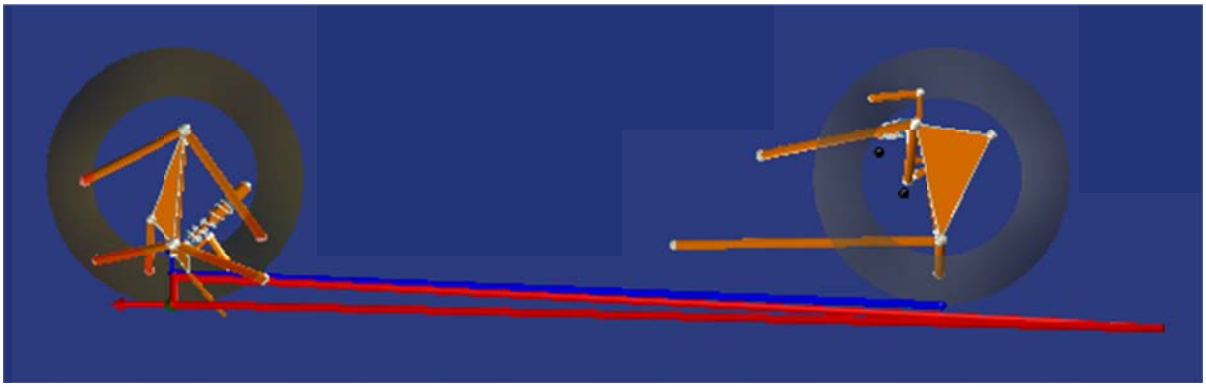

FIGURE 5: SIDE VIEW AFT AND APPROXIMATELY AT GROUND SVIC(-1725, 3.4)

-5% to 5% Anti dive, 3.2mm rearward wheel movement through 25mm downward body heave

WORKS CITED

Milliken, M. a. (n.d.). *Race Car Vehicle Dynamics.*

OptimumG. (2011). *OptimumG Vehicle Dynamics Seminar.* Denver, Colorado.

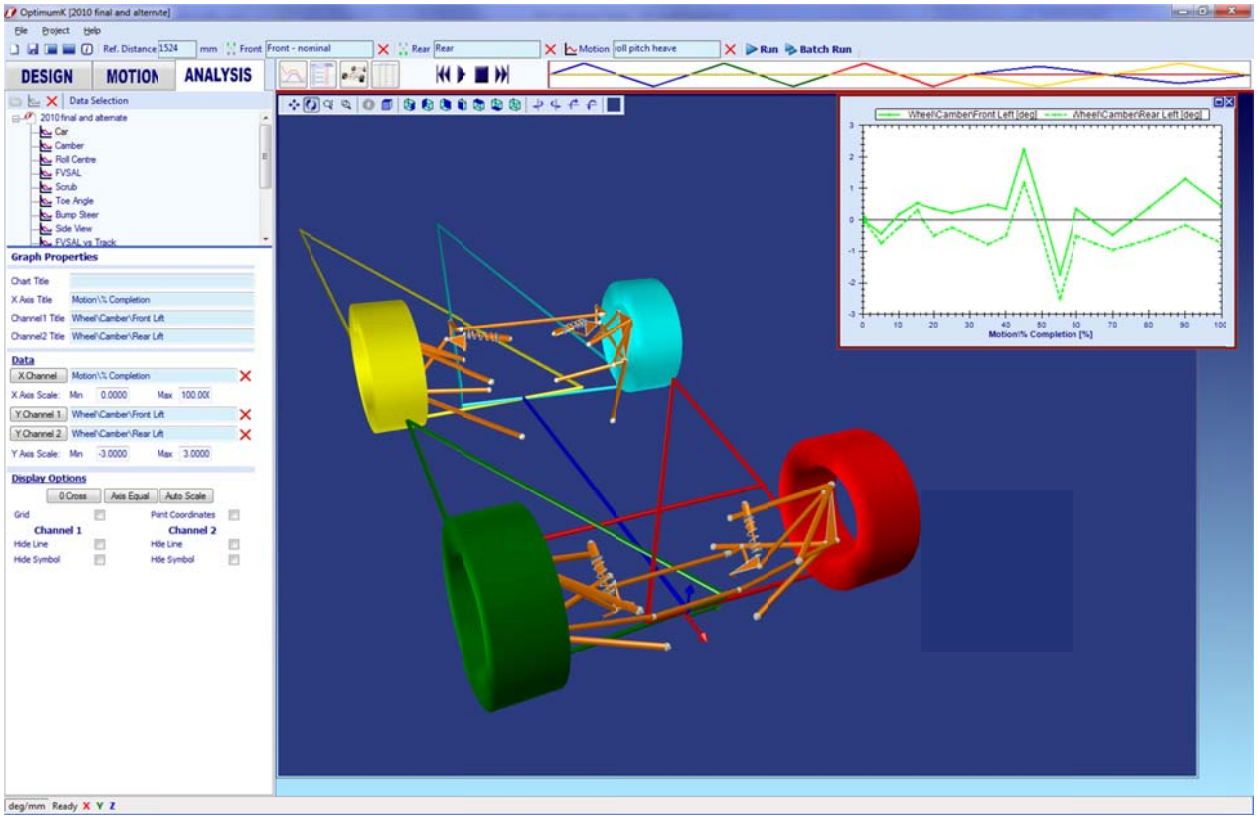

FIGURE 6: OPTIMUMK SIMULATION OVERVIEW