The Mark Ortiz Automotive

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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: markortiz@vnet.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

PANHARD BAR LONGITUDINAL LOCATION

What is the effect of locating the Panhard bar in a live axle rear suspension a) behind the rear axle, or b) just ahead of the rear axle, or c) even further forward in the car? For example, the Frankie Grill All-American Race Car chassis is now attaching the Panhard bar to the right-side rear door post. From there the bar runs across the car and about eight inches rearward, and attaches to a bracket extending about eleven inches forward from the left axle tube. These cars appear to be dominating at the current time.

These cars are a variety of Super Late Model, running on paved ovals in the northeastern US. Longitudinal axle location is by a form of 3-link system, with dual, compliant upper links. One upper link reacts tension forces occurring under power. The other reacts compression loads occurring in braking, including engine braking. The two links generally have different angles. They both have rubber or urethane biscuits in them that can be varied to change the rigidity of the link. The rules prohibit compliant lower trailing arms, which are commonly used at the right rear where legal.

The effect of locating the Panhard bar forward or back with respect to the axle depends on the layout of the rest of the rear suspension system. In some cases there is little or no effect; in other cases there can be a significant effect.

To understand this better, it is helpful to introduce the concept of the rear axle axis of rotation in roll. This is sometimes called the axle's roll axis. There is nothing wrong with calling it that, provided one understands that it is not the same as the the car's roll axis, the line connecting the front and rear roll centers.

The axle roll axis is a notional line about which the axle moves in the roll mode of suspension movement. The point where this line intercepts the rear axle plane – the vertical plane containing the rear wheel axis – is considered the rear roll center.

The axle roll axis is usually constructed as a line connecting two points: the instant center of the links or arms that locate the outer ends of the axle, and a point taken as representing the height and longitudinal location of the Panhard bar or equivalent lateral locating device.

In some cases, the assignment of these points can be rather tricky, and may call for some approximation. For example, it is quite possible that there may not really be an intersection point of the lower trailing arms in a three-link system. The link centerlines may converge a bit toward the front of the car, and may have an intersection in plan view, but they may pass over and under each other at that location, rather than truly intersecting. Or they may be parallel in plan view and therefore have no intersection, even if they lie in the same plane.

In the former case, it is reasonable to take as an assumed front point for the axle roll axis a point midway between the two link centerlines, where they pass over and under each other. In the latter case, in side view the axle roll axis is parallel to the trailing arm centerlines, or an average of their inclinations if they are not parallel in side view.

In the former case, we need a second point to determine our axle roll axis. In the second case, we know the inclination of our line, but not its height, so we need a point to establish that.

In both cases, we take for this a point representing the height of the Panhard bar or equivalent lateral locating device. In a passenger car, with a Panhard bar, the usual practice is to assume that the car has close to 50% left weight, and take the point where the Panhard bar centerline intercepts the vehicle center plane. If the Panhard bar is centered in the car, this will also be the midpoint of the Panhard bar.

Things get a bit more complex when the c.g., or the Panhard bar, or both, are offset significantly to the right or left. Here, we have a choice of two methods. We can take the point where the Panhard bar centerline intercepts the sprung mass c.g. plane (the longitudinal, vertical plane containing the sprung mass c.g.). Alternatively, we can take the Panhard bar midpoint.

When the Panhard bar is significantly off center, and significantly inclined, as in many dirt chassis these days, the heights of the c.g. plane intercept and the bar midpoint can differ by as much as two or three inches. Which method is more correct? They are both reasonably correct, provided we apply them properly. If we use the c.g. plane intercept, we do not make an additional correction for the vertical component, or jacking force, resulting from the Panhard bar inclination, when modeling roll behavior and wheel loads when cornering. If we use the bar midpoint, we have to include the jacking force in our calculations. The former method is simpler, and yields a good enough approximation for most purposes; the latter is more rigorous and accurate, but more complex.

In any case, by some rationally defensible method we choose an effective acting height for our lateral locating mechanism. We now still have to assign it a longitudinal position. If we have a Panhard bar that runs straight across the car in plan view, this is presents no difficulty. On the other hand, if the bar has significant plan view angularity, we have a bit of a puzzle. I think the right approach for assigning the x-axis, or longitudinal, coordinate is to use the x coordinate of the bar midpoint in all cases.

We now have vertical and longitudinal coordinates for a point that is a reasonable approximation of a lateral force coupling point between the sprung mass and the rear axle assembly. We can now draw our rear axle roll axis, or axis of rotation in roll, in side view. If we have an exact or approximated instant center for the longitudinal locating links, we draw our line from that point through the lateral force coupling point. If instead we know the inclination of our axis of rotation, we draw a line at that angle, passing through the lateral force coupling point.

Once we do that, we can see where this axis of rotation intercepts the axle plane, and we can take that as our rear roll center when modeling roll and wheel loads in cornering.

Now, returning to the original question, what happens to the roll center when the lateral force coupling point moves forward or back? It depends on the rear axle roll axis inclination angle.

If the axle roll axis slopes down toward the front, then moving the lateral force coupling point forward while keeping it at constant height raises the rear roll center. If the axle roll axis slopes up toward the front, the effect reverses: moving the lateral force coupling point forward while keeping it at constant height lowers the roll center. If the axle roll axis is horizontal, then we get no change in rear roll center height from moving the lateral force coupling point forward or back.

There are other effects as well, when we move the Panhard bar forward or back. If the axle rotates under power or braking, as it does when the upper link is compliant, the end of the Panhard bar that attaches to the axle rises or falls as the axle rotates. That means the roll center rises or falls with power or braking. The further the Panhard bar is from the axle centerline, the more it rises or falls, and the more the roll center rises or falls.

When the Panhard bar is far ahead of the axle, as the questioner describes, the roll center rises under power and drops under braking. That makes the car tighter (adds understeer) on entry and loosens the car (adds oversteer) on exit. I don't see how that would make a car faster, but it would make it different. There are other ways of controlling the car's balance during entry and exit, so with the right combination overall, such a car could win races.

One advantage of having the Panhard bar really far forward, if you’re going to have it ahead of the axle at all, is that it's easier to keep the Panhard bar out of the way of the driveshaft, without putting a bend in the bar. There are other packaging implications as well. It becomes harder to find room for the oil tank and the battery behind the driver. Overall, I would have to judge this idea a mixed blessing, and ascribe any success to users having the overall combination dialed in.

PANHARD BAR JACKING FORCES

How do jacking forces (anti-roll, anti-dive, anti-lift, anti-squat) affect transient wheel loading during corner entry/exit? I realize that total lateral load transfer is purely a function of of c.g. height, track width, and lateral acceleration (neglecting the load transferred due to c.g. movement); however, I also feel that magnitude of the jacking forces should have some bearing on how the loads are transferred during the non-steady-state stages of the corner.

Taking a NASCAR rear axle, for example, we can de-rake the track bar (increase the left side track bar height, decrease the right side track bar height) such that the rear roll center height, as it is traditionally understood, remains unchanged. This causes the rear axle jacking force to increase, which will cause the rear spoiler to rise during cornering, and until the spring forces have changed enough to balance the jacking force, keep the left rear tire more heavily loaded – thus keeping the diagonal percentage higher during early corner entry. Is my thought process correct? Can we make similar conclusions regarding the front suspension jacking forces?

Jacking forces are the source of geometric roll and pitch resistance. They are present whenever the tires are generating horizontal forces (lateral or longitudinal) at the contact patches, and they influence wheel loads whenever they are present. Therefore, they influence both transient and steady-state car behavior.

The reason you will sometimes hear that jacking forces have disproportionate influence in transient handling is that when we have an abrupt control input (usually steering or brakes, or both), the forces at the contact patches build up more rapidly than the roll and pitch displacements of the sprung mass. Consequently, for a brief time the elastic components of roll and pitch resistance are smaller than in steady-state longitudinal and/or lateral acceleration, and the geometric components accordingly assume greater importance.

I am reluctant to believe that this effect significantly influences entry or exit behavior in oval track racing. The steering and braking are too gentle and prolonged. The dominant factor in oval track turn entry is the combination of fairly steady braking and turning together, over a period of roughly one to four seconds. The duration of this phase of the cornering process, the severity of braking, and the abruptness of brake and steering application and release all vary with the track, the setup, and the driver's style. However, we can say with certainty that the large radius of the turns inevitably precludes really abrupt control inputs, compared to what we see in other realms of motorsport, unless we are dealing with an unusually small oval.

On the other hand, I am willing to believe that lag in pitch and roll displacement is significant in a passenger car test track j-turn or lane-change test, in a chicane or street intersection turn in road racing, or in the sort of tight turns we encounter in American autocross.

In a NASCAR oval track chassis, a Panhard bar that slopes down from its attachment on the left axle tube to its frame attachment on the right does create a force trying to lift the rear of the car. This force is present through the entire turn, not just during entry. This force does not just load the left rear tire. It does pull down on the axle on the left, but it also lifts up on the frame on the right. Its effect is most commonly modeled as a force spreading the axle and frame apart, acting at the midpoint of the bar's span, approximately in the middle of the car.

If the car has little or no rear spring split, a force in the middle of the car, lifting the frame away from the axle, gets the rear spoiler up in the air but does not significantly change wheel loads, except by aerodynamic effects. However, current NASCAR setups use considerably stiffer springs at the right rear than at the left rear, so there is some increase in left rear load, and diagonal percentage, because of that. If the car has a left-stiff rear spring combination, the effect reverses, and the jacking force actually increases right rear tire loading and reduces diagonal percentage.

Again, these effects persist through the entire turn, and only go away when the rear tires cease making lateral force.