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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.

MORE ON BELT MOUNTING

Regular readers will recall that last month I mentioned seeing improperly mounted lap and shoulder belts on a car displayed to the press at Richard Childress Racing. I have recently talked with Brian Butler of Butler Built seats, who custom-builds seats for RCR and supervises their installation. He tells me that all actual race cars he has worked on lately at RCR have the belts mounted correctly, and we agreed on what "correctly" meant. Brian was sure I had seen a show car that did not reflect actual current race car practice. I am relieved to hear that. I like being proven wrong on something like this.

RACING FRONT-DRIVE CARS

I have had a number of inquiries lately from people racing front-wheel-drive cars, asking about literature or information sources about setting up front-drive cars. It appears there is a distinct lack of literature currently in print on this subject, at least beyond manuals dealing with particular cars, and brief passages in general chassis books. So I'm going to offer some comments on the characteristics of front-drive cars in racing and high-performance applications.

The idea of racing a front-drive car is a bit like the idea of teaching an elephant to dance. It can be done, and people do it, but the basic anatomy of the critter involved is not particularly conducive to the activity. If we drive only two wheels of a car, they really should be the rears, for a number of reasons. The most obvious reason is that under forward acceleration, and when going uphill, tire loading transfers from the front wheels to the rears.

A slightly less obvious reason is that we have better control of the car when we can control the front wheels with the steering wheel and the rear wheels with the throttle. With front wheel drive, the only thing we can use to influence the rear wheels is the brakes. Some drivers become fairly adept at left foot braking and using the hand brake to slide the rear end of a front-drive car, but this is fundamentally awkward compared to throttle-steering. Active yaw control, which selectively applies individual brakes according to a computer's interpretation of car behavior and driver intent, also offers some promise, but it is essentially a band-aid. For racing, any use of the brakes to control the car's balance or yaw behavior is definitely a last-resort approach (except perhaps when trail-braking on entry), because it works the tires against each other and dissipates speed. Even the best electronics are better added to a chassis with good fundamental dynamics.

For these reasons, nobody builds race cars with front wheel drive nowadays, if they have free choice of layout. However, front wheel drive shows up on the race track in production classes, and production-based classes, because it is popular for passenger cars.

Let's examine the reasons for this popularity.

Front wheel drive, with front engine, is one of four possibilities in a four wheeled, two-wheel-drive vehicle, the others being rear engine/rear drive, front engine/rear drive, and rear engine/front drive. This last option is never used, although Buckminster Fuller designed a rear-engine/front-drive car (with rear steering!) in the 1930's. One example was actually built. It ran, but its handling properties did not attract imitators.

Front engine/front drive and rear engine/rear drive are commonly referred to as engine-over-drive-wheels layouts. Both layouts concentrate the entire powertrain at one end of the car. This saves weight and space. It also puts well over 50% of the car's weight on the drive wheels – usually somewhere between 55 and 67 percent. This is good for propulsive traction. However, it is at best a mixed blessing in terms of cornering behavior. Due to *tire load sensitivity* – the decrease in coefficient of friction as loading increases, which we have discussed in previous issues – nose-heavy cars tend to understeer in steady-state cornering, and tail-heavy ones tend to oversteer. The car tries to leave the desired path heavy-end-first.

If we are faced with a choice between heavy understeer and heavy oversteer, understeer is clearly the safer choice. This is one reason why rear-engine/rear-drive layouts have fallen from favor for passenger cars. Another reason is the simple fact that luggage or cargo space in the rear of a vehicle is more useful than luggage or cargo space in the nose, because the space can be filled or over-filled, and the lid left partly open, for short hauls with big loads. The rear seat can be made to fold to accommodate long objects.

Additionally, a nose-heavy car has better directional stability in crosswinds than a tail-heavy one, other things being equal. This is highly significant for a light sedan that spends much of its life on freeways. Tail-heavy cars can be made adequately stable in crosswinds, but this requires careful attention to aerodynamics, and places added constraints on styling.

These practical and safety-related concerns have driven the trend to front-engine/front-drive cars. I personally think that the rear engine/rear drive option has an unrecognized future, for cars with back seats, intended for drivers who place priority on performance. Existing front-drive powertrains, especially the larger V6 and V8 variety, could be adapted to such cars, placing the engine slightly ahead of the rear axle line, with a relatively long wheelbase. In other words, we are envisioning a stretched, larger-engined version of the Toyota MR2/Pontiac Fiero/Fiat X1/9 concept. However, such a layout would not match the practicality of a front-engine car for hauling bulky loads, and would probably have somewhat more interior noise. So front-engine/front-drive cars are here to stay, and will surely command a large share of the passenger car market for the foreseeable future.

I mentioned the tendency for a car to try to leave the desired path heavy-end-first. We have two principal tools we can use to control this tendency: use bigger and/or stickier tires at the heavy end of the car; and/or put most of the roll resistance at the light end. We can also play with secondary factors such as toe, camber, and tire inflation. Finally, we can simply reduce the nose-heaviness or tail-heaviness, by moving the engine toward the center of the car, or by moving heavy components to the light end as much as possible.

In rear-engine/rear-drive cars, it is common nowadays to use larger tires in back. The reliability of modern tires, the increased availability of road service, and the advent of space-saver spare tires have paved the way for this trend. When front-engine/front-drive cars pushed rear-engine/rear-drive cars out of the passenger car market, most manufacturers considered it essential to have a full-size spare that could be used at any corner of the car. This is still a practical advantage, but not the necessity that it once was.

It is also common in rear-engine cars to mitigate some of the tail-heaviness by using a mid-engine layout. Even if the tail-heaviness is modest, drive traction will be quite good, thanks to the rearward load transfer under power.

With front drive, this load transfer works against us. Consequently, we are faced with a dilemma: maximize front-heaviness so we can put power down, or minimize front-heaviness so we can corner. There is no way to achieve one objective without compromising the other. This is also true with tail-heaviness in rear-drive cars, but the compromise is less excruciating thanks to the help we get from rearward load transfer.

If we were designing for an imaginary set of rules that required us to use front wheel drive, but allowed us ample freedom otherwise, we might make the car extremely nose-heavy, use big tires in front and smaller ones in back, and be sure to provide power steering and huge front brakes. We would also make the wheelbase really long. This would be a funny-looking car, and less enjoyable to drive than a rear-drive racing car, but that would be the way to go fastest with front drive.

In real-world classes where front-drive cars compete, we are usually constrained by tire rules and limitations on modifying stock body configurations. Production front-drive cars invariably use the same size tires at both ends – partly for practicality, partly to provide for the occasional heavy load in the rear. Road-racing and oval-track front-drive cars consequently use equal-size tires all around, although big fronts and little rears are seen in drag racing.

We are also usually required to keep most of the stock body/frame structure and suspension, and prohibited from moving the engine. Our control of front/rear weight distribution is then limited to moving minor components, and placing ballast if we run any. To the extent that we can choose our CG location, the principles we want to follow with front wheel drive are these:

- If the track has high-speed turns; if a large portion of the lap is spent cornering; if grip is ample; if power is modest – try to move weight rearward.
- If the track has slow turns followed by straightaways; if a small portion of the lap is spent cornering; if grip is modest; if power is ample – try to move weight forward.
- For drag racing, standing starts, or hill climbing, try to move weight forward.
- If braking is especially important, try to move weight rearward.
- In all cases, try to place weight as low in the car as possible.

Regarding suspension setup, we are forced to work around the fact that the front wheels limit the car. If the car were not nose-heavy, it might make sense to give the front and rear suspension systems similar roll resistance, and try to work all four tires. A front-drive car done this way (if it were possible, which would only occur if we had lots of ballast to work with) would have very poor forward bite. Since a front-drive car is necessarily nose-heavy, it must be set up to work the *front* tires as evenly as possible. That means it must corner with the inside rear tire very lightly loaded or airborne. We trade away lateral grip at the rear to gain more at the front, where we need it.

We also gain drive traction on the inside front wheel. This is important in a front-drive car, because we cannot use limited-slip differentials that lock too firmly or abruptly, unless the driver has great tolerance for steering fight.

It is important to note that once the inside rear wheel is airborne, the rear suspension has contributed all the anti-roll moment it can, and any further roll resistance has to come from the front. Up to the point of rear wheel lift, rear load transfer builds faster than front load transfer. Beyond that point, rear load transfer is 100%, and front load transfer builds rapidly. So does roll angle. So does understeer.

As a general rule, to get a car that has good consistency as grip varies, we want the inside rear wheel to lift just a little in steady-state cornering, when grip is good. If it lifts more than that, we are likely to have a relatively loose car when grip is poor and a much tighter car when grip is good.

Many front-drive cars use MacPherson strut front suspensions. Most of these suspensions, especially when lowered for racing, have camber properties that produce little camber change in ride and substantial camber change in roll. This means we can improve the cornering camber on those overworked front tires by providing ample wheel rates in roll. On the other hand, allowing soft action in ride will not compromise camber control very much at all. This argues for fairly stiff anti-roll bars, even at the front, and relatively soft springs. That is, the front needs to be stiff in roll, and the rear needs to be stiffer yet, by a sufficient amount to make the inside rear wheel lift just a little when grip is good. In the real world, available suspension travel and rules regarding anti-roll bars and their mounting may constrain this approach, but the idea is to get the desired roll stiffness distribution, and do it with bars as much as possible.