

The Mark Ortiz Automotive

# CHASSIS NEWSLETTER

PRESENTED FREE OF CHARGE  
AS A SERVICE TO THE  
MOTORSPORTS COMMUNITY

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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](mailto: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.

## DYNAMICS OF THREE-WHEELERS

*If you were building a three-wheeled vehicle, would you put some roll in the two-wheeled end, or not?*

I am assuming that the questioner is asking whether there should be some roll compliance at the wide end, or whether the suspension should be essentially rigid in roll.

This is a reasonable question because, at least at low speed, a three-wheeler doesn't need suspension to keep all its wheels on the ground. Because any three points invariably lie in a common plane, a tricycle can trundle over very uneven ground at low speed with very little load change at the wheels, and without picking up a wheel, even if the entire chassis is rigid.

This fact led many of the earliest designers of motor vehicles to adopt tricycle layouts. Among these vehicles was the very first self-propelled off-rail vehicle, the Cugnot steam tractor of the 1760's (or 1771, if we go by the still-existing second model). Carl Benz's first gasoline buggy, in 1885, was also three-wheeled.

The trike layout was not universal, however, even in the early days. Benz's gasoline buggy was preceded by two models of internal-combustion, gasoline-fueled (or more accurately, benzene-fueled) cars built by Siegfried Marcus in 1865 and 1874. I don't know what the first of these looked like, but the second model, of which three were built, had four wheels. In 1879, George Selden applied for a US patent on the automobile. The model he submitted to the patent office had four wheels. It also had unitized body/frame construction and front wheel drive!

By the time automobiles became common, a wagon-style four-wheel layout had become the norm. This is not surprising, because this layout provides the best resistance to roll and pitch available within an envelope defined by a maximum length and width. Despite this, the tricycle layout has refused to die out completely.

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The primary reason people have kept building trikes is economic. In most of the world, trikes are licensed and taxed as motorcycles rather than cars. Where cars are heavily taxed, this gives the trike a substantial price advantage. A secondary reason is that a trike can be made very light. Due to the aforementioned fact that a trike's tire contact patches always lie in a common plane, the vehicle's frame does not see the torsional loadings that a four-wheeler's does. Consequently, it can be built considerably lighter.

The tricycle layout brings problems, however. The main problem is poorer resistance to rollover. A trike can tip over by rolling about a line connecting the contact patches of the outer tire at the wide end and the single tire at the narrow end. For a given wheelbase and track, the vehicle's center of mass will unavoidably be closer to this line in plan view than it would be to a line connecting the front and rear outer-tire contact patches on a four-wheeler. Strictly speaking, the tipping motion we refer to here is not pure roll, but a combination of roll and pitch. Still, regardless of what we call the motion, the vehicle is limited by the easiest way it can tip.

The key to minimizing this problem is to put the c.g. toward the wide end as far as we can. If the single wheel is at the front, we need a rear-engine layout, similar to the VW-engined tricycles that are still fairly common in the US. If the single wheel is in the rear, we need a front engine, as in a Morgan trike. It is important to assure that the operator does not place any heavy cargo toward the narrow end.

It is best to drive the two wheels at the wide end, rather than the single wheel at the narrow end. Not only does this provide much better traction, but it further concentrates the masses at the wide end.

One problem we encounter when the c.g. is toward one end of the vehicle is that in hard longitudinal acceleration, the single wheel may lift, or become so lightly loaded as to impair directional stability. In a front-engine trike, the rear wheel will tend to lift in braking. In a rear-engine trike, the vehicle will tend to wheelstand under power. We can minimize this problem, and improve rollover stability, by making the wheelbase long, and by getting the c.g. as low as we can.

When choosing between the rear-engined and front-engined approaches, there is a safety advantage to the front-engine, front-drive layout. It has its best rollover resistance when decelerating, whereas the rear-engine, rear-drive layout is most likely to flip when the driver tries to lose speed upon entering a turn too fast. The front-engine, front-drive layout also provides much better crosswind stability.

Returning to the original question, what sort of characteristics should the suspension have at the wide end? First of all, it should not have large jacking forces. Either it should be an independent layout with a low roll center, or it should be a beam axle layout.

Particularly with an independent suspension, the wheel rate in roll needs to be substantial, but it should not approach infinity. If there is too much wheel rate in roll, the vehicle will see large roll accelerations, and large wheel load changes, when traversing one-wheel bumps at speed.

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Barring a great increase in the popularity of trikes, we are unlikely to see a class for them in racing, except vintage racing where one does see Morgans and their contemporaries. We do, however, have racing for sidecar rigs. These are normally constrained by the rules to have two wheels in line, with the rear one driven, and a third wheel to one side. This is not the way to design a three-wheeler if we have a free hand, but it retains the connection to a roadgoing motorcycle with sidecar, and it provides thrilling, if dangerous, racing.

To optimize the sidecar layout, the wheels should again be spread as far in all directions as the rules will allow. The heavy side should, if possible, be toward the predominant turn direction. The c.g. should be away from the two-wheeled side, and fairly close to the single wheel in the fore-and-aft direction.

Even when all of this is carefully attended to, there will be no substitute for a good “monkey” or passenger, and the best possible helmet and leathers.