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.

BEAM AXLE PROS AND CONS

You mentioned in your latest newsletter [June 2006 issue] *that a beam axle recovers camber in roll (pretty much all of it) but that the usual case for an independent front end is that camber is not recovered in roll at all. So, why not put a beam axle at the front of the Morgan? I know that there is a possibility of tramp and shimmy but surely these can be avoided with appropriate engineering. Most trucks have beam axle front ends as did the Indy roadsters. There do not appear to be shimmy and tramp troubles with those vehicles.*

A while back a friend (ex-chief of Ford New Product Development) of mine told me about a '48 Zephyr he had. This had a beam axle front end. He reckoned there was no shimmy trouble at all. This was due to the transverse leaf spring system which put the attachment points of the spring well outboard. The GM cars of the time had longitudinal leaf springs which were located some distance inboard, in order to provide reasonable lock for the front wheels. They had terrible problems with shimmy and tramp. He surmises that, due to the advantageous outboard positioning of the spring attachment to the axle, in the Ford the spring had better control of the axle. Hence no shimmy or tramp.
He also thinks that the geometry of the shackles had a beneficial effect during cornering as well. When the car negotiated a corner on the tension side the shackle would rotate to form a straight line with the spring while on the compression side the shackle would move more upright. How this worked probably needs some further consideration and thought...

I've searched the literature for any information or papers about the Ford transverse leaf spring front beam axle but without luck. There is plenty about the GM or conventional longitudinal leaf spring and all its woes.

Surely people must have been aware that the transverse spring with its outboard mounting on the axle was far less susceptible to the troubles that plagued the conventional system. The fact that Indy roadsters employed a torsion bar system with outboard pickup points for the lever arms suggests it was known that outboard actuation had a beneficial effect controlling the axle *to prevent shimmy and tramp etc. I have not been able to locate anything that records or documents this knowledge in the literature though.*

Are you aware of anything written up about this? Is there any technical information with a mathematical or even a descriptive treatment of the outboard or transverse spring front beam axle?

I understand from the Milliken book about Olley that front IRS was used to replace the front beam primarily for the purpose of eliminating steering kick, shimmy and tramp. It's likely Ford followed suit for marketing and competitive reasons but they didn't need to as their axle was already under good control. So, it may well be that a modern road car (sedan) could benefit from the fitting of a front beam axle since that suspension would keep more tyre on road in most situations. Since the COG tends to be relatively high for such road cars (compared to a race car) and since it is usually not possible to arrange for enough anti-roll stiffness (without wrecking the ride and mechanical grip) surely there is a case for the re-introduction of the front beam.

Have you any comments on front beam axles for race cars as well as the potential for application to modern road cars?

I doubt that the earlier questioner is up for the kind of major surgery and engineering involved in converting an existing car to a different style of suspension. Street rodders do this, of course, but usually only in the course of a comprehensive frame-off rebuild involving many other modifications.

Regardless, it is definitely interesting to explore the pros, cons, and possibilities of beam axles, and to try to understand what is involved in optimizing them.

I have never driven one of the early GM cars with the beam axle front end, but I have driven a few cars and more trucks with beam axle front ends, and although at times you can feel the axle gallumphing around down there, shimmy and tramp are not common problems. This is true even with parallel leaf springs.

Many trucks nowadays have power steering, which tends to damp out vibrations, but I drove one Class 8 (big) truck a few times that had no power steering, parallel leaf springs, and, I'm pretty sure, no damping aside from inter-leaf friction in the springs. The steering was really heavy, but it didn't shake. It gave you a workout, but it didn't beat you up.

I Googled <"wheel tramp" or "shimmy"> just to see what would come up. Four pages into the search, I had seen a lot of mention of wheel imbalances and worn parts as causes, but absolutely no mention of beam axles as a cause, nor of greater susceptibility in beam axles. There was plenty of mention of independently-suspended cars having shakes in the front wheels.

It may be useful to briefly discuss exactly what we mean by the terms tramp and shimmy. Tramp means a linear up-and-down oscillation of the wheel: basically, the wheel hopping up and down. Shimmy means an angular oscillation of the wheel about the vertical axis (in the yaw or toe direction) and/or the horizontal axis (in the roll or camber direction).

I have read in chassis books explanations of a theory of a combined tramp and shimmy effect in beam axles which relates to gyroscopic precession on a one-wheel bump causing the wheels to want to steer in the direction that the axle tilts, while tire scrub is trying to steer them the opposite way, and somehow all of this gets into a self-exciting feedback loop and the steering shakes like crazy. Oddly, in all the beam axle vehicles I've driven, I've never seen this happen.

I have also read that steering shake didn't become a problem until people started putting front brakes on cars. This apparently caused problems for two reasons. One was that the torque from the front brakes would cause wrap-up of the parallel leaf springs. This would cause the caster to diminish under braking, or even go negative, and this would cause a loss of self-centering in the steering, reducing forces that try to hold the wheels straight or even creating forces that try to pull the wheels away from straight. Additionally, the axle could oscillate rotationally on the springs (springs cyclically wrapping and unwrapping). With a longitudinal drag link, this could also cause the wheels to steer back and forth as the axle rotated, creating all sorts of playful behavior. Height of the drag link, relative to the axle's center of rotation, would have a big influence on this.

Speaking of drag links, in the old days most of them on parallel-spring front ends didn't move in arcs that agreed very well with the motion of the axle, at least for large motions. The springs generally had single pivots in front and shackles in back, so the axle roughly moved in an arc about a point in front of the axle, while the drag link pivoted about a point behind the axle. Modern parallel-spring suspensions on trucks often have the steering box ahead of the axle, and the motions of the drag link and axle agree much better.

The Ford layout of the early '30's was better than the conventional layout of the time in this regard, and would have had less bump steer. Actually, there were two Ford steering layouts. Later models had transverse drag links. The Zephyr would have been one of those.

The Fords also reacted brake torque through radius rods rather than leaf springs. Although the radius rods were fairly thin in section, they were a lot more rigid than a leaf spring.

The other thing that changed when front brakes were added was that the unsprung mass natural frequency in roll greatly decreased. We are considering the frequency at which the axle assembly will oscillate resonantly, in a mode where one wheel moves up as the other moves down – that is, a two-wheel, 180-degree out-of-phase tramp. Other things being equal, this frequency goes down dramatically as we add mass at the outboard ends of the axle. As the frequency goes down, there is increased likelihood that road irregularities will excite the system at or near its natural frequency and cause a resonant oscillation.

Because of this, early front brakes were often smaller than the rears, to keep them lighter, and also to reduce the torque the front springs would have to react. However, it became apparent that for shortest braking distances, the front brakes should be not only as powerful as the rears, but at least twice as powerful. So the front brakes grew, and with them the antics of the front axles.

The questioner brings up the attendant issue of what is sometimes called spring base: how far outboard on the axle the springs act. If the springs act further out, the wheel rate in roll increases, and so does the natural frequency in roll, for both the sprung and unsprung masses. Assuming no anti-roll bar, the wheel rate in roll, and the angular anti-roll rate, increase with the square of spring base. The sprung and unsprung mass natural frequencies in roll increase with the square root of the wheel rate in roll, or the angular anti-roll rate. So the natural frequencies in the roll mode are directly proportional to the spring base.

It is also possible to raise the wheel rate in roll by adding an anti-roll bar. This can help a car with the springs set close together. I don't know when the first anti-roll bar was used or patented, but their widespread adoption coincided with the widespread adoption of independent suspension, and people didn't start using them on beam axles until later.

Incidentally, I have read one or two authors who say that anti-roll bars are unsuitable for beam axles. That is not so. Anti-roll bars may be less necessary with beam axles than with independent suspension because of the usually ample geometric anti-roll of a beam axle, but they do exactly the same thing in a beam axle suspension as they do in an independent suspension, and can be very useful.

Not only does it matter how far apart the springs are, but also how far apart the shocks are. Most dampers in 1930 were lever-action designs. Many were still friction shocks. Some were relatively crude hydraulics. In the Fords, the shocks were mounted with the levers extending transversely, outboard from the frame, so that they acted further out on the axle than in most of the parallel-spring designs. In a traditional parallel-spring design, the shock levers extend longitudinally, parallel to the springs and frame rails, and the shocks act on the axle near the spring mounting points. This results in a system that is not only comparatively lightly sprung in roll, but also lightly damped.

This is particularly true with dampers like the early hydraulic shocks, which were more or less fixed-orifice dampers and therefore steeply progressive. To prevent excessive harshness at high velocities, they had to be very soft at low velocities. This resulted in wallowy vehicles, and poor wheel control over low-amplitude disturbances. And with the shocks mounted well inboard, even a fairly large disturbance at the wheel looks small to the shock.

Consequently, if you were a passenger car manufacturer around 1930, seeking shorter stopping distances with large front brakes, and seeking less impact harshness by replacing friction shocks with the early hydraulics, you would end up producing front suspensions that were prone to 180-degree out-of-phase tramp. If this weren't bad enough, any attempt to improve ride by using softer springs would worsen every problem we've discussed so far.

Another factor in this would have been the roads of the day. In 1930, most roads in the US were still dirt or gravel. Until the discovery and development of the oil fields in Texas in the 1920's, asphalt was expensive. Even after it became cheaper, it took time to lay the acres of pavement we drive on today.

Dirt and gravel roads are prone to washboarding: they develop regular ripples that coincide with the unsprung mass natural frequencies of the vehicles that run on them. Nowadays, we mostly see in-phase ripples that excite rear axles in the ride mode. However, in an era where front axles were prone to excitation in the roll mode, we would have had out-of-phase ripples developing that would create resonant oscillation in that mode. I wasn't around then, but this would seem a logical expectation.

This would at least partially explain why we aren't seeing today the tramp and shimmy problems in beam axles that Olley and his associates faced.

One of the big reasons Ford abandoned beam axles was packaging. If we want to build the car low, and if we want to place any portion of the engine in the plane of the front wheel axis, we have a problem finding room for a beam axle under the engine. Since the axle has to move up and down, it needs more space than the frame crossmember we have under the engine in an independent suspension layout. If Ford had retained the beam axle, the '49 Ford would have had to be a much taller car, or a considerably longer one.

Packaging remains a dominant issue in passenger car suspension design. If a suspension will give at least decent dynamic properties, and it saves room, it is attractive for a passenger vehicle. This is a big factor in the continuing popularity of strut suspension. Any rival concept must be competitive in terms of space-saving, even if it offers superior dynamics.

For race cars, I think beam axles offer interesting possibilities. The UNC Charlotte team, which I have been advising, has considered beam axles in the past, and is taking a fresh look at them for 2007. In many classes of racing, the choice of beam axle or independent is made for us by the rules. Even where the rules do not explicitly dictate the choice, packaging considerations may virtually dictate independent suspension at one end of the car. In that case, we may want independent suspension at the other end, merely to maintain similar properties at both ends of the car.