The Mark Ortiz Automotive

CHASSIS NEWSLETTER

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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: markortizauto@windstream.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

SELECTING REAR END RATIO

I have a 1966 Mustang Fastback that I have been working on for several years now with the goal of having my favorite vintage muscle car that I can enjoy performance driving through the remote winding/hilly roads throughout the NW Arkansas area as well as to take to a road track (Hallett Motor Racing Circuit - 1.8 mile track) near where I live. At some point down the road I may decide to travel to some other road racing tracks as well and who knows may make the necessary preparations to run in some Vintage Mustang events, but for now I just run in the Open Tracking events at the Hallet Motor Racing Circuit that they call their High Speed Touring Series. I have just in the past few months installed a new engine in my Mustang which has really allowed me to start pushing my car more towards its limits, and in my search to try to optimize performance have noticed that my power band with my current rear gear ratio which is 3.25:1 is not quite where I would like for it to be. I was wondering if you could provide me with a little advice in regards to which gear ratio you would recommend I install in my Mustang to meet my performance desires in the way that I utilize my car as a "pro touring" type for performance street driving through the remote roads of NW Arkansas and also for attempting to push it to the limits at the road course tracks which is my real passion. The following is some additional information about my Mustang:

I currently have the complete Total Control Products (TCP) front suspension system with power rack & pinion and coil overs with dual adjustable shocks, triangulated shock tower supports and full sub-frame cross member assembly system. My rear suspension contains Maier Racing - Race 165 leaf springs and their Panhard rod system. I have a Top Loader 4-speed (1:1 in 4th gear) transmission, a 3 1/2" aluminum drive shaft with 1350 tail shaft and pinion yokes, and a Currie 9" Ford rearend with 3.25 gears, 31 spline axles and TSD (torque sensing) limited slip differential. I am currently running Yokohama 235-45-ZR17 tires mounted on American Racing Torque Thrust II 17 x 8 wheels. My engine is a 351W block stroked to 427 cu.in. displacement producing ~ 530 hp at flywheel, which as mentioned has only been in the car a few months.

I am thinking that I could improve performance by changing my rear gear ratio to either a 3.50 or 3.70 and this is where I could sure use your advice. I have good power with my new engine, but with the 3.25 gears I seem to be lacking some in low end transfer of power to the wheels. I have plenty of top end speed and the benefit of lower rpm's at those higher speeds, but I would like to be able to get to those upper speeds quicker and thus the reason I feel that I need to change the gear ratio. I have calculated my top end speeds using my current tire diameter, my transmission in 4th gear being a 1:1 ratio and top engine speed of 6500 rpm's to be the following for the different rear gear ratios:

Gear Ratio	*Top Speed*
3.25	*150 mph*
3.50	*140 mph*
3.55	*138 mph*
3.70	*132 mph*

The top end speed of 132 mph with the 3.70 gear is just a little bit lower than I would really like, but realize it would give me more lower end power transfer to the wheels. The fastest speed that I have actually had my car up to so far is 135 mph on the longest straight stretch at the local road course track (and I have to admit a few times on about a ½ mile straight stretch of isolated/remote road near my rural home where there are no access roads, houses, businesses, etc.). The winding roads that I normally drive are through remote areas of the Ozark National Forest which is like a 100 mile long road course but doesn't have very many straight stretches with the longest being around a 1/4 mile or so in length. I am fortunate to be able to push my car pretty hard through this area as there is almost never any traffic and no houses, businesses, etc. So as you can see, currently most of my driving is performance street driving through the remote winding/hilly roads of NW Arkansas along with the Open Track (lap timed) road course racing which as mentioned is my real passion.

If I had a 5-speed or some type of overdrive for my current transmission I think it would be more of a no-brainer for me to go with a 3.70 or perhaps even higher gear ratio but with the 1:1 ratio of the 4-speed I just don't have enough experience to know if the 3.70 would meet my needs as described or not.

You don't mention the transmission ratios, other than top being direct. I assume you have the close-ratio version of the transmission, which has third gear of 1.29, second of 1.69, and first of 2.32.

Ignoring frictional losses in the indirect gears, what matters for acceleration is the product of the rear end ratio and the transmission ratio for the gear you're in. This product determines the torque multiplication from the engine to the wheels.

With a shorter rear end ratio (numerically higher, as conventionally expressed), you will have more torque multiplication in a given gear. However, you will also have a lower top speed in that gear, so at certain road speeds you will actually have less torque multiplication overall because you will have to be in a higher transmission gear.

In general, the car will be fastest on a given track if geared so you just barely run out of revs at the end of the longest straight. From the information above, that would suggest trying the 3.50 or the 3.55. Hopefully, if you do improve your acceleration, that will translate to a bit more speed at the end of that straight, and you would rather not have to lift prematurely to avoid overrevving.

At lesser speeds, you may or may not be faster with a shorter rear gear, depending on whether you are forced to upshift. In many cars, there is an advantage to being higher in the gears, because the ratios get closer as we go up. With the 2.32, 1.69, and 1.29 ratios, there isn't much such effect: the spreads are 1.37 from first to second, 1.31 from second to third, and 1.29 from third to fourth. You're not getting significantly closer ratios by being higher up in the box.

Based on the calculated top speeds in high given above, with the current 3.25 rear, you have top speeds in the indirect gears of 65, 89, and 116mph. With the 3.50, those change to 60, 83, and 109.

So, assuming of course that the car is power-limited and not traction-limited, based purely on torque multiplication: with the 3.50 you'd accelerate about 8% quicker from zero to 60mph, from 65 to 83, and from 116 to 140. However, you'd also accelerate about 22% slower (78% as fast) from 60 to 65, 18% slower (82% as fast) from 83 to 89, and 17% slower (83% as fast) from 109 to 116, because in those ranges you have to be in the next gear up.

All of this is based on a simplifying assumption that the car makes equal torque at all rpm's, which of course is not the case. But as long as you're not much past the power peak, it does basically hold true that the car accelerates faster with the shorter rear end gear, except where that gear forces you to upshift and the taller one doesn't.

TORQUE TUBE FOR FRONT-ENGINE IRS CAR

I wonder if you could consider answering this question on the reasons makers use torque tubes please?

Car in mind is a Mazda RX-7 FD model of mid nineties. They run what Mazda term a "Power Plant Frame" which is a lightweight pressed steel frame tying the gearbox extension housing to the front of the differential casing. The car has independent rear suspension by double wishbones. Why would a maker choose this means of locating the rear of the gearbox and the nose of the diff instead of using a gearbox X member and supporting the diff nose of the rar subframe? Some quite low end Opels used a torque tube, as did some of the bigger Peugeots like the old RWD 504. If one were to fabricate conventional mounts for the diff nose using a weld in multi point roll cage to tie the shell *together more rigidly, and did something similar with a different but similarly sited gearbox (thinking engine and box change to something with pistons for circuit race usage), what disadvantages can you think of, handling wise? Any? My personal take on this is that it may have been instigated to allow compliant diff mounting to reduce NVH, yet control unwanted diff nose movement to control drive train wind up and wheel hop. I can't find much on the pros and cons of this setup.*

There are basically two reasons for tying vibration-isolated components together with subframes. The first is to allow soft mounts for good isolation, without incurring undue movement of the individual isolated components. The second is to unite the isolated components as one large mass, which can then be used to achieve a measure of inertia damping by tuning the natural frequency of this mass to interfere with the natural frequencies of the sprung structure as a whole.

In the case of a torque tube or similar structure tying a front engine and transmission to a sprung differential, not only do we suppress side-view windup of the diff in response to axle torque, we also create a structure that resists front-view rotation of the engine and diff relative to each other due to driveshaft torque – the same torque that creates torque roll and torque wedge when the diff is unsprung. This relieves the frame or unibody of the need to resist this torque.

In most cases, there is a penalty in space efficiency and weight efficiency for using subframes, although to some extent this can be recovered in the main structure by either eliminating loadings as just described, or at least spreading loadings among a smaller number of more widely separated points.

When the suspension is softly damped, in pursuit of soft ride, inertial damping from major isolated components can actually help handling as well as ride, as least in terms of the car's behavior on irregular surfaces. But in race cars, we normally use stiffer shocks, which make all tuning of natural frequencies less important, and we want light weight and a stiff overall structure much more than good NVH characteristics.

Therefore, traditionally, we build race cars with little or no isolation of the engine, trans, and diff. We solid-mount everything, try to get some structural stiffness gain from the components, and deal with any NVH issues by having a loud exhaust and wearing earplugs. If the shocks are stiff enough for good handling, there won't be much oscillatory behavior from the suspension.

However, in recent years race car designers have taken a fresh look at inertia damping, as readers will know who have followed inertia damping's recent introduction, and prohibition, in F1. The reason for the renewed interest in inertia damping is that modern high-downforce race cars have such stiff springing that tire deflection becomes a very significant portion of the total "suspension" compliance: the tires deflect anywhere from half as much to just as much as the suspension proper.

The tire deflection does not displace the shock absorbers, so the shocks can't damp it. There is some internal damping in a tire, but nowhere near as much as we'd like. A very stiffly sprung car can bounce or pitch on the tires much like a tractor (although with smaller amplitude and higher frequency), and the shocks can't suppress this – hence the interest in inertia damping.

So if the car is going to have ground effects and wings, and very stiff suspension, there could be a case for trying to use compliant mounting to get some inertia damping. This could involve using a torque tube, or not. It is common practice in live-axle passenger cars to use the engine/trans assembly for inertial damping, without a torque tube. It would be quite possible to do that in a race car with a sprung diff, and solid-mount the diff. The only downside would be that the engine/trans assembly will undergo rotational displacement on its mounts when it applies torque to the propshaft, and all packaging, plumbing, wiring, and linkages will have to accommodate that movement. This can be mitigated somewhat by wide spacing of the motor mounts.

It should be mentioned that we don't necessarily get inertia damping from compliant mounting of a major mass. If the frequency is not tailored to the tire and suspension frequencies, it is quite possible to get reinforcement of suspension and tire oscillation, rather than interference. So this would not be something to be undertaken lightly. For most of us, the most prudent recommendation is still to go for rigidity, lightness, and simplicity, and solid-mount everything.