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: 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.

February 2003

SHOCK RESEARCH UPDATE

Last month I announced that I am undertaking a project to explore sensitivity of suspension dampers to acceleration, jerk, and perhaps other factors. I am still looking for shocks to test, particularly groups of two or more shocks that produce similar results in typical crank dyno tests but act different on-track.

I do have some preliminary feedback. One shock company tested one of their dampers at the usual 2" stroke and 100 cpm (5/3 Hz), then at 1" stroke and 200 cpm (10/3 Hz). These two tests produce equal ranges of velocity, but at any velocity the second test produces 2 times the acceleration and 4 times the jerk (change of acceleration). In this case, the forces were identical in both tests, within the window of accuracy attainable. This doesn't mean the test was a failure. It means that the shock tested is insensitive to acceleration and jerk, at least at the values tested.

I think it is quite possible that many shocks are acceleration-insensitive. My object is to devise ways of systematically testing to find out, and also to find out whether acceleration sensitivity can be a performance advantage if used correctly.

The shock dyno company I'm working with at this point, Performance Data Systems, also tested two shocks that were provided to them by a different shock company, which were identical except for gas pressure. PDS has a unique dyno design that allows unusually precise motion control, and will follow almost any desired motion pattern, since it uses a linear motor rather than a crank. One test this dyno can do is a step test: the shock is rapidly accelerated to one velocity, held at that velocity for a given distance, then accelerated abruptly to a higher constant velocity, held at that velocity for a specified distance, and so on.

The acceleration zones between one step and the next can be programmed to have defined limiting values for acceleration and jerk. The machine can also be programmed to reach a particular peak acceleration with either maximum jerk at the ends of the acceleration zone, or minimum jerk for a desired mid-zone acceleration, within a specified acceleration time between velocity steps. If jerk is set at maximum, then jerk is zero in the middle of the acceleration zone. If jerk is set at minimum, then peak jerk is much less, but there is still a non-zero jerk value in the middle of the acceleration zone. This means that this test can produce points where both velocity and acceleration are the same, but jerk is either zero or some known value. This allows isolation of jerk effects from acceleration effects, which is not possible in sinusoidal testing. Alternatively, a shock can be tested at different known accelerations, with identical velocities, and zero jerk. This allows isolation of acceleration sensitivity from both velocity and jerk effects.

In the test of the similar shocks with differing gas pressures, PDS reports that varying accelerations did not produce different forces at mid-acceleration, but varying jerk values did produce differing forces. And the difference was greater in one shock than in the other. In other words, the shocks appeared to be jerk-sensitive without being acceleration-sensitive, and the jerk sensitivity appeared to vary with gas pressure.

Stock car teams are reporting that shocks with a given piston and shim package definitely feel softer to the driver when gas pressure is reduced.

Some caveats here: I was not present at the tests I am describing. I am relying on the accounts of others. Also, we are not looking at results of an exhaustive, systematic testing program. What we do have is preliminary, anecdotal evidence that suggests there are effects worth measuring and exploring through unconventional damper testing.

MORE ON REAR WHEEL PLACEMENT AND TRACTION

Simon McBeath, whose comments regarding rear wheel placement and its effects on traction prompted my remarks in the October 2002 newsletter, writes:

Question:

I've just been catching up on some overdue reading and noticed in your October newsletter that you picked up my suggestion for a discussion on the above. Many thanks a) for doing that and b) for reading the feature (on the DJ Firehawk hillclimber) where the suggestion was placed!

I read what you had to say in your newletter with great interest. But is there also another mechanism at work with swung back rear suspension? The Firehawk's designer mentioned to me something I was very unclear about, and hence did not go into in the article, but it involved the suggestion of gyroscopic effects aiding traction, and it was in *reference to buggy racing. Have you heard of this effect being exploited this way? I couldn't figure how that would work, to be honest.*

I tried an experiment in the workshop with a hand held grinder, angled back, as it were, as if the grinder's disc was a wheel swung back on its suspension, and as you move such a tool around up and down you can feel gyroscopic forces, but when the tool is held still (but powered up) there are no sensations or reactive forces.

But when you first power the tool up there is, obviously, a reaction force. I wondered if this instantaneous response could be usefully exploited for improved traction - to add to the weight transfer under acceleration and make the tyre dig in harder, initially at any rate. I have a feeling as I type this that what you might gain on one side of the car you'd lose on the other, but I can't figure it out in the middle of a Sunday afternoon! Any thoughts would help still my curiosity and soothe my confused brain!

Answer:

What you're feeling when you turn the grinder on is mainly the grinding wheel acting as a flywheel, not a gyro. The body of the grinder is more analogous to an axle housing than a semi-trailing arm in a buggy rear suspension, because drive torque reacts through the grinder body. The arm on the buggy only reacts thrust under power. Drive torque reacts through the powertrain mounts, and does not act through the suspension.

Wheels on a car do produce gyroscopic forces, but only when their toe or steer angle changes, or their camber angle changes. Rotational acceleration or velocity about the wheel's main axis (axle axis) does not produce gyroscopic forces. When we steer the wheel to the left, it tries to lean to the right. When we lean the wheel to the left, it tries to steer to the left. These effects are called gyroscopic precession.

The precession force depends on the wheel's angular velocity in the plane perpendicular to the force. That is, when the wheel steers left, the magnitude of the rightward camber-wise or roll torque about the wheel-longitudinal axis depends on the wheel's velocity (not acceleration, not position) about the vertical axis. The wheel's rotational speed on its axle also matters. More rpm, more precession force; wheel not rotating, no precession. Lastly, the wheel's moment of inertia about the axle axis matters. More flywheel effect, more precession force.

In a motorcycle or bicycle, precession forces are an important factor in vehicle behavior. We use them to hold the vehicle upright, and to steer it. But in a tricycle or a car, we just live with these forces; we don't harness them. If anything, they're a problem, because they are part of the reason for shimmy in steering systems.

With the grinder, you are holding the device by the body, which is not quite in the same plane as the disc. Consequently, the grinder may try to move in a complex manner when you power it up. It may try to tilt the disc as well as rotate the body about the spindle axis. If the disc tilts, then there will be some gyroscopic precession.

In any case, gyroscopic precession does not increase traction.

As for transient (short-lived) forces that try to lift the car momentarily increasing traction, that's possible. However, the brief traction improvement is followed by a corresponding unloading of the wheel a fraction of a second later. What counts for this is the vertical acceleration (not position, not velocity) of the sprung mass (F = ma). The sprung mass is lifted a bit, but only to a point. So its velocity upward increases to some value, and then decreases to zero again. That means its acceleration is first upward, and then downward. When the sprung mass acceleration is upward, there is a wheel load increase. When the sprung mass acceleration is downward, there is a wheel load decrease.

It's probably better for traction not to have such an effect. In certain instances, the driver may be able to time the momentary traction increase to occur when it's most needed, but in general the car is limited by its instants of poorest traction, rather than its instants of greatest traction. Therefore, we would like the wheel loads to vary as little as possible.

There is also another effect when the car is being carried in a lifted position: the center of gravity is higher, and that increases rearward load transfer. So anti-squat does improve traction, but not as much as many people imagine.

Now, if you move the rear wheels back on a buggy, what happens to the anti-squat, and other properties? The answer depends on what type of rear suspension the car has, and exactly what you change to move the wheels back. Traditionally, buggies have semi-trailing-arm rear suspension, derived from the design on late VW beetles. However, this is not always the case any more.

Assuming we have semi-trailing arms, there are a number of ways the wheelbase could be lengthened, and the various methods have different effects on the rear suspension geometry. Probably the simplest method, on an existing car, would be to merely fit longer arms, without modifying the frame. If we do this, we get the following effects:

1. The static rear percentage decreases. As previously noted, this hurts traction.
2. The static anti-squat diminishes, assuming the trailing arm slopes up toward the front.
3. Changes in anti-squat with suspension motion are reduced, because of the longer side-view swing arm.
4. Changes in camber over bumps are reduced, due to the longer front-view (rear-view, end-view) swing arm. Also, there is less bump steer.
5. The rear roll center is lower.
6. In all likelihood, the suspension will be softer with a given spring and shock package, due to a decreased spring-to-wheel motion ratio.

The last five of these effects could all improve traction, especially while cornering, and on bumpy surfaces. This might account for perceived or reported improvements. Note, however, that all of these effects could also be achieved by moving the pickup points forward, and leaving the wheel location unchanged. That would probably involve redesigning the frame, of course. And a better approach yet is to forget about using semi-trailing arms altogether, and build a proper five-link, or short-and-long-arm, suspension.

If we do that, we can have any rear geometry we want, with any wheel location, and we can have much less variation in anti-squat than with any semi-trailing arm system. And any arguments for moving the wheels back that might apply with semi-trailing arms become irrelevant.