February 2002

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.

WINSTON CUP HARNESS INSTALLATION

NASCAR has announced that they are now going to require that safety harnesses be installed according to the harness manufacturer's instructions. Harness manufacturers, without exception, recommend that lap belts go downward or slightly rearward to their anchor points, and that all belts have as short a run as possible, and not be bent around any sharp edges.

As a consequence of my now being a columnist for *Racecar Engineering*, I got to visit Richard Childress Racing as part of the annual UAW-GM media tour. (Actually, Paul Van Valkenburgh was the magazine's designated representative, but he had to go to Atlanta the last day of the tour, so I snagged his seat on the bus.)

The folks at Childress gave us a really nice meal and presentation, after which they formally unveiled their new paint schemes, apparently on new cars. Following that, they let all of us check out the cars up close, and interview the drivers and other personnel.

Late during this period I was looking at Kevin Harvick's car. I noticed that the belts were mounted just like they used to be in Dale Earnhardt's cars: lap belt mounts almost straight back from the seat holes; shoulder harness run over a bar at shoulder height and then another foot and a half or so down to an anchor point around kidney level.

It occurred to me that maybe I was looking at an older show car, used to display the paint scheme. Yet the car appeared new. The lower seatback mount, a square steel tube a bit above the floor, which held the seat in place and carried the lap belt mounts, was unpainted, and definitely appeared to be brand new.

Following Dale Earnhardt's death, the belt mounting issue assumed great significance, and this is of course the reason for the new rule. It was a point of public contention whether the Childress organization had been informed that there was a problem with their belt installation. I don't recall anybody saying that the installation was correct, or superior to the recommended geometry. The only controversy was whether the incorrect installation had been brought to the team's attention. Surely they can't claim ignorance now.

I will be watching the press for mention of this matter in upcoming Daytona coverage. I also invite anybody from RCR who may see my remarks to comment.

THINGS THAT MAKE SPRING CHANGES WORK BACKWARDS, REVISITED

In the August 2001 issue of this newsletter, I pointed out that on oval tracks there is a *critical angle* of track banking for a particular end of a particular car, at which the left side suspension no longer extends as the car rolls. At this banking angle, the car becomes insensitive to left spring changes. Beyond this banking angle, the effect of left spring changes reverses.

It has recently come to my attention that in beam axle suspensions, there will be a range of banking angles within which the left suspension will extend, as measured at the wheel – yet the left spring will compress! This is possible because the spring is inboard of the tire. It is possible that a *node*, or point of zero motion, may exist between the wheel and the spring.

For example, suppose the springs are exactly ½ the track width apart, and suppose that the suspension is in a condition of 1" per wheel of roll (about 2 degrees) and 3/4" of "squash" or ride compression due to track banking. The right wheel then has 1 3/4" of compression, and the left wheel has 1/4" extension. The left *spring*, however, has 1/4" *compression*. The right spring has
1 ¼" compression. A node, or point of zero displacement, exists midway between the left tire center plane and the left spring.

If this is the rear suspension, and the front suspension is an independent system in the same state of roll and ride, we have a situation where stiffening *either* left spring tightens the car (adds understeer). Fortunately, such conditions will mainly be encountered close to the critical angle, where sensitivity to left spring changes is fairly small in any case. It is possible, however, that substantial reverse sensitivity to left spring changes may be encountered when compression at the left rear wheel is small.

For those with good simulation software or data acquisition, questions of whether a spring is compressed or extended from static at a particular point in the lap are more easily resolved. For those of us who rely largely on our butts and our brains, qualitatively understanding physical principles is the only way to make sense of our observations. And even for those with electronic help, qualitative insight is part of making sense of the data.

SOME BASIC SHOCK QUESTIONS

Mark, could you help me understand some things about shocks?

- *What is hysteresis?*
- *What is the difference between force and absolute velocity?*
- *What are they referring to when they talk about compression open, compression closed, rebound open, and rebound closed?*
- *Why does a shock cycle have 4 strokes instead of just one compression and one rebound stroke?*

Webster's defines hysteresis as "a retardation of the effect when forces acting upon a body are changed (as from viscous or internal friction)". Applied to a damper, this means the damping force or work.

Most of us have a pretty good idea what a force is. Webster's definition is "an agency or influence that if applied to a free body results chiefly in acceleration of the body and sometimes in elastic deformation and other effects". In the case of a shock, the force we measure is the force acting at the damper shaft. The force can act in two directions: extension or compression.

Shocks generate two kinds of forces: damping forces and gas spring forces. Gas spring forces are always in the extension direction. Damping forces are always opposite to the direction of motion.

Velocity, in physics and engineering, means the rate *and direction* of position change. With a shock, we have a simple case where motion is either in the extension or the compression direction. We can therefore express a velocity simply as a magnitude (inches or millimeters per second) with a positive or negative sign to denote direction.

The absolute value of a number is the greater of the number and its opposite (or additive inverse). The absolute value of 4 is 4; the absolute value of –4 is also 4. The absolute velocity of a shock shaft is the magnitude of its rate of position change, irrespective of the direction. If the velocity is 5 in/sec in extension, the absolute velocity is 5 in/sec. If the velocity is 5 in/sec in compression, that is also an absolute velocity of 5 in/sec. Absolute velocity is therefore just a fancy way of saying shaft speed.

The earliest shock dynos were purely mechanical devices (except for the electric motor) that generated a plot of force (on the vertical axis) versus position (horizontal axis). The resulting curve would be a loop. Modern dynos can also produce such a plot. Such a loop is sometimes called a *hysteresis loop*. The area enclosed by the loop corresponds to the mechanical work done upon the shock by the dyno during one cycle. This mechanical work in turn corresponds to the watt-hours of electricity used by the dyno to produce the movement, and the heat energy that warms up the shock as we work it.

Modern shock dynos can calculate velocity from position. With most dynos, the shock is worked through a two inch stroke at 100 cycles per minute. This gives a peak velocity at mid-stroke of just over 10 in/sec, and a velocity at any other point in the cycle that can be directly calculated by multiplying the peak velocity by the sine of the crank angle.

The dyno can therefore display force versus velocity, in a number of different formats. The most popular format is force (on the vertical axis) versus absolute velocity (on the horizontal axis). This means that force is displayed as a negative or positive value, but absolute velocity is always positive. The axes take the form of a letter T rotated 90 degrees to the left. The horizontal axis extends across the middle of the screen or page, with zero at the left. The vertical axis runs along the left edge of the screen or page, with zero in the middle.

Force during the extension (rebound) stroke is customarily displayed as negative; force during the compression (bump or jounce) stroke is positive. Note that damping force always acts in opposition to motion, so the compression damping force actually acts in the extension direction, and extension damping force actually acts in the compression direction.

One cycle of the dyno does have just one compression stroke and one extension stroke. But on the type of plot described above, this produces four traces. On the compression stroke, the absolute velocity starts at zero, builds to just over 10 in/sec at mid-stroke, then decreases to zero again at the end of the stroke. Commonly, the absolute velocity scale reads up to ten. Higher values are off the screen or page. So the trace for this stroke starts at the left, runs across the screen or page and off the right edge briefly (at mid-stroke), then comes back to the left and ends at zero. The height of the trace at any given point corresponds to the force at that point in the stroke. A similar process occurs during the extension stroke, generating two more traces, running mostly below the horizontal axis.

During the first half of the compression stroke, the velocity is increasing, so the valves are opening. This is referred to as the compression, opening (not open) phase of the cycle. The second half of the compression stroke is the compression, closing phase. Correspondingly, the first half of the extension stroke is the extension, opening phase, and the second half is the extension, closing phase. Each of these phases corresponds to one of the four traces on the graph.