SHOCK DYNAMOMETER: WHERE THE GRAPHS COME FROM

Damper performance is still voodoo to most racers, and they're scrambling to learn all they can. A shock dynamometer is the newest line item appearing in all test and development budgets. The most serious teams have one at the shop and another one in the trailer. They need a person responsible for the operation of this equipment and the associated computers, so now a lot of big teams have a "shock guy" who's either a full-time employee or an outside consultant who's there at tests and on race weekends.

Dampers produce a force proportional to the speed of shaft movement. If you compress a damper slowly, it generates less resistant force than if you move it faster. As mentioned before, a damper on a race car does several very important things including providing a tunable "feel" for the driver during cornering, controlling wheel travel over road irregularities, and, most important for a ground-effects car, stabilizing the under wing of the car at optimum ride height and rake.

Since dampers are a critical component of a race car, they should be tested periodically to make sure they are working correctly. Also, when a race engineer finds a damper set-up that makes the car faster under certain conditions at a certain racetrack, that engineer will want to have dampers set up the same way the next time the car runs on that or a similar track. As with any critical component, the race engineer would like to know more about how it works. The shock dyno is a tool used to test dampers and learn about their behavior.

What Is a Shock Dyno

The force vs. shaft speed graphs you see in this article come from data generated by testing a damper in what is generally known as a shock dyno or damper dynamometer. This is a machine that compresses and extends a damper at known speeds and measure the forces produced by the damper. I'll start out by describing the simplest form of a shock dyno. Figure 1 shows a frame holding an electric motor with a drive belt and pulleys that spins a crank attached to the damper shaft through a linear bearing. As the motor spins the crank, the damper piston moves up and down just like the piston in a cylinder of an engine. Bolt holes in the crank allow several different stroke lengths. Different pulley diameters or a variable speed motor give different crank rotation speeds. The load cell measures the damper force.

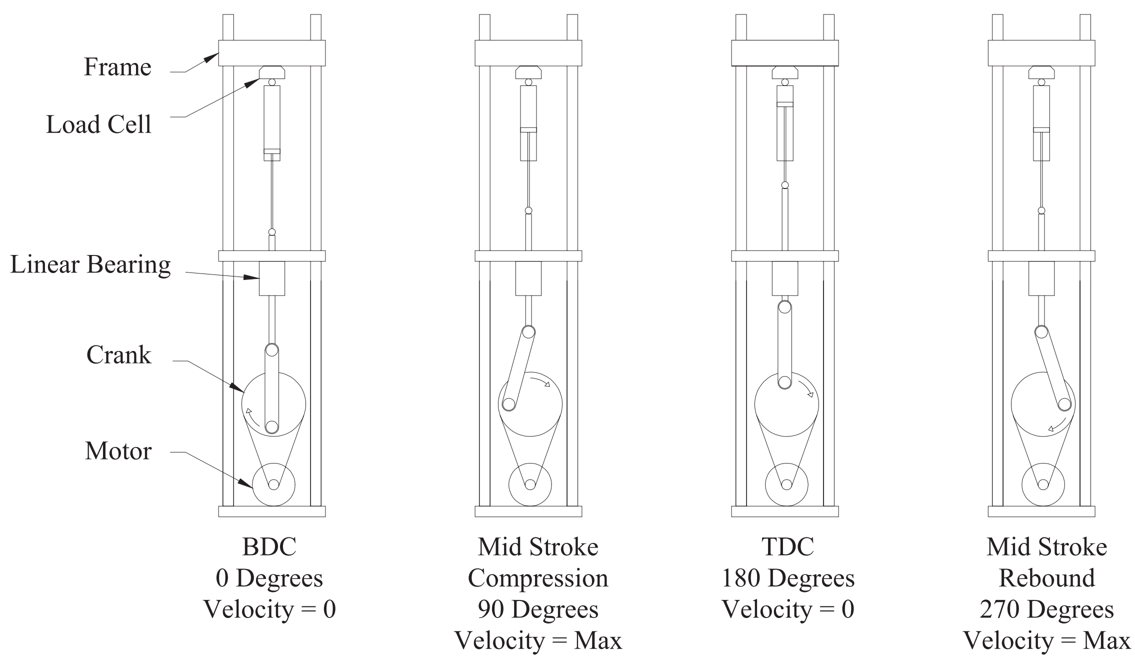

Figure 1

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Shock Dynamometer

We all know that the speed of a piston connected to a crank varies continuously as the crank rotates. You might remember from high school math or physics that this type of motion is called sinusoidal because it varies with the sine of the crank angle. The piston comes to a stop at bottom dead center (BDC), accelerates to a maximum speed halfway up the cylinder, and slows down to a stop again at the top (TDC). If you have a damper attached to a crank, its piston does the same, and the force generated also varies continuously. We know, however, that the maximum speed of the piston happens only once per stroke, when the piston is halfway between top and bottom, and that's also when the damper generates maximum force. With our simple shock dyno we could change the crank stroke to vary the maximum shaft speed and/or we could use drive pulleys of different sizes. However both of these methods are cumbersome and time consuming during testing. Variable speed AC motors allow easy manipulation of the crank RPM.

Here's How It Works

You put a damper in the dyno, choose a stroke and RPM, and turn on the motor. The crank turns and the damper shaft moves up and down until you turn off the motor. If you know the crank RPM, and the stroke, you can calculate the maximum damper shaft speed. For example, let's say the crank turns 100 RPM, and the stroke is I inch. 100 rpm is 1.67 revolutions per second and the length of I revolution is the circumference of the circle traveled by the crank bolt or Pi times the stroke. 1.67 x 3.14 x I inches is about 5 inches per second. This is the maximum speed of the damper piston, and it happens twice each revolution of the crank, once with the piston going up in compression and once again with the piston going down in rebound.

If we keep this example really simple and connect the damper directly to a weighing scale with a circular dial, we can stand there and read the scale pointer directly. What we'll see is the pointer cycling from 0 to some maximum bump force as the shock compresses, returns to 0, and then peaks out again at the max. rebound force as the piston comes back down. The needle on our scale goes from plus some number to minus some number as the damper cycles from compression to rebound and back. We can just write down the numbers at which the needle peaks as it goes back and forth. A commercially available shock dyno uses a computer to read the load cell and store the data.

Some dampers are set up to give more force in rebound than compression so, as our simple machine cranks away; we might see the scale peak at 190 pounds in compression and 250 pounds in rebound. So we know that, at a shaft speed of 5 inches per second, the damper produces 190 pounds in compression (or bump) and 250 pounds in rebound. We'd like several data points so we can draw a curve. If we reduce the crank speed to 50 RPM, and 25 RPM, and also speed it up to 150, and 200 RPM, this gives us five data points. After we make these runs and read the scale we can make a table like this:

CRANK RPM	MAX SPEED IN/SEC	BUMP FORCE LBS	REBOUND FORCE LBS
25	1.3	75	50
50	2.6	170	150
100	5.2	190	250
150	7.8	220	350
200	10.4	250	470

Chart 1

Presented as a force vs. shaft speed graph, it looks like Figure 2. We generated this data by running the crank at a 1.0" stroke and changing the crank RPM to give us 5 maximum piston speeds, and we read the bump and rebound forces at those maximum speeds. Then we made a graph by connecting the dots. If we want data at higher shaft speeds we need to speed up the crank or lengthen the stroke. Figure 2 shows us that the shock we tested has a pretty steep rebound curve while the compression curve starts low, rises quickly, and then levels off.

The real benefit of a machine like this comes when you test all four dampers off your race car and find out that they all give different readings even though they are supposed to have the same valving, and you've, hopefully, set them all to the same external adjustments before you started the test. Some small difference in readings is OK, but the closer together the better. If you've got the tools and experience, you can overhaul your shocks and test them again. Maybe you'll find contaminated oil, bad seals, or worn parts. Shocks wear out like any other mechanism and need to be rebuilt periodically.

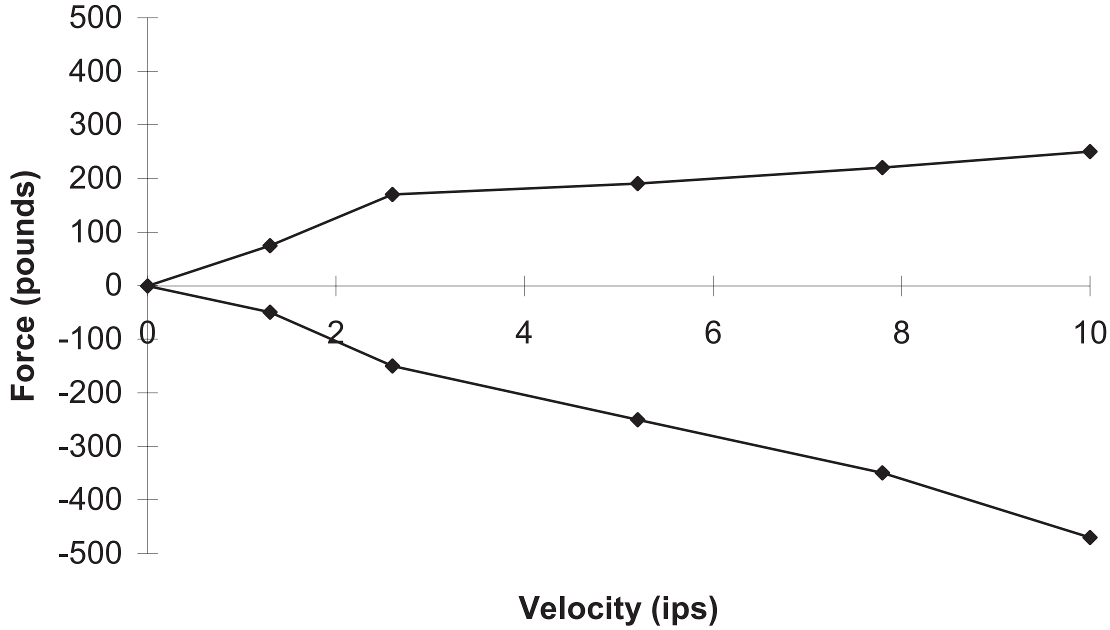

Figure 2

A shock dyno also allows you to see the effects of external adjustments. If the data above represents settings in the middle of the range of adjustments, varying them in increments from full-hard to full-soft will give you curves that show the effect of those changes. That will happen if your dampers produce changes big enough to be seen by your machine. If you really are just reading a scale by eye you might miss some fine points. That's why people buy dynos instead of building them

Figure 2 above came from data generated by looking at maximum or peak velocities. This is called Peak Velocity Pickoff, and that's the way a simple dyno works. We varied crank speed and the damper stroke to give us peak velocities in our range of interest.

Data from an Entire Cycle

You can get more data from a damper by taking data over a complete cycle of compression and rebound and graphing that. This is called a Continuous Velocity Plot, and there are commercially available damper dynamometers that do this. Figure 1 has notations around the crank for Bottom Dead Center (BDC,0 deg.), Top Dead Center (TDC,180 deg.), and 90/270 degrees. When the crank pin is at BDC the damper is fully extended. As the crank rotates clockwise it's compressing the shock in the bump direction so that the damper piston accelerates from a stop to maximum speed at 90 degrees and then slows to a stop again at TDC. Rotation continues and the piston accelerates in rebound direction to maximum speed at 270 degrees and slows to a stop again at BDC.

Figure 3 shows force data taken continuously during one revolution of the crank. Shaft speed in the down direction is positive and compression force is positive. The bottom part of the curve shows shaft speed and negative force increasing as the crank goes from TDC (180 deg.) to 270 degrees and then decreasing as the curve goes back toward zero speed and force at BDC (0 deg.). As rotation continues, speed goes negative (compression) and force increases to a maximum at 90 degrees and back to 0 at TDC (180 deg.). The speed and force data taken to produce a graph like this comes from a velocity sensor and a strain-gauge load cell. A data acquisition system in a personal computer reads these sensors 1,000 times a cycle or more. Software processes the data and displays it in this form.

This can be confusing and you might have to look at this sketch and the graph a while before it becomes clear. The important point is the force increases with piston speed. On the lower section of the curve the piston is accelerating where the curve is headed down and slowing down as the curve swings back up. It's the same on the top part. The piston speed and damping force increase to a maximum and then slow again. This is a lot more data than we had when we just changed crank RPM and looked at the damper force at maximum piston speed. So why doesn't the damper develop the same force when it's slowing down as it did when it speeded up? I'm not certain, myself, but remember you've got a bunch of oil moving through the washer stacks and bypass paths, and it has some mass and momentum. Those washer valves do not necessarily close the same way they open. Also, the fact that the damper piston is always accelerating, slowing down or speeding up, may have something to do with the shape of this curve.

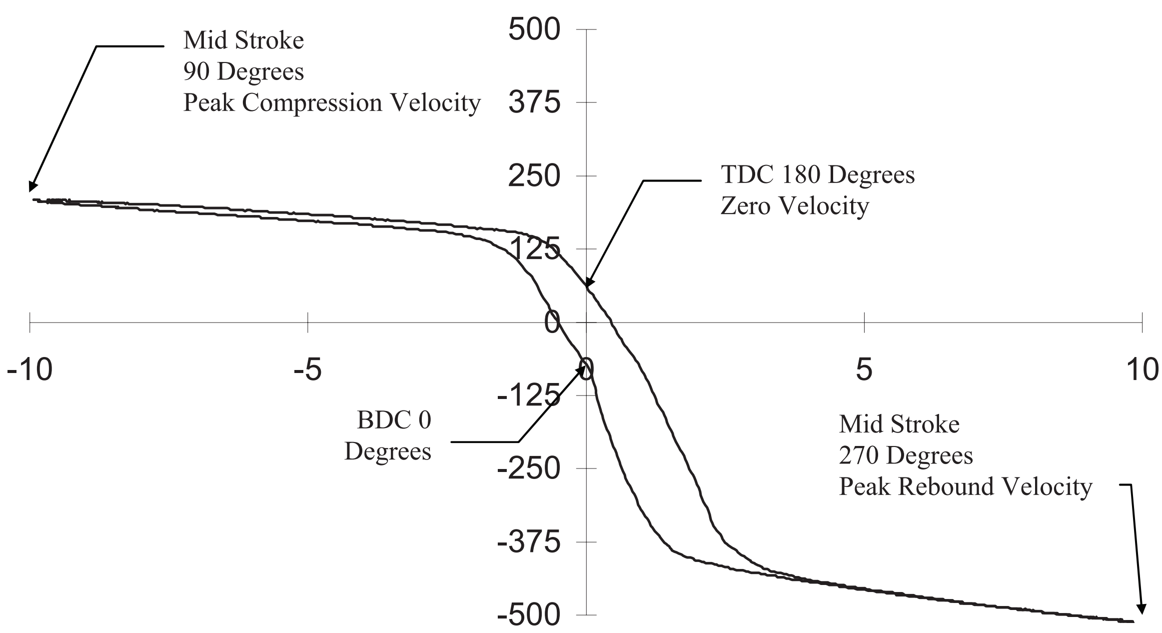

Figure 3

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