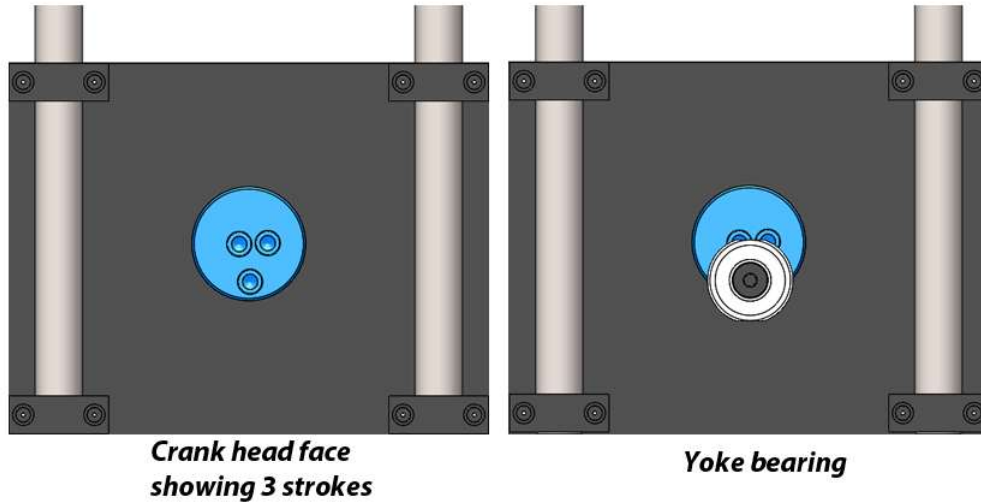


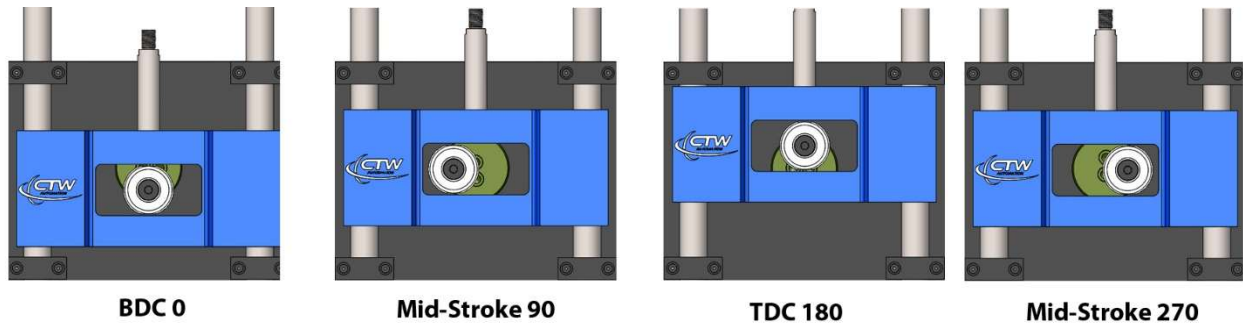
### CTW Explains How Rotation Becomes Linear Velocity

A crank type of dyno, one that turns rotary motion into linear motion is based on the rotation of the crank head and the stroke of the machine, or in our case, which hole that bolt is placed into. Many people get confused as to how fast the dyno can go and then believe if it can go 1 M/sec on a 50mm stroke then it should be able to go 1 M/sec on the 15mm stroke. This is not correct. Let's begin with the mechanics of a scotch yoke design.



*A crank head with various stroke (holes) as measured from the center*

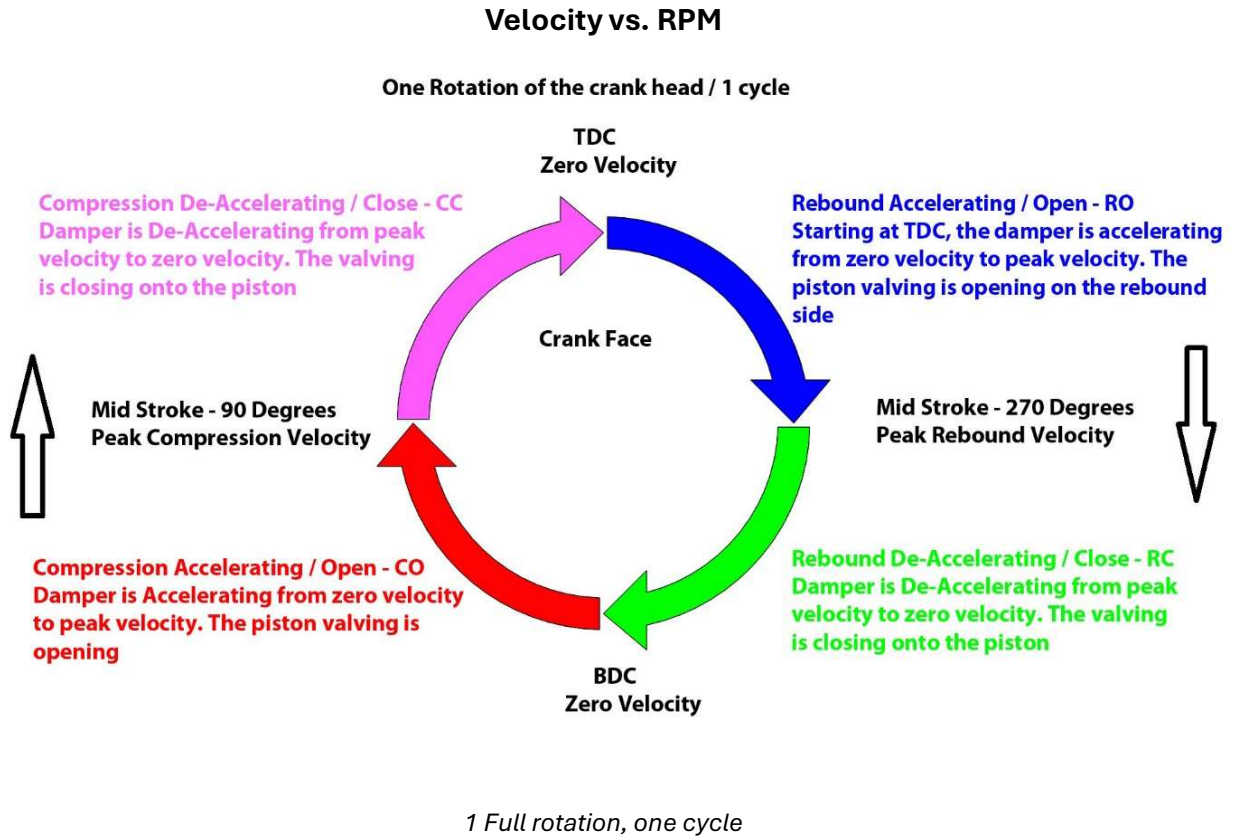
Note: CTW and Roehrig dynos used fixed holes to determine stroke to create the most repeatable testing as the stroke is fixed once secured in the given hole.



*A graphic representation of the rotation of the crank and the result at the yoke*

Note: As the crank rotates, the scotch yoke design creates a linear motion at the actuator, damper connection. (For a more complete explanation, see CTW – Where the Graphs Come From)

Your **Test Speed** is defined by:  **$\pi \times \text{stroke} \times \text{Hz}$**



Linear velocity (the actuator going up and down) is related to the stroke and the rotational frequency of the crank head. Think of it as RPM, but really, we speak of the rotation of the crank, which moves the yoke, in terms of frequency. How many times per second does it complete one full revolution / cycle. If the crank is rotating at 60 RPM, then it is rotating 1 full cycle per second; 1 Hz. The larger the stroke, the faster the peak velocity for a given crank rotation. The shorter the stroke, the slower it is going for a given crank frequency. Understanding circular motion is helpful.

When you want to run your damper at 10 in/sec, the software must calculate how fast to rotate the crank which is done using the motor controller, a ratio and some math.

Quick Terms:

Linear velocity <> rotational velocity

\* Hz is cycles per second

\* RPM is 60 x Hz

1 Hz (cycles per second) x 60 seconds = RPM (revolutions per minute)

**60 RPM** (revolution per minute) = **1 Hz** (rev per second)

\*\* You should notice that for a given crank frequency (Hz), think RPM if you need to, the velocity will vary with the stroke. Short strokes, slower velocity. Longer stroke and faster velocity.

Now let's put it all together: Velocity and Frequency.

$$\text{Velocity} = \pi (3.14) \times \text{stroke} \times \text{Hz}$$

$$\text{Hz} = \text{Velocity} / (\pi \times \text{stroke})$$

*Example using 50 mm vs. 25 mm stroke*

50 mm stroke and 250 mm/sec velocity

$$\text{Hz} = 250 \text{ mm/sec} / (3.14 \times 50 \text{ mm}) = 1.59 \text{ Hz}$$

This means ..... on a 50 mm stroke, if you want your damper to run at 250 mm/sec then the crank of the dyno is rotating 1.59 times EVERY second.

25mm stroke at the same crank frequency (rotation), we have:

$$\text{Vel} = 3.14 \times 25\text{mm} \times 1.59 = 125 \text{ mm/sec, half the velocity for the same crank rotation.}$$

\*\*\* This is why a crank dyno on a 50mm stroke has a peak velocity of 1.0 m/sec and on a 25mm stroke, it is 0.5 m/sec.

A crank type of dyno has a range of 0 to about 8 Hz, maybe 10 Hz

Now, here is the next thing to consider. And this takes a moment. If you maintain the same crank rotation, Hz, and reduce the stroke, you get less velocity, as we have discussed. But, if you reduce the stroke and speed up the crank rotation, then you can run the same velocity at a shorter stroke. This concept starts the learning curve to work in the frequency domain.

Next....

### **Frequency Domain (intro)**

If you run a damper at 250 mm/sec on a 50mm stroke it operates at a frequency of 1.59 Hz. If you run a damper at the same speed but reduce the stroke by ½, it is now operating at twice the frequency which would be 3.18 Hz. The damper, the internals, the fluids all operate at twice the frequency.

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A damper run at 250 mm/sec on a 50mm stroke will probably look different than a damper run at 250 mm/sec on a 25 mm stroke because there is a large frequency change. You can also think about it this way. On a 50 mm stroke, the damper is accelerated to peak velocity within 25 mm of the stroke, BDC to mid-stroke. It is then slowed down to zero velocity in the next 25 mm (mid-stroke to TDC). If you reduce the stroke by half, 25 mm, and the same velocity is used, then it now only has 12.5 mm to accelerate to the same peak velocity. It must accelerate faster to get to peak velocity.

The crazy thing to think about, late at night, we speak of the damper in terms of velocity, but based on the stroke, there is acceleration which leads to this new idea of frequency. At what frequency are things, events, happening? Are they happening at large strokes and low frequencies or at small strokes and high frequencies? Within your damper there are parts, fluids, components, air and gas chambers that all react differently for a given frequency. A short stroke and high frequency input will affect each part differently. A short stroke does not displace as much fluid as a larger stroke. A large diameter shaft displaces more fluid than a small diameter shaft. Moving fluid, slow or fast, is how you get action in the damper and handling on the track, reactions of the chassis, mechanical mounts and bars all react based on these inputs. Bleed, chamber size, temperature, aluminum or steel, valves or check balls, springs and pistons all are influenced by the frequency of the inputs and they likely change along the way.

If it helps, keep in mind that in the beginning, we only used a 10 in/sec test to define everything!

Fun facts.

A linear actuator goes well over 100 Hz and more. We have machines capable of testing beyond 400 Hz rated at 3dB down.

Vibration testing is beyond 300 Hz.

On a passenger car, the suspension reactions are dominant out to about 30 Hz, beyond that events are dominated by the tire.

Further Examples and conclusions.

The rotation of your shock dyno crank / yoke – that thingy that goes round and round, is defined by rotational dynamics. Many of you will understand RPM, revolutions per minute, but in this case, it makes more sense to discuss cycles per second which is **FREQUENCY**.

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**Frequency** = how many times per second the crank rotates one full cycle.

$$F \text{ (hz)} = \text{Velocity (in/sec)} / (\pi) \times \text{stroke (in)}$$

To understand the difference between a 2-inch stroke and a 1-inch stroke when using the same peak velocity, CTW presents the following math.

*At 10 in/sec and **2-inch stroke**:*

$$F = 10 / (3.14 \times 2) = 1.59 \text{ hz or the crank will rotate 1.59 times each second.}$$

*At 10 in/sec on a **1-inch stroke**:*

$$F = 10 / (3.14 \times 1) = 3.18 \text{ hz.}$$

The crank is rotating twice as fast on the 1-inch stroke compared to the 2-inch stroke.

If you run your damper to 10 in/sec on a 2-inch stroke, then change to the 1-inch stroke and run the same test, you can easily see and hear the difference that is driving your damper. And, like every in-person training I have ever done, do not just believe me, do it!! You have the tool in front of you.

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“Don’t Panic”