THE ORIGINAL

ENGINE VIBRATION

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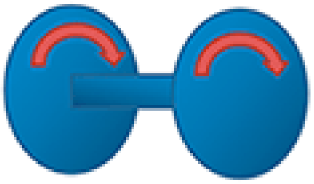
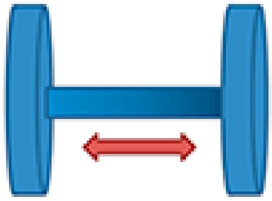
ENGINE VIBRATION

Vibration accelerates wear, breaks parts and robs power. There are three types of engine vibration that professional engine builders concentrate on minimizing. Each has its own method to control it. They are:



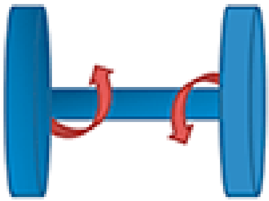
1. UNBALANCED VIBRATION

Unbalanced vibration is what comes to mind first. It is a weight imbalance vibration that occurs once per revolution. Like the consistent thumping you feel when you lose a wheel weight. In regards to an engine, even measure and distribution of the rotating assembly weight prevents this. A balancing service refers to precision matching the pistons, connecting rods and crankshaft counterweights to minimize unbalanced vibration.



2. AXIAL VIBRATION

Axial vibration is forward and backward movement of the crankshaft. The main bearing support plate and thrust bearings are in place to avoid this movement.



3. TORSIONAL VIBRATION

Torsional vibration is the end-to-end twisting and rebounding of the crankshaft caused by combustion. The harmonic balancer (damper) controls the twist to achieve durability and efficiency. Not all are constructed or function the same.

*** Fluidampr specializes in torsional vibration.**

ENGINE VIBRATION BY ANY OTHER NAME

Three unique movements of engine vibration. Three completely different ways to control each. It is important to know the differences to understand what parts and services are best for your engine build.

You may hear all three grouped into the general term, engine harmonics. The Noise, Vibration Harshness (NVH) automotive engineering field also focuses on these vibrations and how it impacts consumer quality. Terminology nuances can lead to confusion. You can rest easy knowing that managing these three engine vibrations here is a fundamental step to achieving a high quality, long lasting build no matter what it's called.

Important note. A balancing service does not remedy torsional vibration. A harmonic balancer only effects unbalanced engine vibration if it contains a counterweight. This is referred to as an external balanced engine. Today the Ford Power Stroke and Chevy Duramax fall into this category. Classic external balanced engines include the Ford Windsor and 454-502ci Chevy Big Blocks.

WHAT IS TORSIONAL VIBRATION

This is a workbench understanding of what crankshaft torsional vibration is and how it relates to your engine.

It's an interesting physics topic. The implications we witness firsthand with performance racing industry and OEM partners. Fluidampr has presented at the Advanced Engineering Technology Conference and Engine Expo-North America. Educational articles and contributions have been published by many professional magazines. These include EngineLabs.com, AERA Engine Professional, Race Engine Technology and Precision Engine. We have performed countless training seminars at industry leading parts suppliers. Have no fear. Engine harmonics is not mystical black magic or fear mongering. It's science. Ready? Let's begin.

There's two things that kill an engine. Heat and vibration. We all know you need to keep the oil and the coolant pumping. Watch your manifold air pressure and be mindful of your boost. What about engine vibration? It is a major concern of professional race engine builders. Did you know the Cosworth CA 2.4L flat-plane crank V8 raced in Formula One in the mid-2000s had 13 vibration damping devices to help achieve 20,000rpm. Including 5 viscous dampers. One on the crankshaft. One on each camshaft. [Source: Extract of "King of speed", an article written by Ian Bamsey and published in Race Engine Technology Issue 73.] Serious engineering right there.

From our introduction we learned that there are three main crankshaft vibrations. We manage unbalanced vibration with a balancing service. Axial by the main bearing support and thrust bearings. Torsional by the harmonic balancer or damper.

THE TORSIONAL VIBRATION SET UP

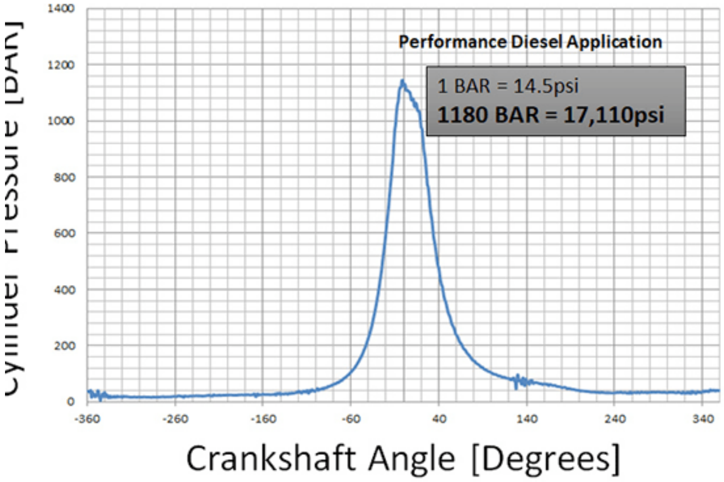
Your rotating assembly comprises the crankshaft, rods, pistons, flexplate/flywheel and damper. This assembly is a series of masses. Mass has stiffness and inertia properties. In basic terms, if you hit it, how much will it flex? At what velocity and force? A simple analogy is a tuning fork. It has mass. It vibrates at a given frequency when you strike it. Strike it harder and it becomes louder.

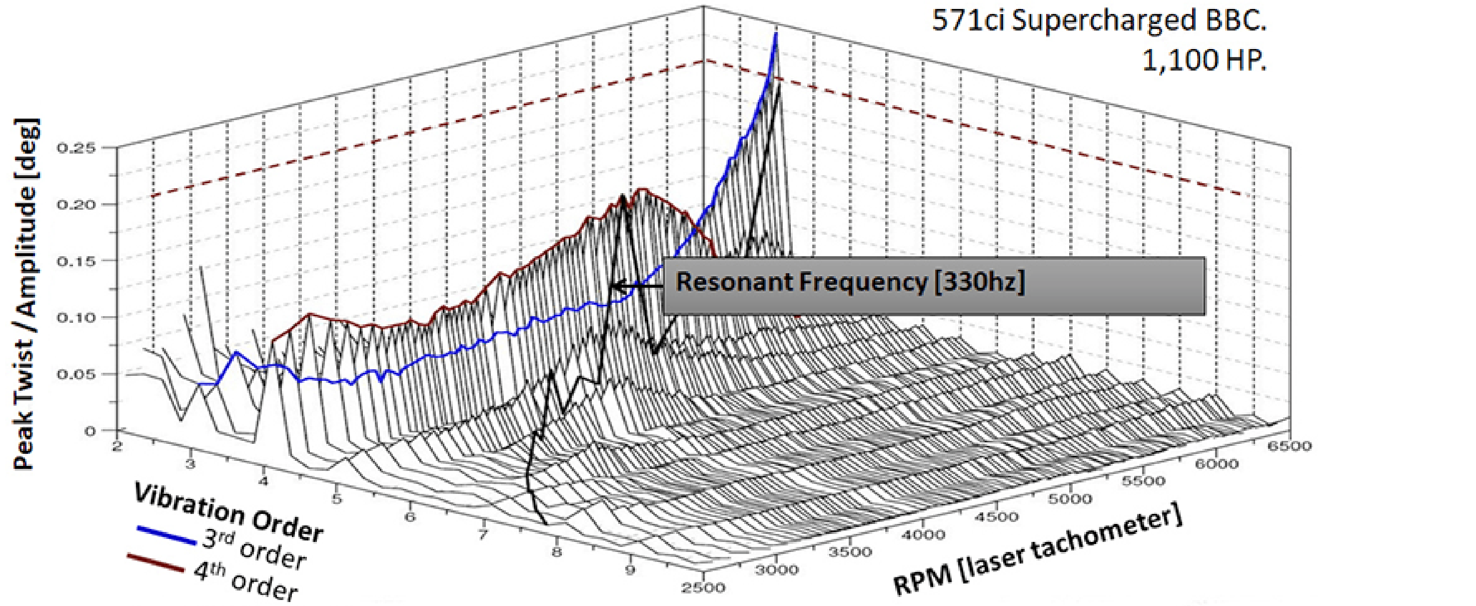
With us? Great! It's about to get real.

The rotating assembly goes in the block. Pistons fit in the cylinders. We close it off with the cylinder head. Bring on the power. *Suck. Squish. Bang! Blow.*

The bang we love raises cylinder mean effective pressure. A 427ci LS engine producing 450 foot-pounds of torque can generate 1,088 psi on the crank. In a mild performance diesel application we've seen it exceed 17,000 psi. That spike of pressure moves the piston in a sudden not so gentle way. The crankshaft undergoes stress. Every single ignition. Across every single cylinder. Repeatedly through the rpm range.

What does the crankshaft do besides rotate? It is a mass. In the ignition micro-moments during a rotation it will twist ahead of its natural rotation and rebound back. This triggers torsional vibration.





Torsional vibration map. 4th order crosses resonant frequency at 5,000 rpm. The result is a potentially dangerous 3rd order vibration near redline.

FREQUENCY & ORDER

Torsional vibration has a frequency measured in hertz or cycles per second. Frequency is RPM times order, divided by 60 (cycles per second). An order is how often a vibration event occurs during one revolution of the crankshaft.

In a four-stroke engine, the primary order is half the number of the cylinders. This is because only half the cylinders fire during one revolution of the crankshaft.

Other orders that set up are deviations from vibration oscillating through the crankshaft. As you move up through the RPM range, the frequency of each order increases.

For example, our 427ci LS V8 has a primary order of 4. At 6,500 RPM torsional vibration is occurring at a frequency of 433 hertz ((4 x 6,500) / 60). That means the crank is cycling through twisting and rebounding 433 times per second! That's a single order. There's multiple deviant orders happening at different rates too!

AMPLITUDE

Torsional vibration has amplitude. Amplitude is the amount of crankshaft deflection in degrees.

You can measure two ways. One from center to peak twist. The other is the total amount of deflection from peak twist, through center, to peak rebound.

Crankshaft length in relation to the firing order, mass elastics or stiffness, and the amount of mean effective cylinder pressure applied determines amplitude. Amplitude increases with higher pressure and/ or a longer crankshaft and/or taller connecting rods.

From our 427ci LS engine example, as frequency is occurring 433 times at 6,500 rpm, the crankshaft may be twisting and rebounding peak-to-peak through an amplitude of 0.7 degrees. On 2.559-inch-diameter mains that equates to 0.015 inches of movement. (.7xw/180) x (2.559/2).

RESONANCE

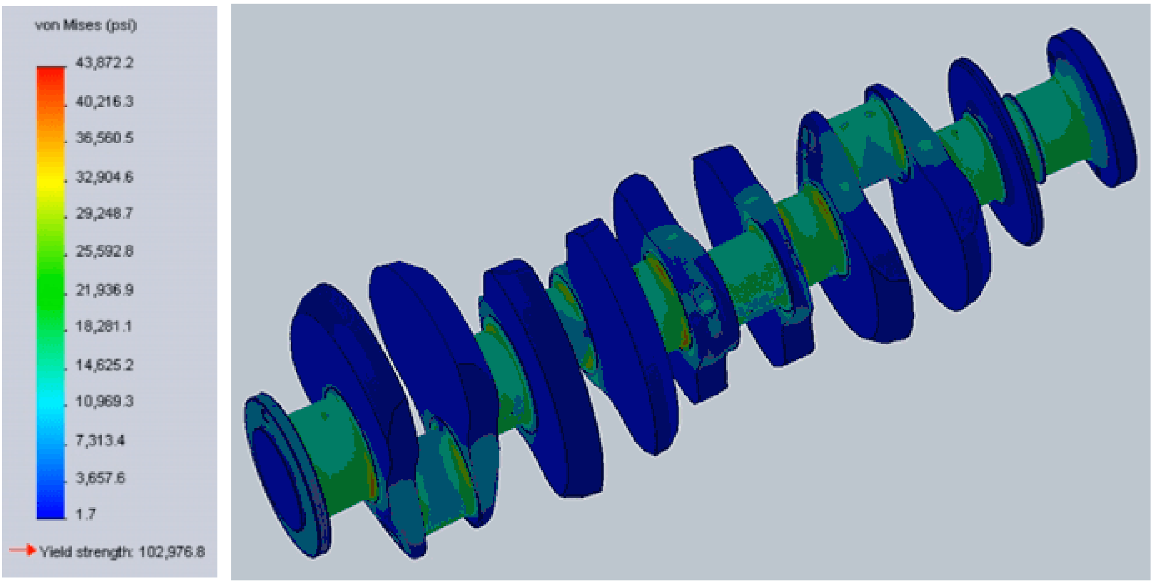
Meh. So we've got some torsional vibration going on. There's always a given level of stress on internal engine components. What's the big deal? Where's the failures?

Back to the simple analogy of a tuning fork. The rotating assembly is a series of system masses. Together they have a natural resonant frequency. The right pitch will put a tuning fork in motion. Likewise, the right torsional vibration frequency when aligned with natural resonance frequency will spike the twisting and rebounding of the rotating assembly.

System mass has spring stiffness and inertia. We need to watch the speed and torque behind the amplitude. Unfold a paper clip. You can bend it in short strokes nice and slow for a while. Long strokes real fast and it breaks.

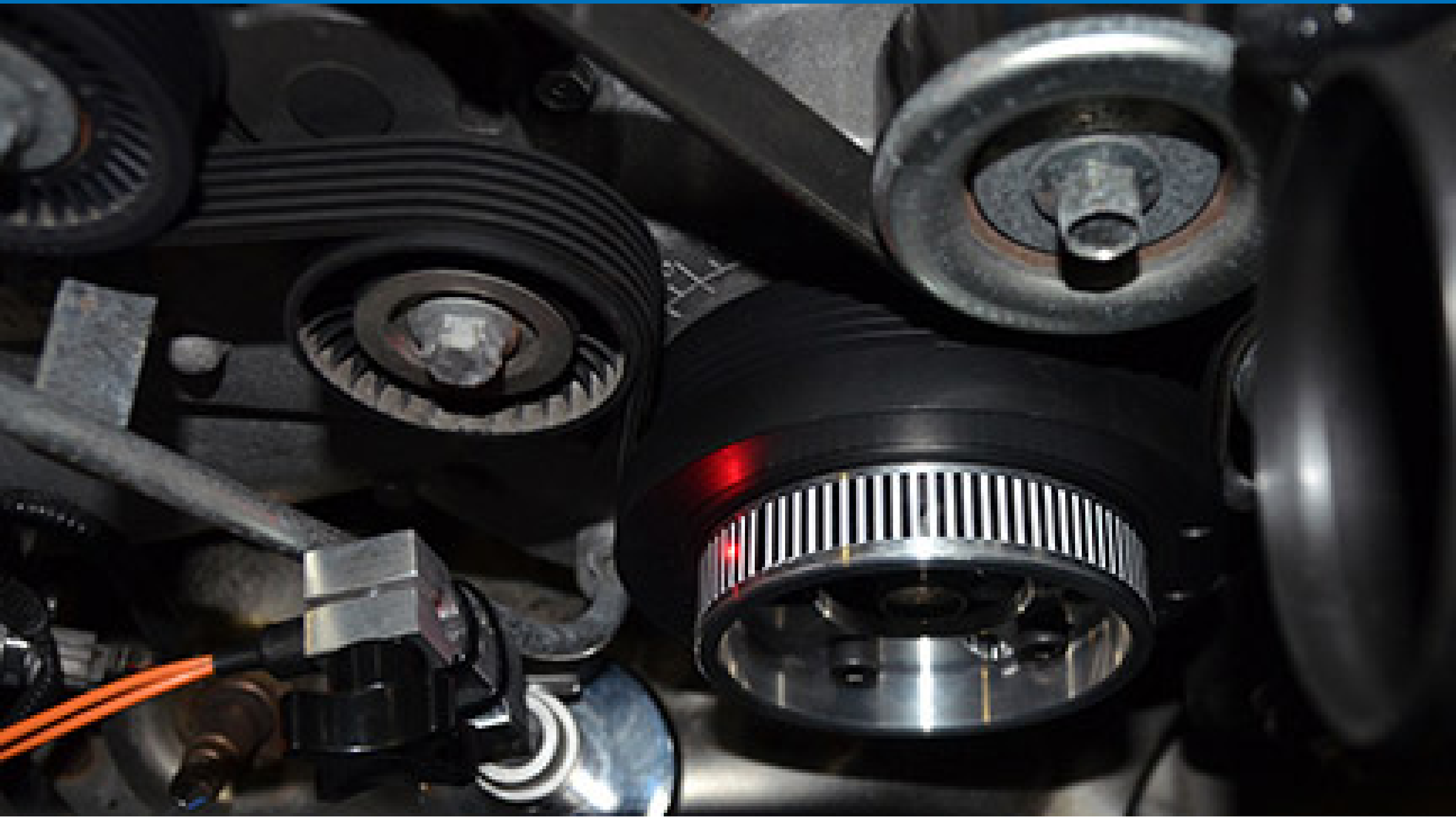
At this critical moment of frequency alignment amplitude can double or triple in size. It's happening at a high frequency. That's most likely when the carnage will happen.

Continuing with our example, and for simplicity, let's assume the natural frequency of the rotating assembly is also 433 hertz. When RPMs reach 6,500, torsional vibration frequency aligns with natural resonance frequency. Peak-to-peak amplitude doubles to 1.4 degrees. Now crankshaft fluctuation is 0.03 inches!



Torsional vibration doesn't care. Over time, or sometimes very quick, it will find the weak spot in the crank and snap it. At Fluidampr, we've seen failures at the crank snout, at the flywheel, and every point between. For good measure vibration passes through metal-to-metal contact. The oil pump, timing gear & chain, valve train, main bearings all see added wear or failure. Accessory brackets fracture. Bolts back out. Drive belts slap or come off. Hard times if you don't get torsional vibration under control at the source.

HOW IS TORSIONAL VIBRATION MEASURED?



There are two approaches for calculating torsional vibration. I'm designing an engine or I'm wrenching on an engine. In the context of this being a simple workbench talk, let's assume you are in the latter category. You have a running engine or the components to build or modify one.

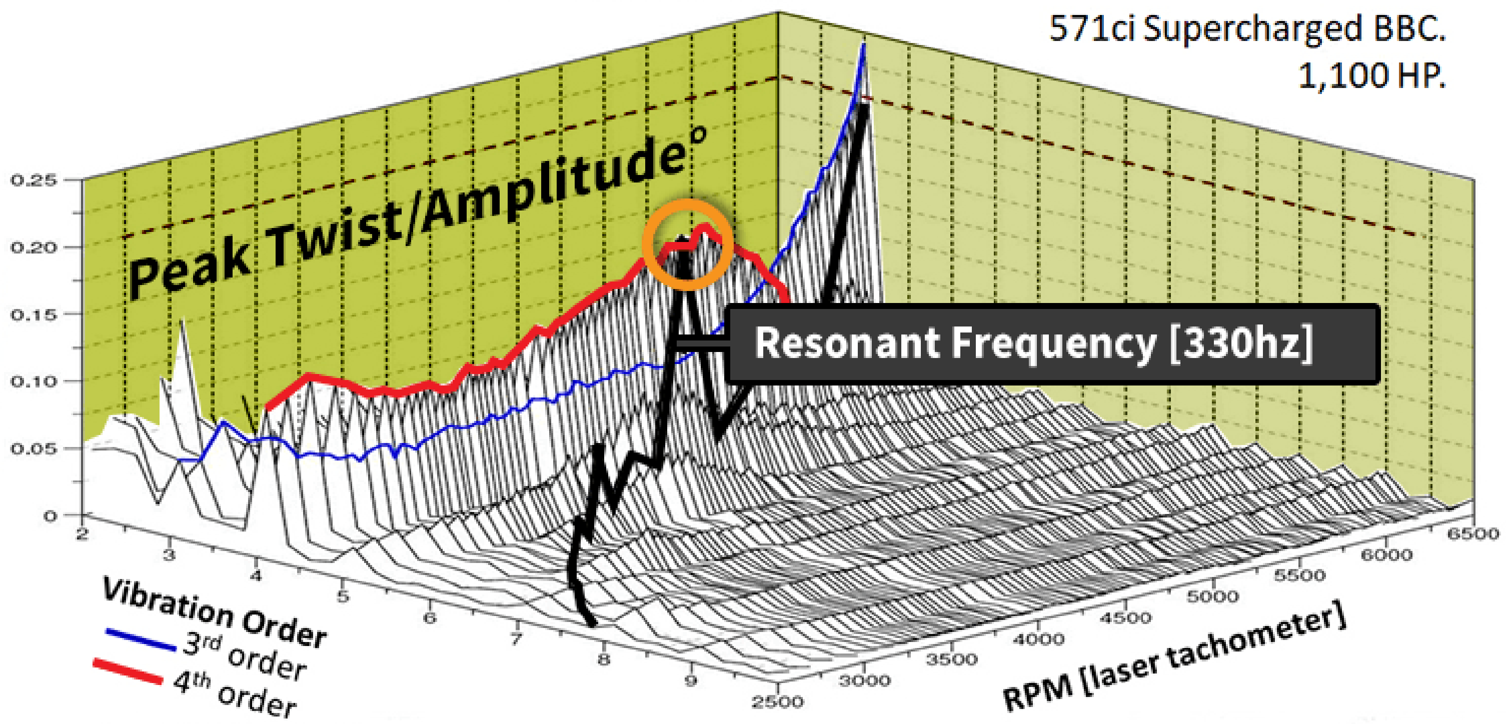
If you are a professional powertrain design engineer, you should explore what Fluidampr is fully capable of through our parent company, Vibratech TVD.

MEASUREMENT PROCESS

Torsional vibration has multiple orders, frequencies, amplitudes across the RPM range. Some are critical, some are not. Aligning with resonance frequency is something we like to avoid too. So how do you sort all this out? To the dyno cell!

At Fluidampr we use a very sophisticated fast furrier transfer analyzer and a high resolution laser tachometer. Sorry, you're more likely to find these tools in an OEM's or pro motorsport's Noise, Vibration, Harshness (NVH) lab than your local auto parts store. We collect data points so granular you can identify individual micro-moments of where a crankshaft relative position is during a vibration cycle. A controlled speed sweep at a rate of 200rpm per second tells all.

In this example the results look like this:



VIBRATION ORDERS

The 4th order is the primary order. This is the ignition event. Around 5,000 RPM ignition induced torsional vibration is occurring at 330 hz. That's an important number we'll get to later.

Here's an identified resonance frequency line. It is 330 hz.

Notice where it crosses the primary order where it is also 330 hz at 5,000 RPM.

Now look at the 3rd Order amplitudes just beyond where they cross.

WHAT DOES THE DATA MEAN?

To a NVH engineer it shows how to construct a harmonic balancer. But only on this data set. For this particular engine. Which is great on a stock engine when you're mass producing the same design. Even for OE replacement all you need is an inexpensive tuned narrow range harmonic balancer.

The reality is we like to modify our engines. How does that change things?

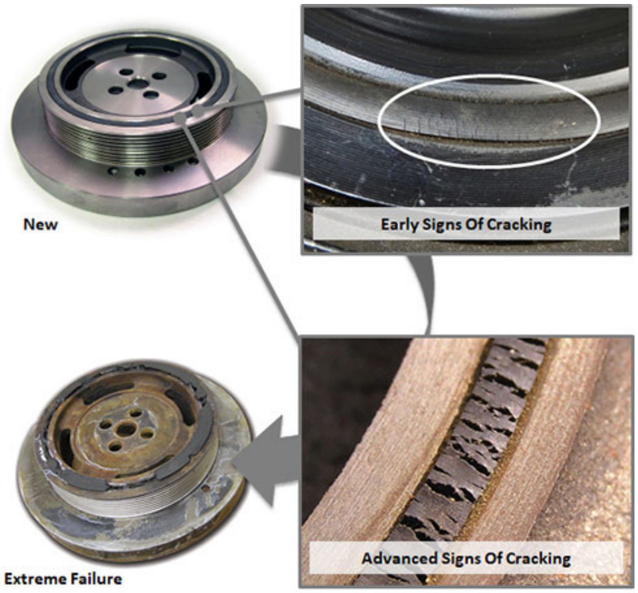
WHAT ENGINE MODS AFFECT TORSIONAL VIBRATION

Two questions we hear are *'What do engine modifications do?'* and *'When should I upgrade the harmonic balancer?'*

It's one thing to measure torsional vibration. But like all data it needs context. In our shop we like to tinker. We like to make more power. We like lighter parts. What does all that do to our baseline torsional vibration map? Should I have a concern?
The blunt answers are YES and A LOT.

HOW IMPORTANT IS THAT HARMONIC BALANCER?

The harmonic balancer is a fundamental engine component to provide durability. The OEMs have already figured out the torsional vibration map. The majority of the time they equip your engine with a tuned, narrow range elastomer harmonic balancer. This reduces it in a key spot for durability, comfort or both. It is a very cost effective part to last the life of the warranty under stock conditions. It is also cheap to manufacture. It does its job. For daily drivers it's all most of us need. Furthermore, torsional vibration is not generally a concern for OEMs in low torque, small displacement engines. Only a drive pulley with no damping capability is used. Let it be your concern if you do engine modifications. 'Wait a minute!' you say. That's not me. This isn't another car off the lot. I don't want that at all! Yeah, us either. Pull a chair up to the workbench and let's review the basic playbook.



CREATING MORE TORQUE

Our first steps to more power is a cold air intake and performance exhaust. Next you go forced induction or high flow heads to boot. Larger injectors. A pro tune. These engine modifications all give you more air & fuel which of course translates to more torque and horsepower. The cylinder mean effective pressure spike of combustion is what triggers torsional vibration. You're spiking it with a bigger bang now. Vibration amplitude increases. The stock tuned narrow range elastomer harmonic balancer tries to control it. But it's only designed for stock power level tolerances. The elastomer layer becomes susceptible to the heat generated by damping. Cracked, bulging or missing rubber are tell-tale signs you're overworking your stock harmonic balancer. It's time to upgrade. It's good practice to inspect for this on routine intervals.

During this time the harmonic balancer becomes more and more inefficient. Increased amplitudes accelerate wear on critical engine components. You'll see this show up on the main bearings. You're also more likely to see other signs a harmonic balancer is failing. In motorsports, the SFI 18.1 safety standard regulates the design construction of harmonic balancers. This rule is in place because when the stock unit fails and separates it can cause a lot of harm in and out of the engine bay.

REV HAPPY LIGHT WEIGHT ENGINE MODIFICATION PARTS

Lighter is better, right? Lightweight flywheel. Lightweight pistons. Light weight harmonic balancer or solid pulley?

Watch the video below and note the comparison it takes for each to come to a rest. Imagine if this was torsional vibration occurring in your engine. This example shows an extreme amount of twist but it does prove a damper's comparative ability to rapidly control vibration.

In regards to the harmonic balancer that is the last place to consider cutting weight. It needs optimum inertia weight to control vibration. There's a very good reason they weigh what they do.

Let's recap a section from *What is torsional vibration*. The rotating assembly is a system of masses. Together it has a natural resonance frequency. As you power through the RPM range and torsional vibration frequency aligns with it the vibration amplitude spikes. This can be bad. Real bad. Catastrophic engine failure bad.

When you do engine modifications that change part of the system mass you shift the resonance frequency. Lighter parts will shift it higher. Heavier parts lower. Sometimes you can put the resonance right where you don't want it. Other times you unintentionally discover it by pushing beyond the factory set rev limiter.

The stock tuned narrow range harmonic balancer, and even similarly constructed aftermarket performance replacement dampers, are optimized to function at a known frequency. It will work, just now not 'in-tune' to do the most good. Which increases your risks.

When engine modifications are done to rotating assembly components and resonance frequency becomes unkown, the most cost-effective solution for optimum protection is to install a quality broad-range harmonic balancer.

Side-by-side video of a five pound solid mass vs a five pound viscous damper on a validation test rig. When the torsion bar releases it throws each in motion to about 45°. The viscous damper (Right) stops moving in about 15 seconds, while the solid mass keeps moving well over 30 seconds later. **youtu.be/tNLersfbodE**

TYPES OF HARMONIC BALANCERS

The harmonic balancer is the most misunderstood engine part. The confusion comes from its name. Engine harmonics is a general term to lump various vibrations together. Balancer, or to balance a rotating assembly, is a common engine performance service. So a harmonic balancer must be a simple, one part fix, to smooth out an engine. Not always true.

The harmonic balancer reduces torsional vibration. To reduce means to damp. More accurate, a harmonic balancer is a torsional vibration damper (TVD) - as in Vibratech TVD, original inventor of the viscous torsional damper and Fluidampr brand.

The terms damper, dampener and harmonic balancer are all interchangeable. Chances are you'll find the term damper used by performance parts retailers and professional race engine builders. The term, harmonic balancer, is common among OE replacement part stores.

There are many harmonic balancer options. Common to all are a few basic design principles you need to know before choosing one.

External balance. Note the large counterweight mass CNC machined into the housing. Fluidampr #800221 for 6.7L Ford Power Stroke applications.

Fluidampr for 454-502ci external balance Chevy Big Block. The removable hub contains the counterweight mass. By changing only the hub this damper can then be used on an internal balance conversion.

INTERNAL BALANCE VS EXTERNAL BALANCE

Internal combustion engines come in all sorts of configurations. None is more important than knowing if it is internal balance or external balance.

If there is not enough space within the engine block to place all of the necessary crankshaft counterweights, then designers will add that weight to the harmonic balancer and / or flywheel. Since this weight is outside the engine block it is referred to as external balance.

Today, the Ford Power Stroke and GM Duramax are two popular external balance engines. Both are large displacement light duty truck diesels. Classic external balance engines include the:

• Ford Windsor, Cleveland & FE engines
• Chevy 400ci Small Block
• Chevy 454-502ci Big Blocks
• Oldsmobile V8s

Be aware that external to internal balance conversion is a popular performance upgrade. Internal balance dampers are available from Fluidampr and other brands for this conversion. When working on any vehicle, especially classic muscle cars, it is best practice to physically verify an internal or external balance set up. You can cause spectacular devastation with unbalanced rotating assembly weight otherwise.

Internal balance refers to all the necessary crankshaft counterweights being within the engine block. There is no counterweight mass on the harmonic balancer. Most modern automotive engines are internal balance.

BROAD RANGE VS NARROW RANGE

Torsional vibration occurs throughout the RPM range. Some RPMs see higher vibration amplitudes than others. Some uncomfortable vibration may be at cruising RPM. In a stock passenger car or truck it makes sense to target torsional vibration control at that specific RPM. A tuned narrow range harmonic balancer is a cost effective option for OE designers.

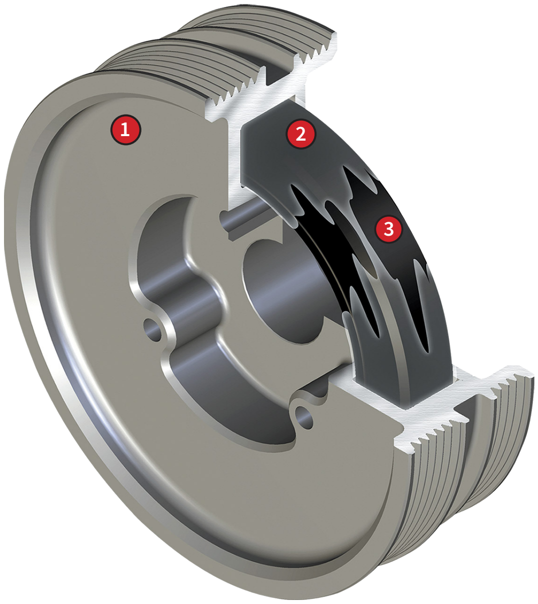
What happens if you modify the rotating assembly and that target shifts? Your stock tuned narrow range harmonic balancer is no longer optimal. Broad range harmonic balancers, like premium ones found in professional motorsports and high-end factory sports cars, provide durability and performance across the entire RPM range.

Fluidampr performance dampers are broad range.

OEM harmonic balancer with frequency range stamp. It controls torsional vibration in a *narrow range* between 380 to 420 hertz.

Internal balance.
Fluidampr #571101
for Subaru FA20 engines.

HOW FLUIDAMPR WORKS



Fluidampr is a torsional vibration damper. Its function is to provide durability by controlling destructive torsional vibration. A side benefit to vibration control is releasing lost torque and horsepower through greater efficiency.

A Fluidampr performance damper is constructed from three main components:

1. Outer housing
2. Silicone
3. Inner inertia ring

The outer housing mounts to the crankshaft. When combustion triggers rapid twisting and rebounding (torsional vibration), the outer housing and inner inertia ring will move in-and-out of phase with each other. The motion of the inner inertia ring through the silicone creates shear. Shear eliminates unwanted vibration.

QUALITY MATTERS

Not all viscous dampers are the same. They may be referred to as a fluid damper, but they are not a Fluidampr brand performance damper. Always look for the official 'The Original' Fluidampr logo when purchasing. Fluidampr performance dampers are only available through reputable performance parts retailers, jobber shops and distributors.

Leading OEMs also trust Fluidampr, and parent company Vibratech TVD, because of our ISO 9001:2015 certified quality standards and proven experience in professional motorsports since 1985. Modern design and manufacturing advances pioneered by Fluidampr are used in Vibratech TVD viscous dampers. These include cutting edge military vehicles, extreme weather commercial vehicles, race boats and high-end sports cars.

WHY SILICONE?

Viscous silicone maintains viscosity tolerance across a wide temperature range. Approximately -40° F to 300° F. This provides very consistent and predictable damping properties.

Excellent heat dissipation and low friction of silicone are other key silicone advantages.

BENEFITS OF A FLUIDAMPR PERFORMANCE DAMPER

Protecting your engine from destructive torsional vibration is the leading benefit to installing a Fluidampr performance damper early in your build process. By doing this you can:

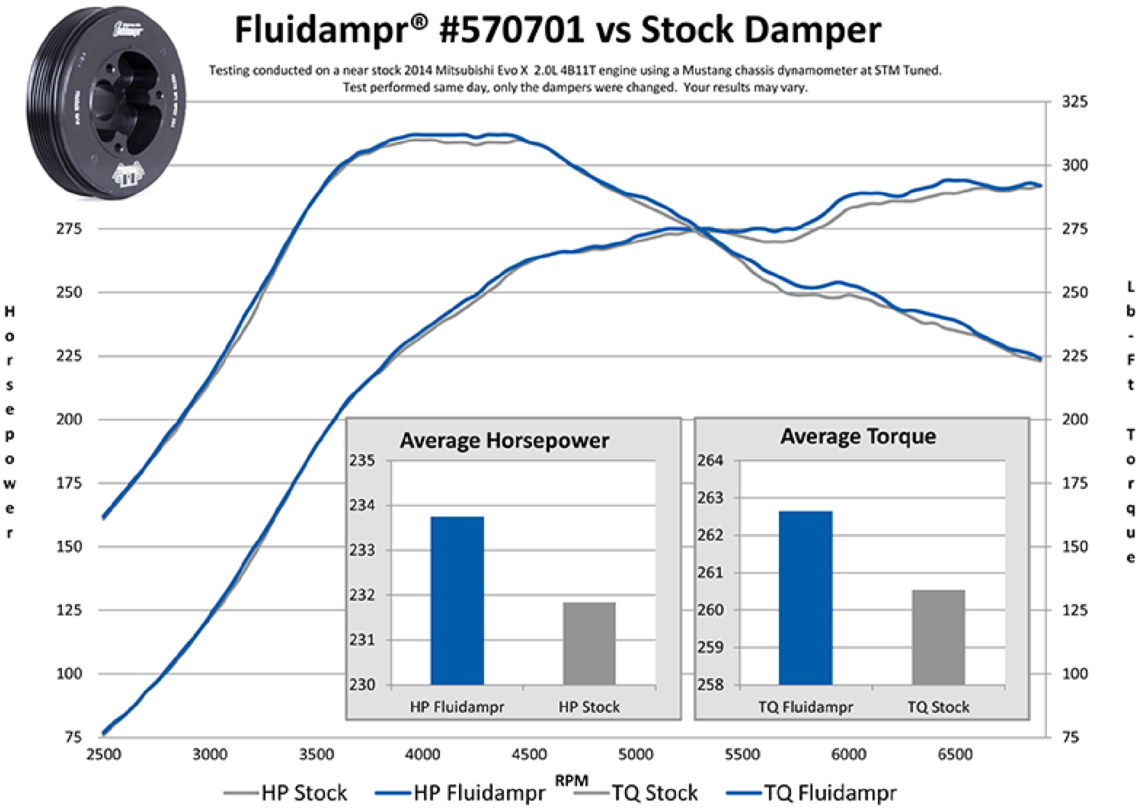
- Improve the life of critical engine components.
- Improve valve timing accuracy.
- Safely gain horsepower and torque through improved efficiency.
- Optimize the performance gains of other add-ons.

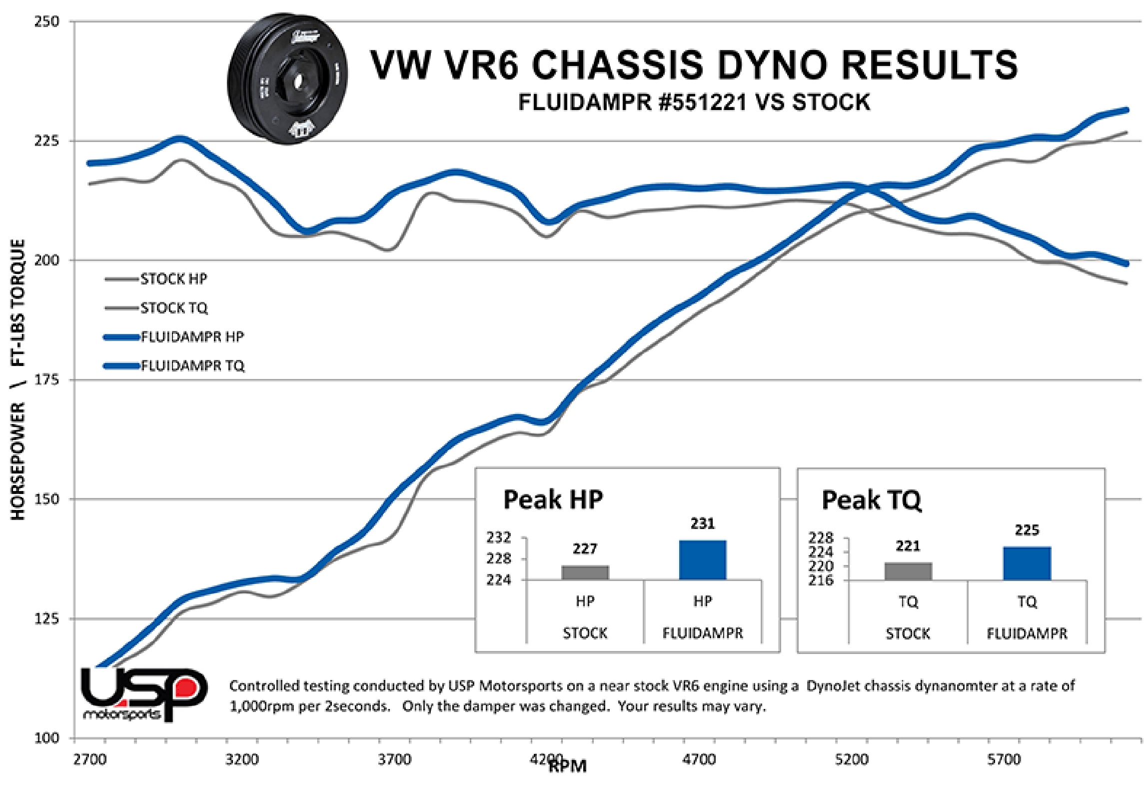
Superior damper durability and broad RPM range coverage are why champion engine builders trust Fluidampr.

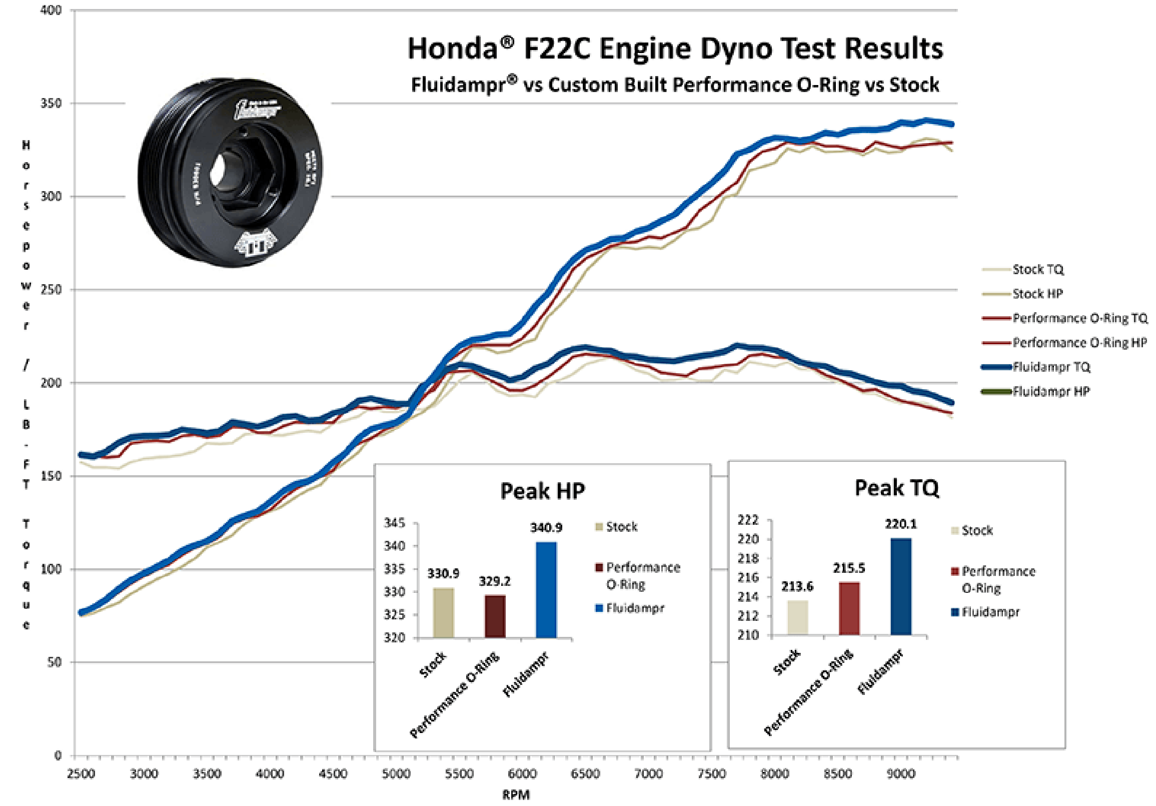
“Fluidampr was able to supply us with an item that has a lot more durability than our previous elastomeric damper. The new damper gives us more confidence for the 24-hour races.”
- Vince Tiaga, Corvette Racing Project Lead, GM Perforamnce. Race Engine Technology Magazine. Sept/Oct 2017.

“Fluidampr proved to be the best...On top of the numerical data, there was a noticeable reduction in harmonics that could be felt in the concrete floor of the dyno cell. We’ll be using Fluidampr on all of our in-house builds...”
- Jeremy Wagler. Engine Builder Magazine – Engine Builder of the Year. Wagler Competition Products

FLUIDAMPR COMPARISONS

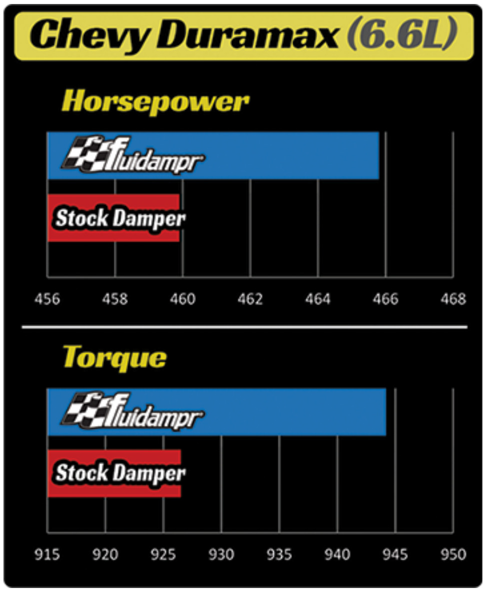


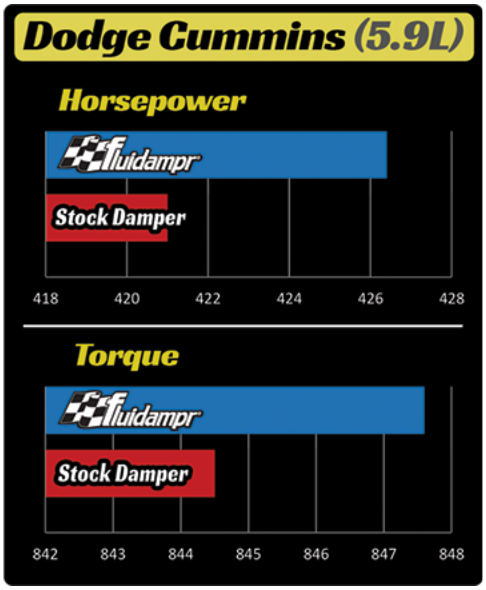


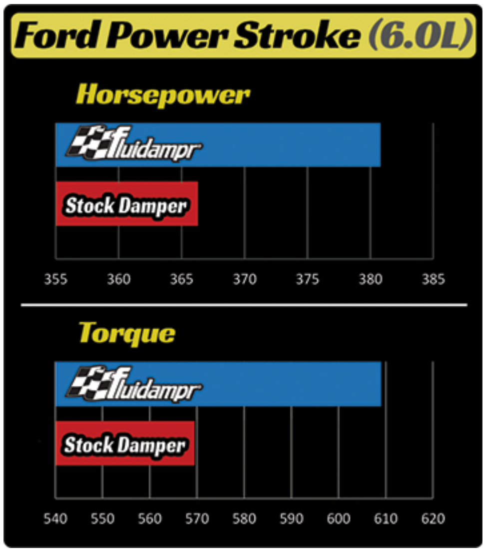


Controlled engine lab testing using a mildly tuned F22C engine on a Superflow water brake engine dynometer at a rate of 1,000rpm per 2 seconds. Only the dampers were changed. Your results may vary.

Diesel Engine Dyno Results







ABOUT VIBRATECH TVD

Vibratech TVD, the parent company of Fluidampr, is a torsional vibration solutions provider to powertrain OEMs. The company designs and manufactures the widest range of viscous dampers in the industry. Applications include crankshafts, camshafts, drivelines and electric/hybrid drives. Vibratech TVD dampers can be found in the automotive, marine, commercial, rail & transit, energy, off-highway, aviation and defense industries.

Vibratech TVD offers complete turn-key service to assist powertrain engineers accomplish their goals.

DESIGN AND DEVELOPMENT

- Torsional vibration analysis
- Modeling and simulation
- Integrated design
- Prototyping
- Validation testing
- ISO 9001:2015 Design & Development certified

HEAVY-DUTY REPLACEMENT DAMPERS

Vibratech TVD heavy-duty replacement dampers are available for popular Class 8 truck engines from Cummins, Caterpillar, Detroit and Mack.

ADVANCED MANUFACTURING HIGHLIGHTS

- Highly skilled workforce.
- Robotic automation.
- Live statistical process control.
- Inventory replenishment blanket order programs.
- Refurbish and remanufacturing programs.
- ISO 9001:2015 Quality Systems certified.

EDUCATIONAL TRAINING

Leading powertrain OEMs and engineering conferences welcome Vibratech TVD for custom tailored educational training and speaking engagements. Gain first hand knowledge into our 70+ years of experience across the widest application range in the industry. Vibratech TVD was formally Houdaille, the original inventor of the torsional viscous damper in 1946.