VIBRATECH® TVD

# CRANKSHAFT DAMPER DEVELOPMENT

## FLUIDAMPR® BRAND **PERFORMANCE VISCOUS DAMPER UPGRADE** FOR THE **SUBARU® BRZ/SCION® FR-S** ENGINE

**By: Brian LeBarron**

VIBRATECH® TVD
VISCOUS DAMPERS

## INTRODUCTION

During the mid-1980s Vibratech® TVD was approached by high level race engine builders to bring the durability and broad frequency range protection of a viscous damper found in commercial and industrial applications to professional motorsports. Fluidampr® performance dampers originated from this endeavor. Today, Fluidampr® performance dampers continue to be one of the market leading premium crankshaft dampers sold for domestic, import and diesel street performance and motorsports applications.

Fluidampr performance dampers challenge the misconception that a viscous damper is only suitable for large, low rpm industrial and commercial diesel engines. In this e-book we will follow the actual ISO9001:2008 certified design and development, plus comparative testing of a Fluidampr performance damper for the Subaru FA20/Toyota 4U-GSE 2.0L opposed-four cylinder engine. The engine is featured in the popular 2013-present Subaru BR-Z, Scion FR-S, Toyota GT86 and new 2015 Subaru WRX.

## DESIGN CRITERIA

In conjunction with a leading performance parts wholesale distributor, Vibratech TVD began the process of developing a new Fluidampr performance damper by interviewing intended users, understanding the challenges they face and analyzing the technical specifications of the engine. Above all, it would have to prove itself to sell successfully in the intensely-competitive performance aftermarket. Competitors include other crankshaft damper designs and inexpensive non-damped lightweight crankshaft pulleys.

> **“IT WOULD HAVE TO PROVE ITSELF TO SELL SUCCESSFULLY IN THE INTENSELY-COMPETITIVE PERFORMANCE AFTERMARKET.”**


Photo Courtesy: DSPORT

Photo Courtesy: Power Automedia

## From Those Market and Product Research Sessions, the Following Goals Were Established:

1. The damper would need to be light weight, yet effective and durable. It would be required to pass the strict professional racing industry's SFI 18.1 safety certification. According to SFI quality assurance specification, section 18.1 refers to crankshaft hub harmonic dampers. Article 3.0 Construction, dictates that "the damper shall be constructed in such a manner that the inertia devices shall not become disengaged during use... For inertia disc style dampers, the containment device must cover a minimum of 50 percent of the cavity containing the disc. The thickness of the containment material must be a minimum of 0.062 inch steel or 0.180 inch aluminum." Article 5.1.3 B Testing Procedure mandates that "The damper shall be driven to a rotational speed between 12,500 and 13,500 rpm and maintained at that level for one hour." Furthermore, the steel of a SFI certified Fluidampr housing must meet a minimum 40,000psi yield strength and 60,000psi tensile strength under testing.

2. The damper would need to provide broad frequency and amplitude coverage to account for a wide variety of engine modifications including changes to the bore and stroke, rod and piston composition, crankshaft composition, and the potential for much higher cylinder mean effective pressure.
**>>** For quality conscious race teams, in addition to providing excellent torsional vibration protection, the damper would require superior longevity and no maintenance, tuning or replacement once installed.

3. Through creating greater efficiency, the damper would need to release more lost torque and horsepower over the stock tuned elastomer damper and a light weight pulley.

4. The damper dimensions would need to remain as close to stock as possible.

5. The damper would need to accommodate additional accessory drives, such as a dry sump system or supercharger.

"Viscous damper technology will provide the broad frequency range and amplitude control. The toughest challenge is going to be fitting enough inertia mass in the same amount of physical space the stock damper consumes," remarks Aaron Neyman, Fluidampr Senior Product Engineer. Tuned elastomer style dampers bond the inertia mass to the outside diameter. Its leveraging effect provides a functional design in a smaller and lighter package.

A viscous style damper carries a portion of its inertia mass in the outer housing with the remaining mass contained in the inner inertia ring. The advantage of the viscous style design is that the outer housing provides heat dissipation that contributes to overall superior damper life.

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## MEASUREMENTS

Through membership in the Specialty Equipment Manufacturers Association (SEMA) Technology Transfer, details regarding the FA20/4U-GSE engine were obtained. In addition, an OEM crankshaft damper and timing cover were obtained. Through the use of calibrated precision measurement equipment the dimensions of the OEM crankshaft damper and timing cover were configured. In combination with other data obtained, measurements confirmed that the Fluidampr performance damper would be restricted to the same 5-7/8" outer diameter dimensions as the OEM crankshaft damper.

Layout then began in computer-aided design software from the measurements collected. Detailed finite element analysis was performed to determine the damper's resonance frequency and structural integrity. SFI requirements mandate the damper to be spun at 12,500rpm for one hour without failure to meet certification for professional motorsports. The materials and manufacturing process chosen for this Fluidampr application provide nearly four times the requirement for added safety.

Once the preliminary computer design was complete a 3D additive printed prototype was produced. Shown above, the prototype was shared with established performance engine shops to verify fitment and tolerances using actual engines.

With the ABS plastic prototypes passing inspection and the design meeting the initial objectives for optimum weight, size constraint and provisions for future accessory drive changes, the team moved forward with creating fully functional test prototypes.

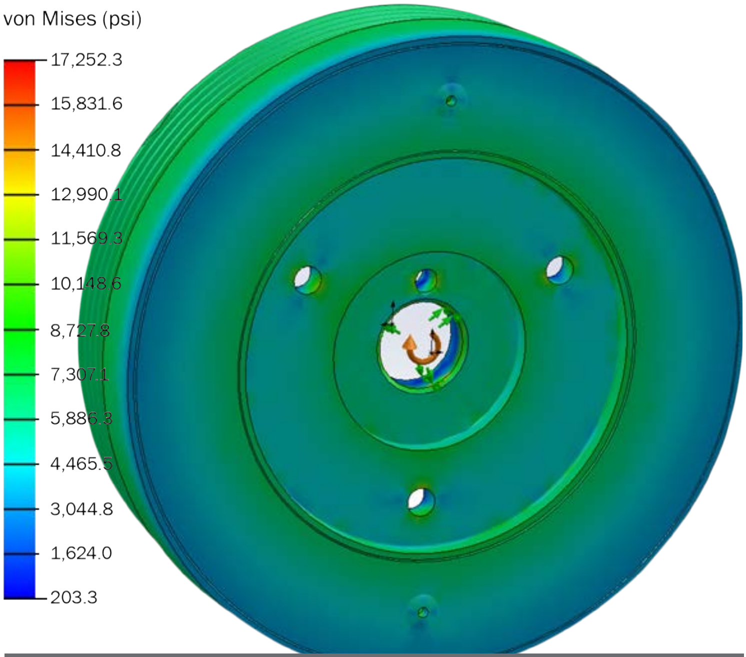
## VALIDATION TESTING

"Computer modeling and rapid prototyping is fantastic," comments Neyman. "The true test however is how well it functions. In motorsports it has to outperform and outlast the stock tuned elastomer crankshaft damper." To validate the new Fluidampr performance damper for the Subaru FA20/Toyota 4U-GSE engine the team partnered with a well-recognized speed shop in the industry.

"We want to get as close to a common real world set up as possible," continued Neyman. "We know high power builds benefit extraordinarily well from a Fluidampr performance damper because you're inducing much greater torsional vibration amplitudes and heat for what the stock tuned elastomer damper is designed for. For this validation test we went the other direction." The car chosen was a 2013 Scion FRS equipped with only a high flow air kit and exhaust, plus a mild tune. Initial peak torque and horsepower measured 141lb-ft and 149rwhp respectively on the Mustang Dynamometer chassis dyno. Torsional vibration control, along with horsepower and torque gains realized with the Fluidampr performance damper found here will only increase as future modifications are made.

Vibratech TVD developed a comparative test that would analyze torsional vibration levels and its effect on performance between the Fluidampr performance damper, the stock tuned elastomer style crankshaft damper and an un-damped lightweight pulley. To conduct the testing, the OEM tuned elastomer damper was drilled and tapped with 4 holes to mount an aluminum trigger wheel. An optical sensor was installed to register off the timing strip. Steady state data was taken at idle to determine if the laser sensor was adjusted properly in order to provide clean data. This setup was also used on the Fluidampr performance damper to eliminate a possible variance due to dissimilar fixtures. For torsional vibration measurements, data sets were taken using speed sweeps from 2500rpm – 7500rpm over a time of 30 seconds in order to capture any resonance points in the operating range of the engine. Each speed sweep was conducted twice, back-to-back to verify consistency.

The laser sensor generates digital signals that are counted thousands of times per second and then run through a fast fourier transform (FFT) to calculate speed fluctuations of the crankshaft hub, across the engine frequency spectrum. The result plots the amplitude of each vibration order across the rpm range and determines system resonance frequencies. Figures 1, 2 and 3 show the overall torsional vibration map for each test.




Above: Finite Element Von Mises Stress Analysis Simulating 12,500 RPM SFI Certification Testing.

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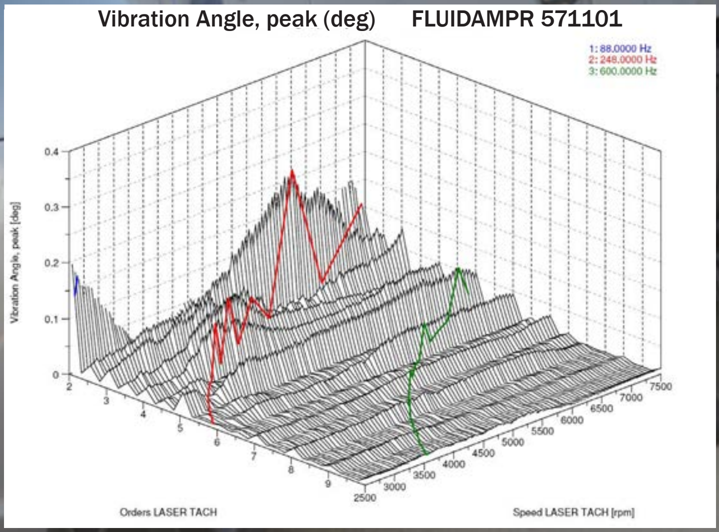


Fig. 2 – FA20 engine torsional vibration map with Fluidampr performance damper. The Fluidampr performance damper effectively reduced all vibration amplitudes to less than 0.25 degrees peak across the testing range. Amplitudes also show a general reduction trend while approaching the upper limit of the rpm range.

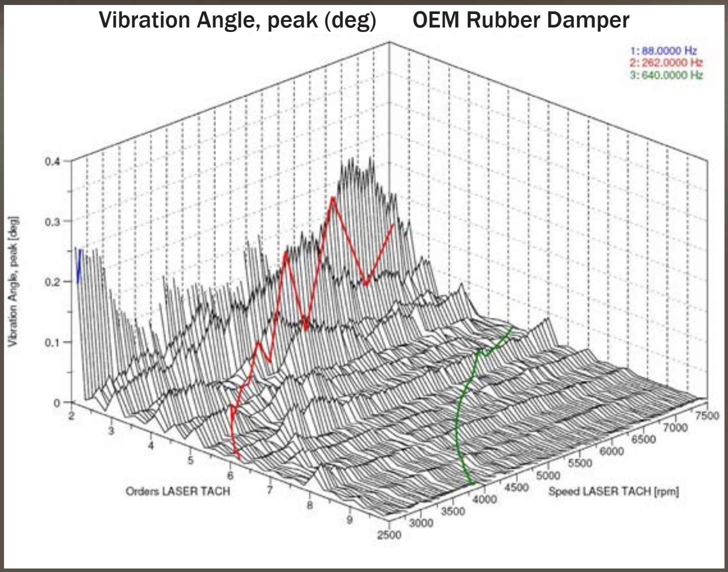


Fig. 1 – FA20 engine torsional vibration map with the OEM tuned elastomer crankshaft damper. The first crankshaft resonance appeared at 88Hz and was almost below the testing rpm range. A second crankshaft resonance was also seen near 260 Hz.

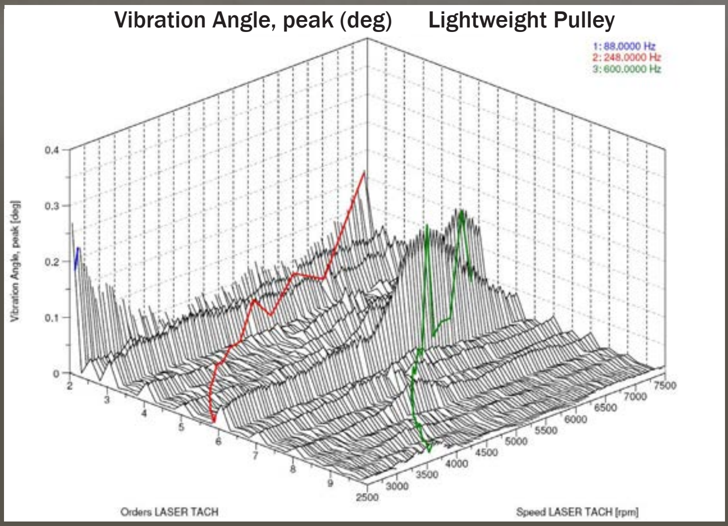


Fig. 3 – FA20 engine torsional vibration map with an un-damped lightweight pulley. The lightweight pulley shifted a third crankshaft resonance into the operating range at 600Hz. The 600Hz resonance excited 5.5th and 6th order vibrations. High frequency amplitudes carry much more stress than equivalent low frequency amplitudes because they occur more times per revolution. Crankshaft driven timing components and oil pump drives can be more susceptible to high frequency vibrations.

 Photo Courtesy: Power Automedia

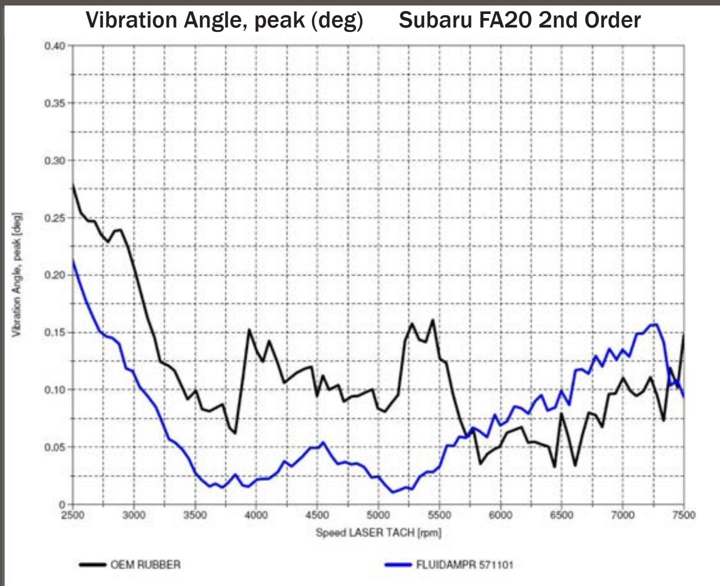


Fig. 4 – 2nd order comparison between the OEM tuned elastomer damper and Fluidampr performance damper. The dominant 2nd order represents the firing order in 4 cylinder, 4 stroke engines. Clear start and stop damping range spikes of the tuned elastomer damper is present at 3900 and 5250 rpm, or 130Hz to 175Hz, for a narrow operating range of only 45Hz. Note the smoothness of the Fluidampr damping capability through the same rpm range.

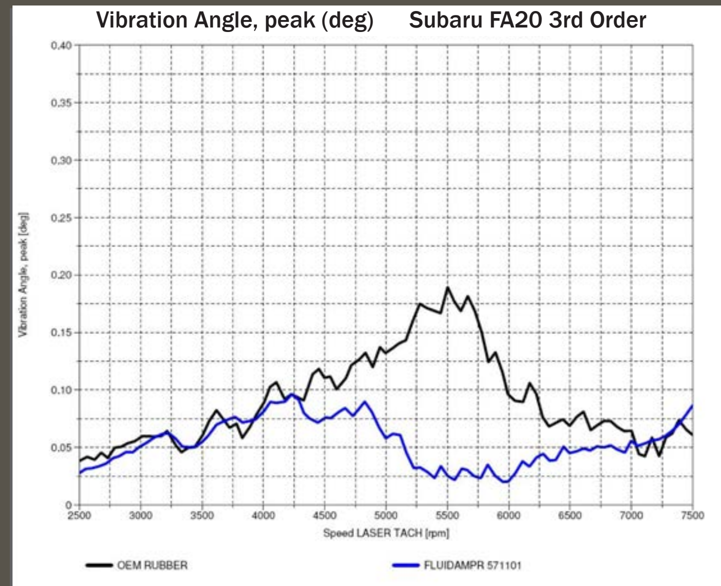


Fig. 5 – 3rd order comparison between the OEM tuned elastomer damper and Fluidampr performance damper. The Fluidampr performance damper was able to cut amplitude of the excited 3rd order vibration generated by the 260Hz crankshaft resonance in half, down to below .1 degrees peak.

## After reviewing the vibration overview waterfall plots, some individual orders were examined to show the differences in detail.

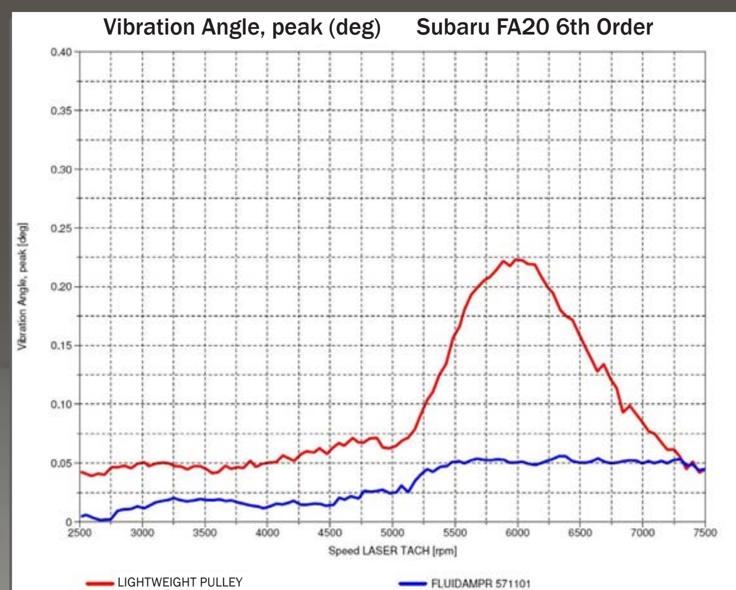


Fig. 6 – The 6th order difference between an un-damped lightweight pulley and the Fluidampr performance damper.

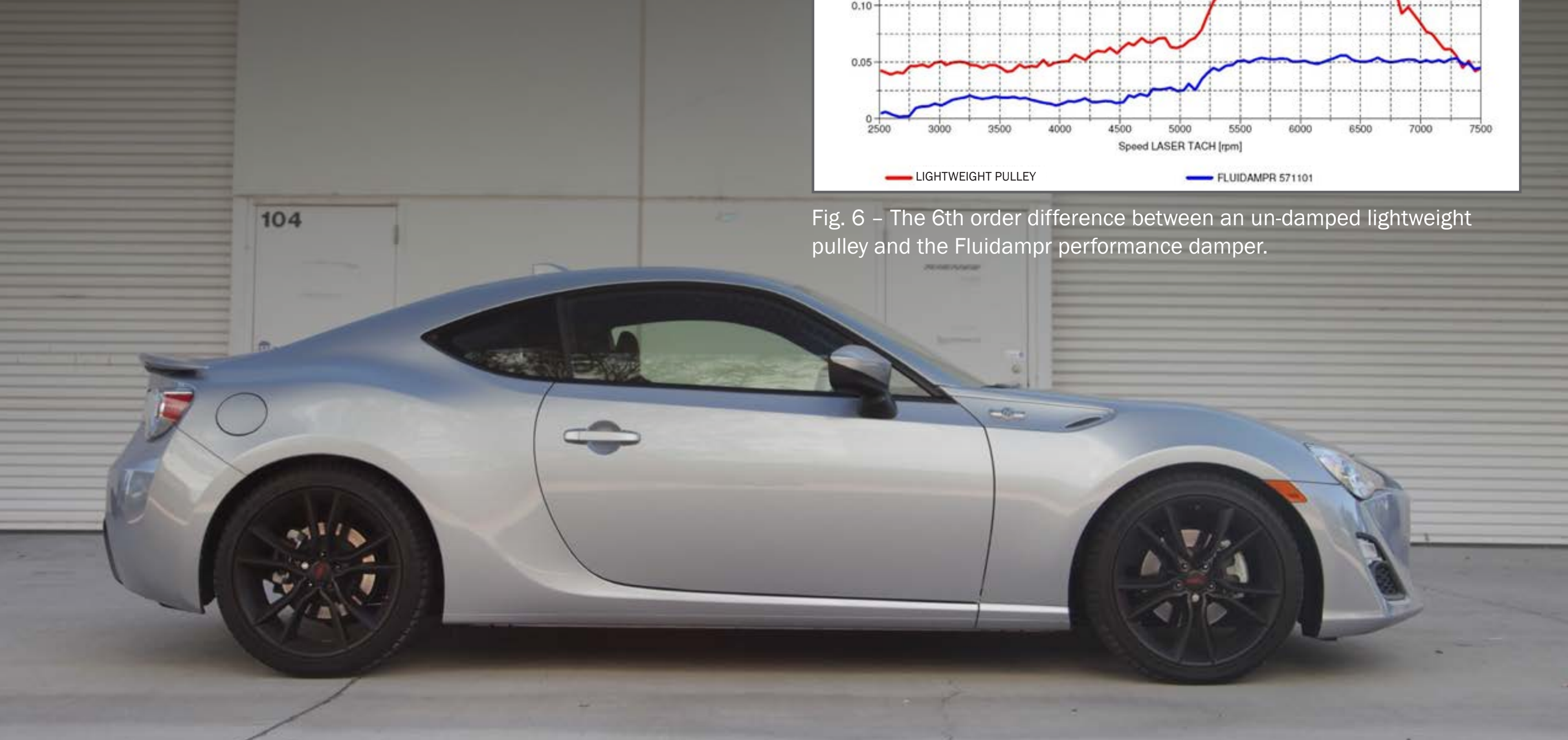


 Photo Courtesy: Power Automedia

**Differences between the Fluidampr performance damper, stock tuned elastomer damper and un-damped lightweight pulley also appear on the dynamometer.**

## FLUIDAMPR #571101, STOCK DAMPER, LIGHTWEIGHT PULLEY TESTED ON SCION FR-S - 2.0L FA20

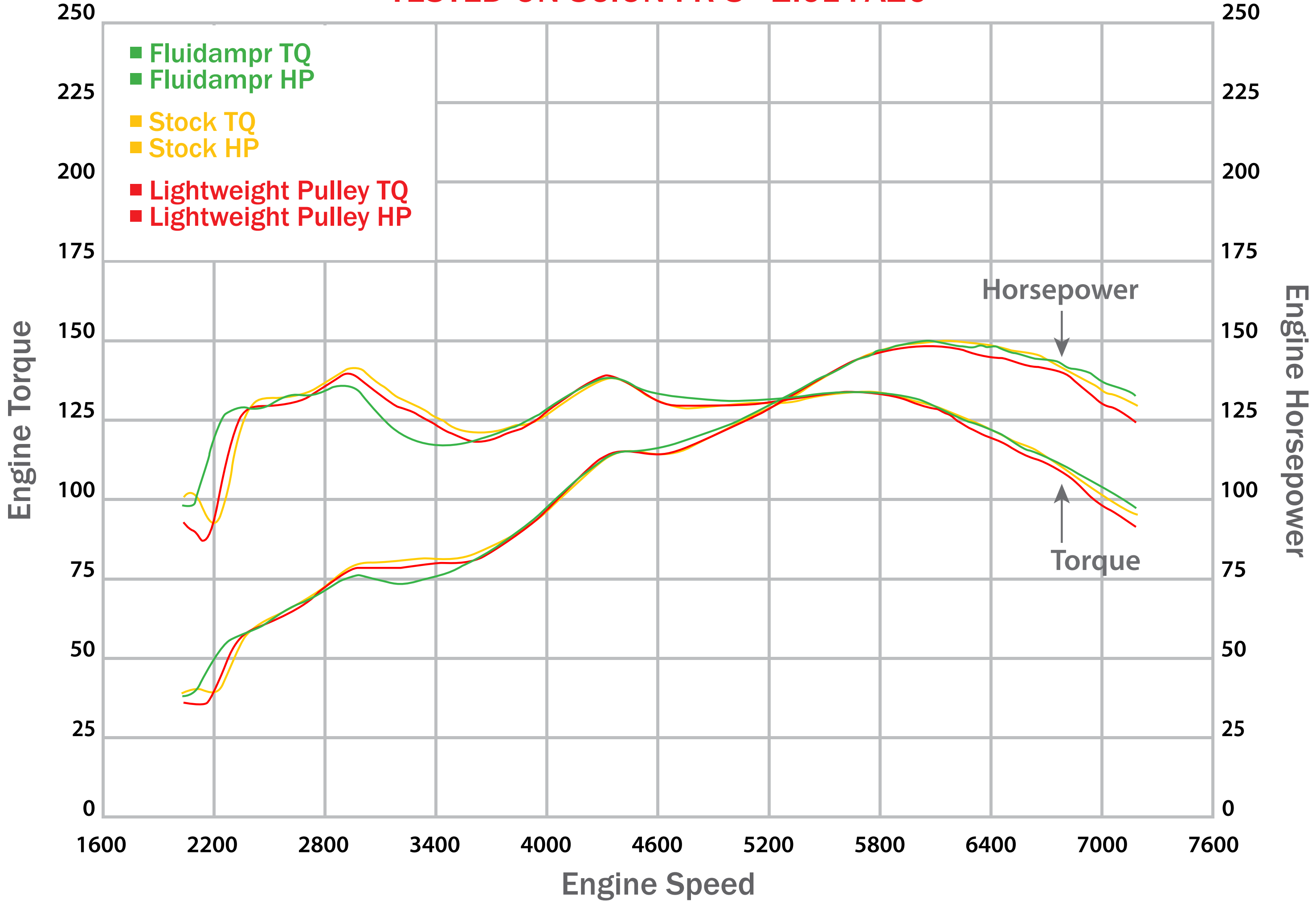


Fig. 7 – Comparative torque and horsepower results. Measured on a Mustang Dynamometer chassis dyno. Your results may vary.


## FORWARD THOUGHTS

Vibratech TVD successfully improved torsional vibration control and efficiency of the Subaru FA20/Toyota 4U-GSE engine with their Fluidampr brand performance damper. It was an ever greater accomplishment to have proven viscous damper feasibility within the same size constraint as the OEM tuned elastomer damper and on a small displacement, short crankshaft opposed-four engine.

Through Vibratech TVD's advanced manufacturing capabilities and distribution partners this Fluidampr performance damper is now available extensively through the performance aftermarket industry. OEMs can also immediately benefit by introducing this and other Vibratech TVD viscous damper applications through their own performance parts catalogs and crate engine programs.

The trend towards higher mean effective pressure per cylinder associated with modern forced induction, smaller displacement engines and consumer demand for extraordinary NVH control in luxury brand automobiles, a quality improvement and potential overall cost reduction exists to control a major source of vibration with a Vibratech TVD designed and developed viscous crankshaft damper. Vibratech TVD, located in Springville, New York, is an ISO 9001:2008 certified developer and manufacturer of torsional vibration dampers for global OEM powertrain divisions in the agriculture, transportation, energy, aviation and defense industries.
Learn more at www.vibratechtvd.com or call (716) 592-1000.



 Photo Courtesy: DSPORT