Where the Rubber Meets the Road ……. Establishing a Base Line

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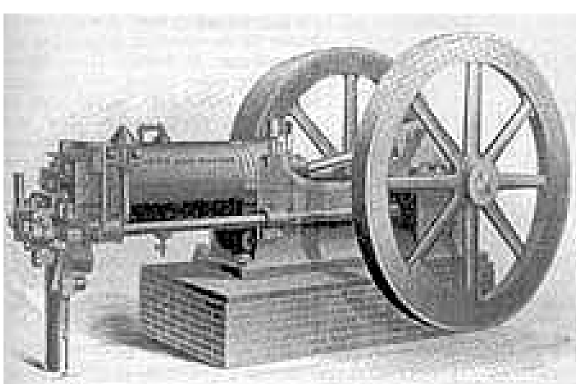
What's a Dyno? How can I use it to measure the differences in engine modifications, and dial in a stock or modified engine?

When talking with fellow automotive enthusiasts and the word Dynamometer or Dyno for short, comes up, the subject can conjure up all kinds of images in ones mind. Things like big horsepower and monster torque, bragging rights at the local pub, and for some, statements like "I don't race a dyno, I race my car". The mystique surrounding this marvelous machine can be incredible.

This article is not about pushing an engine to the limit, instead it's about what I call non-destructive testing. In short, we test the car in the environment in which it will be used. We will briefly examine:

- The history of the four-cycle engine.
- The dynamometer and what it measures.
- A look at various types of dyno's.
- Why Dyno-tune your MG?
- A day at the dyno with Dave Evans of EvanSpeed Mobile Chassis Dynamometer Service, and my humble TD.



Prototype "Otto-cycle" four stroke engine circa 1876

History of the four-cycle engine

Nikolaus August Otto (1832-1891), a German Engineer's stroke of genius was an engine with valves timed to produce *four* separate strokes. His prototype engine ran in 1876, by 1880 over 50,000 "Otto-Cycle" engines were built and sold in the US and Europe, and effectively started the internal combustion industry.

Otto produced an engine in which the piston made four strokes. As the piston moved outward (first stroke), a mixture of air and fuel would be drawn into the cylinder. As the piston moved inward (second stroke), the mixture would be compressed, and at the height of the compression, a spark would set off an explosion. The explosion would drive the piston outward (third stroke), which would supply the power that did the work. As the piston moved inward (forth stroke), the waste gases would be forced out. The cycle would then be repeated. This is the activity that takes place approximately 24,000 full Otto cycles per minute when our MG's are motoring down the road.

Otto's assumption that the intake and exhaust valves should be opened and closed right at Top Dead Center (TDC) or Bottom Dead Center (BDC), is based on the belief that the air-fuel mixture and exhaust gasses start and stop insistently. At very low engine speeds, like 160-rpm peak speed of Otto's original four-cycle engine, this assumption is not far off from the truth. However, as engine speeds increase to 2,500 rpm and higher, gases develop considerable momentum. In addition, finite amplitude waves that are within the induction

and exhaust systems, carries substantial energy and influence mass flow.
This complex phenomenon changed everything. To a great extent, it is the understanding and harnessing of this phenomenon that determines the success of most engine modifications. Induction design, camshaft profiles, cylinder head ports, valve size, exhaust tubing and length, and many other engine components must harness the hidden forces in the flow of gasses if they are to produce optimum power, efficiency and/or economy.

The Dynamometer and what it measures

Rich Gaspard baron de Prony

The need to accurately measure the power output of and engine has been around since the days of the steam engine. In 1821 Gasoard Clair Francois Marie Riche de Prony (1755-1839) invented the "de Prony brake" Dynamometer. This invention was based on ideas of Jean Nicolas Pierre Hachette (1796-1834) and Pierre Simon Girard (1765-1836).

Before we continue exploring the evolution of dynamometers and engine testing, It's helpful to understand the forces that a dyno must absorb and how these forces are utilized to produce measurements of **Torque** and **Horsepower.**

Understanding torque and horsepower can be seam to be complicated and confusing. In simple terms torque as it relates to our MG, is the force that propels our cars down the high way. Horsepower is the force that determines how fast the force (torque) makes it happen.

Torque

Let's take a look at physics behind what "comes out" of an engine and what goes into the dynamometer. To begin, let's define the *force* the engine produces as something we will call *torque*. Richard Feyman, (1918-1988) once described this concept as: "Force is the stuff that is needed to *make things* move in a straight line and the stuff that *makes something rotate* is 'rotary force,' or 'twisting force,' and that is called torque."

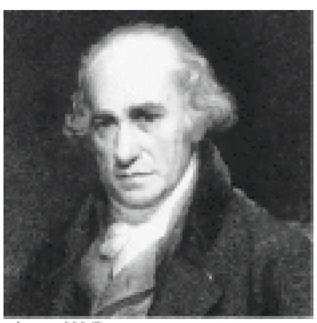
The engine is now generating rotary *motion*. According to Feyman: "If we maintain the analogy between straight-line and angular motion, force times the distance of movement is work, and force times the swept angle of movement is also work"

David Vizard author of the book Tuning BL's A-Series Engine explains torque this way; the lever arm length in an engine is, to all intents and purposes, half the stroke length. The distance from the crank center to the big end centerline, and the force the engine exerts at that radius is due to the pressures in the cylinder. The stroke length can't be changed, at least not without redesigning the engine. The pressures in the cylinder are limited by the amount of air drawn into the cylinder.

So ultimately the torque output of an engine is limited by just how effectively we can make it breath. The more air we can cram into the cylinder then all other things being equal, the more torque the engine will produce. With out the help of tuned intake or exhaust systems, an engine reaches the limit of breathing in a normally aspirated form at 100% Volumetric Efficiency. Volumetric Efficiency refers to how breathing efficiency has been achieved. Unmodified engines usually range between 70 and 85% cylinder fill. VE for a modified engine can be as high as 130%. Airflow generally increases with rpm until it reaches the maximum flow capacity of the valves, ports, intake manifold, carburetors or whichever is the major restriction. Once maximum flow capacity is reached it remains constant despite increases in rpm. At this point the engine becomes “flow limited,” therefore volumetric efficiency and torque go down. If you increase the engine cylinder filling capability, the torque peak moves up the rpm band along with horsepower. The greater the cylinder is filled, the greater the force exerted on the piston by the expanding gases and the greater torque.

An engine is sometimes referred to as a “torque engine,” meaning that it was built predominately with torque in mind. In reality, there is no such thing because any engine that has torque also has horsepower. At some point within the operating range of the engine, as rpm increases, the peak torque will cross over and peak horsepower will increase.

Horsepower


James Watt
PAR

James Watt (1736-1819) a British engineer and inventor of the steam engine, (Based on the work of Thomas Savery and Thomas Newcomen, who created a steam-powered pump called the "Miners' Friend"), dreamed up what we are all searching for: Horsepower. Watt wanted to know how many horses his steam engine would replace. He found that a robust horse could lift a 150-pound weight 220 feet in the air (using a pulley system) in 60 seconds. He eventually settled on the figure that is now the currently accepted standard for one horsepower: 33,000 pound-feet per minute or 550 pound-feet per second.

Torque and horsepower are often confused, although they are closely related in the equation for measuring horsepower. By definition, horsepower is equal to force multiplied by distance; divide by time as expressed below;

$$hp = \frac{2\ pi\ x\ torque\ x\ rpm}{33{,}000}$$

To simplify the equation we can substitute Watt’s 17^{th} Century definition of horsepower, by using the constant 5252. If 33,000 pounds-feet per minute is divided by 2 times *pi* (6.2832), the result is 5252.1008 rounded to 5252 therefore;

$$hp = \frac{torque\ x\ rpm}{5252}$$

If we want to develop a torque curve relative to

$$torque = \frac{hp\ x\ 5252}{rpm}$$

horsepower then;

Since horsepower is equal to torque multiplied by rpm, any torque increase results in a power increase at a given rpm level. This is why it is better to concentrate on improving torque instead of horsepower for the best performing engine.

A look at various types of dyno’s

I think that it’s important to note up front that there are so many variables involved in testing an engine on a dynamometer that trying to relate the results from one type of dyno to the next is foolish. Just getting repeatability on the same dyno can sometimes be very difficult.

An Internet search of the US Patent Office turned up an astounding 2,398,174 patents relating to the Dynamometer. Well I think we can narrow it down to the following types:

- Engine Dynamometer
- Stationary Chassis Dynamometer
- Rolling Road Mobile Dynamometer

- Driving your own Dyno and measuring performance using an Accelerometer

Engine Dynamometer

What is an engine dynamometer and what is it used for? An engine dynamometer primary function is for Research and Development. It is normally located in a test cell. This is an enclosed room where the complete environment is controlled.

There are several companies that manufacture engine dynamometers. The one that I am most familiar with is the SuperFlow SF-901. To my knowledge this product is one of the most accurate engine dynamometers available today.

SuperFlow 901 engine dynamometer

Because we have our engine in an isolated area, we can make changes to the engine, make a pull and immediately review the results. (Pull refers to the handle that is located on the dyno console). Today, the SF-901 can be used in conjunction with a computer and can provide *real-time* graphs of power and torque and other variables.

SuperFlow 901 Operators console

If we wanted to compare the power differences of a well-ported stock cylinder head and let's say aluminum "Laystall Lucas" head, this is the dyno that would be used. The engine dynamometer is also used to establish a base line for a new engine combination.

The SF-901 can monitor over 80 Channel Descriptions, i.e. engine torque, engine power in horsepower, brake specific fuel consumption, volumetric efficiency, all kinds of pressure and temperature measurements.

What most people seam to be interested in is horsepower output. On an engine dyno it is often measured as bhp (brake horsepower). This is number can be misleading if the engine being tested does not have a fan, generator, the exact exhaust system used, etc. Additionally, a correction factor is used. The industry standard corrected data for 29.92 inches Hg, 60 degrees Fahrenheit dry air. These are the highest numbers you will see for an engine tested in this manner.

Stationary Chassis Dynamometer

The British actually use a more accurate description for this dyno, they call it a Rolling Road dynamometer.

Dynojet's Automotive Chassis Dynamometer is widely used in the country for testing and is the officially licensed NASCAR dynamometer. This chassis dyno uses 48-inch knurled, precision balanced drums. The car is actually driven and can attain speeds up to 160 mph.

Dynojet Automotive Chassis Dynamometer

Let's say that we have built what we believe is the ultimate XPAG or XPEG engine. Now we want to install the engine in the car. This is where the rubber really meets the road, well almost.

First off we will find that the horsepower and torque are down from the results that we recorded on the engine dyno. We are now testing our MG at close to 400-500 feet above sea level. Lets say that we recorded a 'corrected' 100 hp at the flywheel. Now we are down to 87-installed hp. That's because the 12 hp we lost is something we never had in the first place, due to changes in air density, and increased temperature in the engine compartment. Next we have losses in the transmission, rear axle, and tires. It's entirely conceivable that the 100 hp we started with is now down to 60-65. If we through out the initial 12 hp we didn't have to begin with we are now producing 72-77 net horsepower.

Rolling Road Mobile Dynamometer

When using a rolling Road Mobile Dynamometer we can have the dyno come to us or locate it in an area that is easily accessible. The reason that I am bringing this up is that I believe that we are very lucky to have one in our area.

David Evans owner of EvenSpeed mobile chassis dynamometer service, is located in upland. David specializes in dyno-tuning British cars. He is well versed in tuning SU's as well as Weber or Dellorto carburetors. In fact, if you have a blown MG with a single carb, David can tailor a needle to provide the correct air fuel mixture from idle to WOT (Wide Open Throttle).

Driving you're own Dyno and measuring performance using an Accelerometer

Tesla Electronics manufactures a very unique product. It's called the G-TECH/Pro. The product has been around for a number of years. In 1995 the original G-TECH product garnered SEMA (Specialty Equipment Market Association) "Best New Accessory." The latest configuration includes new Digital Signal Processing algorithms coupled with a precision Silicon Accelerometer.

G-TECH Performance Meter Pro

The G-TECH can calculate many different measurements that can be gathered from acceleration over time and include; Horsepower, ¼ mile E.T. (Elapsed Time), ¼ mile Speed, 0-60 E.T., Longitudinal G's, 60-0 Braking and Lateral G's. Although I have never used this product, It looks pretty good. And sells for only $140. If this thing works it could provide a substantial savings, compared to the cost of a rolling road dyno session.

Why Dyno-tune your MG?

If you have recently rebuilt your XPAG or XPEG engine, and changes were made to the engine like; increased bore, camshaft change, cylinder head work, larger carburetors etc. Then, in my opinion, it would be beneficial to have you car dyno tuned on a rolling road dyno.

If you have built a completely stock engine; standard bore, standard camshaft, etc. and you want to tune your engine for it best performance and or economy, then I would recommend the engine be run on a rolling road dyno.

Why? In the case of a modified engine the basic design has been changed or altered. If for example the engine bore was increased from 1250 cc to 1328 cc (.080 overbore), then the compression ratio has just increased.

If the compression ration is increased then:

- Cylinder pressure will increase. Brake mean effective pressure (BMEP), is the engineering term that refers to the amount of cylinder pressure that controls the power output of a given engine displacement and is measured on an engine dyno.
- The greater the air/fuel mixture is compressed, thus requiring a change in the mixture calibration.
- The potential for detonation is increased. Note that it is not always possible to hear the detonation occurring.
- Engine timing and the mechanical advance curve may need to be changed.

As changes in an engine are made, (even as slightly as running the new and improved California fuel), re-calibration of the engine is required for optimum performance and economy.

A day at the dyno with Dave Evans

On July 18, 1997, after spending the better part of a year sorting out various engine problems, The engine was run in and it was time to see what I ended up with. Earlier in this article I used the term “Non-Destructive Testing.” My objective was not out to set any new horsepower records but to attempt to dial in the engine combination.

By no means has this engine been built to realize its full potential. That won’t happen until I replace the pistons next spring, raising the compression from approximately 7.9:1 to 9.5:1. Since I have planned to make additional changes to my engine, my goal was to establish a base line so that I could use to measure the differences between modifications.

I had agreed to meet David at Advanced Performance Technology, located in Riverside next to the K&N factory. This helped me keep my costs down.

I pulled in at 9:30 A.M. David had his mobile dyno set up and was ready to start. Prior to running my car I had made sure that the fuel tank was full and that the rear tire pressure was the same for both rear wheels.

The air temperature was 85 degrees Fahrenheit. Air pressure was 15.4 psi. Humidity was 59%. All runs were made with the bonnet closed. The horsepower figures were not corrected to standard temperature or barometric pressure. The dyno uses an Exhaust Gas Analyzer to measure CO% and HC. Measurements are taken at four points; Idle, Low Cruise, Cruise and High Cruise.

Run No. 1, the engine produced 48 hp at 5,000 rpm. The engine was running so rich at Idle that HC was off the scale and the CO% was 8.2

Run No. 2, the engine produced 46 hp at 4,500 rpm CO% was 9.0. Prior to each run David continued to attempt to dial in the mixture.

Run Number 3 the engine produced 40 hp at 4,000 rpm CO% was 10. As you can see so far, the lower the rpm the higher the CO%.

Run No. 4 was the breaking point. The engine produce 34 hp at 3500 rpm and the CO% was off the scale. AT this point we discovered that something was really wrong. David tore into the S&U’s and measured and adjusted everything. He measured my new Moss Motors GJ needles and found one needle to be shorter that the other.

Run No. 5 David fitted new GJ Needles and the engine produced 51 hp at 5,000 rpm. The horsepower was up and the CO% was down a little to 7.8 however HC was still off the scale at idle. At this point I was asking questions like; can we make custom needles to get this sucker dialed in or what?

What the engine was doing was pretty scary. I was running rich at idle, in the midrange it would lean out and at the top end it would run rich again. You would think that I would notice this when driving the car right? Not so, I knew it was rich at idle, but I didn’t realize that It was leaning out in the midrange. With this type of condition it is impossible to even attempt to read the plugs, especially with today’s gas.

Run No. 6 David fitted number 5 needles and the engine produced 50 hp at 5,000 rpm but for the first time the HC were on the scale but at idle they were 1,550! CO% was 10. The engine ran much better that when we started but was still way too rich.

A few months later, I changed the stock muffler for a 3-Chamber Flowmaster. Boy what a difference this made. There was so much back-pressure with the stock muffler, that when the new muffler was installed I could really feel the difference, and the plugs looked much better.

I am once again making another change. This time I am installing a “Derrington” type extractor exhaust system. This will also help lean out the engine. I have been collaborating with Gordon Glass on this project and it will be exciting to stuff one of these under the bonnet.

I hope that you have found this article to be interesting and informative. Next month I will delve into; Understanding the XPAG & XPEG Engines inherent design characteristics, and what effects they have on making modifications to increase Power or Economy.