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X4v2 Testing Update

19th November 2007

Contents

Foreword

The following document explains the torque gains experienced in the latest X4v2 Prototype engine. The Revetec engine project is aimed at development in two key areas. Firstly, we are mechanically increasing the torque lever applied to the output shaft earlier in the stroke when the combustion pressure is at its highest. While the torque figures are higher than both the benchmarked engines, the Toyota engine has advanced engine features such as Variable Valve Timing (VVT) and Variable Length Intake Ports (VLIP) which increase the torque in the lower RPM ranges. Our X4v2 prototype has not utilized such systems, so a benchmark was also made with the GM LS1 5.7litre V8 engine which features a similar top end configuration such as used on the X4v2 and adjusted to the same capacity as both engines being 2.4 litres.

Also note that the X4v2 engine has been developed for the aircraft industry, which has Valve Camshafts ground to provide peak performance at 3,000rpms. The comparison graphs reflect this RPM range, although the focus on the performance area has been the lower range RPMs where most driving occurs. Also note that if advanced engine systems such as VVT and VLIP as well as multi-valve (4 Valves per cylinder) were also incorporated into the X4v2 engine, the torque figures would increase also.

Economy and Driving

In the marketplace there are two stated figures of efficiency being Highway and City cycles.

Highway Cycle:

Highway cycle is the most efficient driving condition as there is little stop/start conditions. If we look at a vehicle driving on the highway at 80-100kph we will see that the RPMs range from 1,300rpm to 2,000rpm depending on the size of the vehicle at the amount of torque available to maintain the desired speed. If torque is higher in this area, then a smaller amount of throttle opening is required, which saves fuel providing the air/fuel ratio is a constant.

City Cycle:

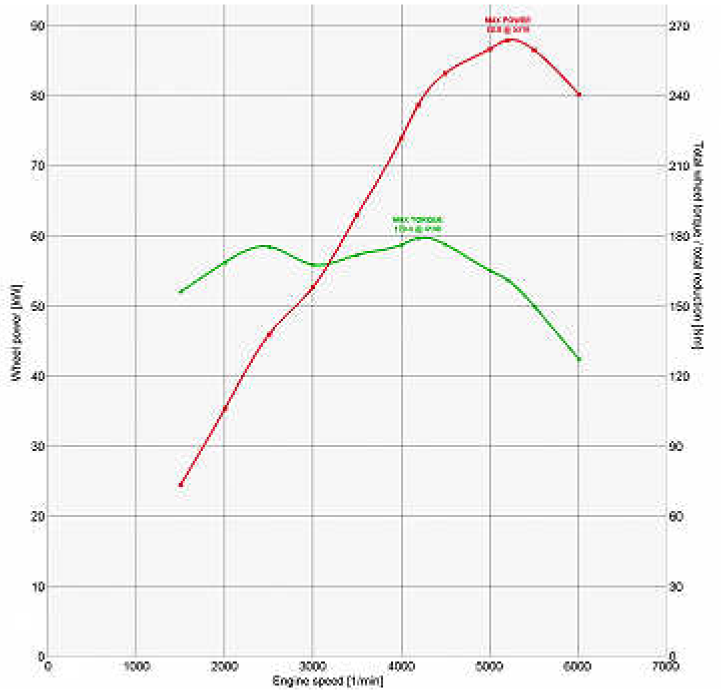
This type of driving requires a great deal more stop starting type of driving. Depending on the type of driver that is in the vehicle this type of driving can provide the most variables as each driver will accelerate at varying amounts. For this reason there are certain test procedures and conditions which are a standard globally. Many drivers find when they drive a vehicle in city conditions will use more fuel than is stated by manufacturers due to being more aggressive on the throttle, an undulating driving environment and variance in traffic conditions. For this reason vehicle/engine manufacturers usually provide small changes to the performance of their product to try and match operational variances. Even though there is this variance, there is mainly one feature of an engine that all manufacturers are trying to achieve. A flat torque curve. Even on city cycle driving, higher torque in the lower RPM ranges plays a big part in efficiency, such as reducing throttle opening required to accelerate a vehicle off the mark. High flat torque is the automotive Holy Grail.

Advances in engine technology to increase/widen torque bands

To increase engine efficiency/economy the car companies have been developing systems to increase or widen the torque band such as:

Variable Length Intake Ports:

Not such a publicized feature as other advances, this feature changes the length of the intake port. A short port provides better responsiveness and torque at lower RPM ranges, and thus a longer intake port provides greater torque in the higher RPM ranges. There are a couple of systems used widely throughout the automotive industry such as the most widely used system of a computer controlled valve that switches from one length to another. This system is the most widely used in the automotive arena. This type of system extends the torque curve by effectively providing two peaks on different RPM ranges and can easily be seen in the dyno graph following.



The Variable Length Intake Ports on this engine dyno graph of the Toyota system clearly shows the effect of this feature in the torque curve (In green).

Other systems such as the Mercedes V8 system which rotate a drum type setup and can vary the length smoothly from the shortest to the longest length is not clearly noticeable in a dyno graph. This system however is best suited to a "V" configuration as the size/shape can be fitted into the valley of the "V".

Given both these systems do work to increase the torque band width in some degree; they all add cost to the development and manufacturing costs of the engines.

Variable Valve Timing:

It is widely known that by increasing the valve opening durations in the higher RPM ranges increases the torque band. While this is a good system for outright performance and quoting higher power and torque figures it is mainly beneficial to the performance vehicle market.

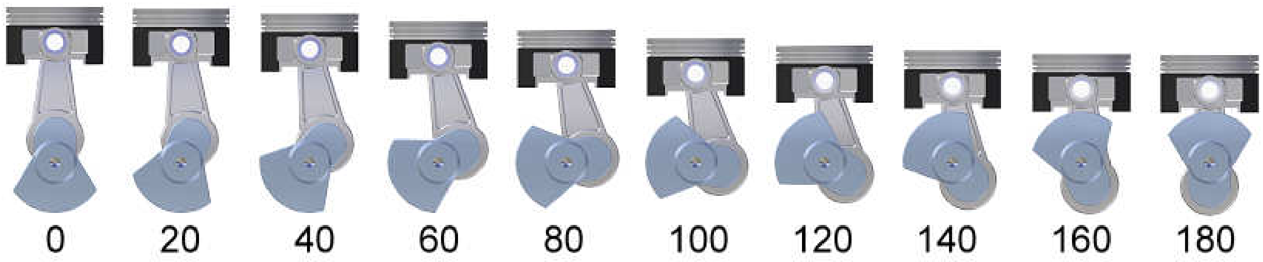
In the higher RPM ranges the valves have less time to induct and exhaust the gasses out of the cylinder heads. For this reason it is advantageous to open the valves for a longer duration to maintain good volumetric efficiency and exhausting. Many people would already realize that a more aggressive cam provides better torque in the higher RPM ranges but in doing so sacrifices low down torque and efficiency. VVT provides the best of both worlds in the mid to high RPM ranges. At the lower RPM ranges, volumetric efficiency is not such a big issue.

Costs of Such Systems

It is commonly known in the automotive manufacturing industry, that to increase an engine's efficiency by 1%, it adds 10% to the cost of an engine. The costs incorporate development design, testing and added manufacturing costs.

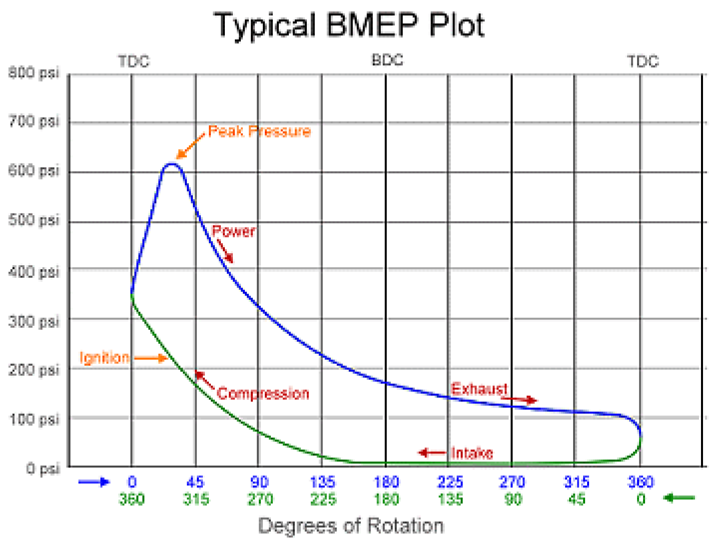
How can torque in the lower RPM ranges be increased further?

Firstly you need to understand the dynamics of a conventional engine. Below is a graphic of what is happening in regards to the torque lever achieved in a conventional engine.



Degrees of Rotation on a Power Stroke

Depending on the length of an engine's connecting rod, the peak torque lever is usually achieved between 60-70 degrees After Top Dead Centre (ATDC), where the connecting rod centerline is at right angles to the crankshaft. If we look at a typical Brake Mean Effective Pressure (BMEP) plot at lower RPM you will notice that the peak cylinder pressure is around 30 degrees ATDC.

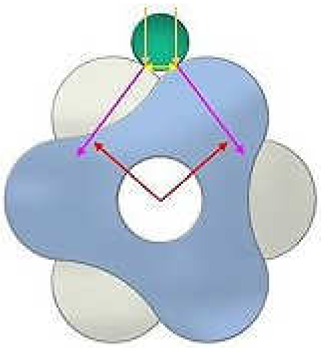


You may notice in the above graphic that the leverage between 20 and 40 degrees ATDC is not desirable. For this reason a conventional engine's torque is not at its peak at the lower RPM ranges. As the revs increase the peak pressure moves away from TDC increasing efficiency. The two start to match at around 3,000-4,000rpm where a conventional engine peaks in torque.

Is there a Solution?

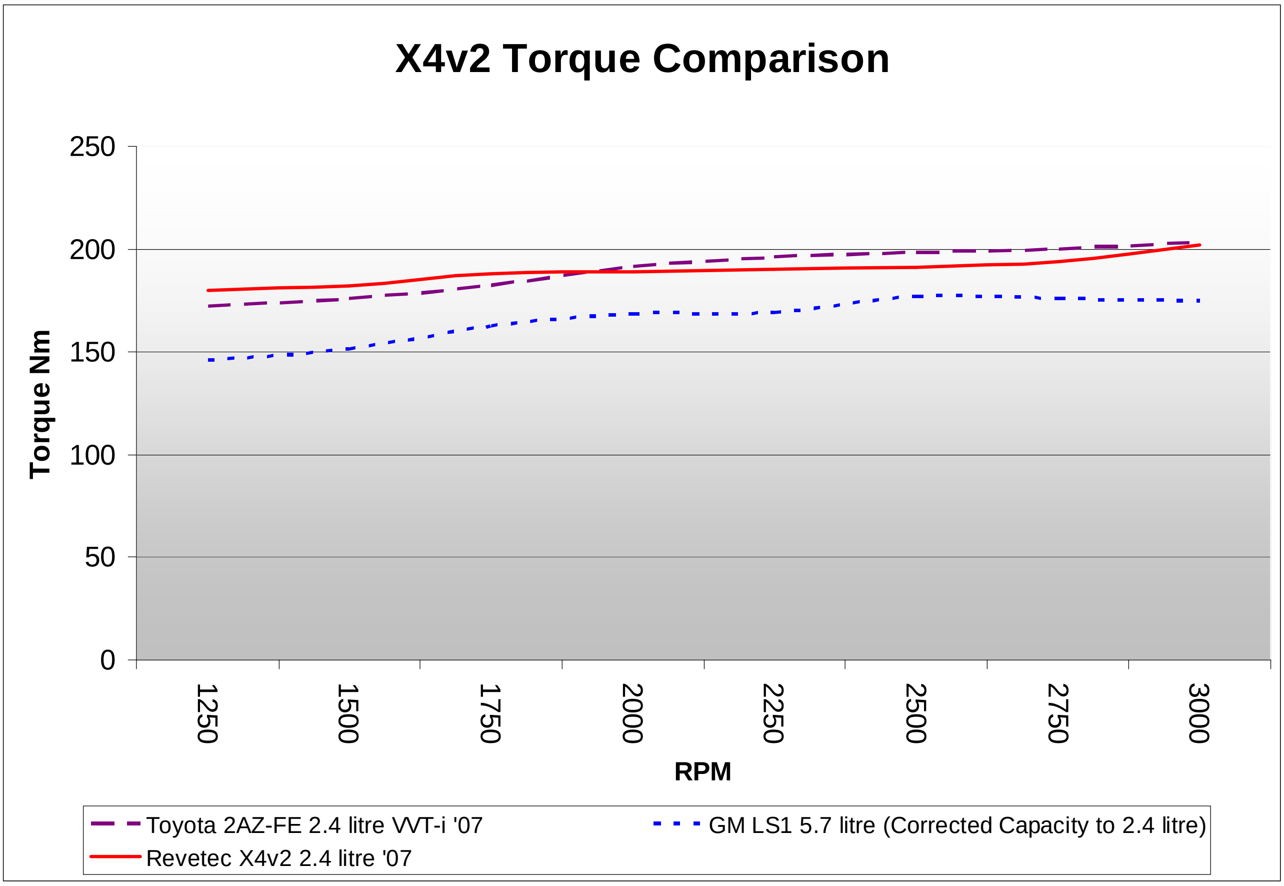
Not in a conventional engine Crank/Connecting rod design.

As you may know, Revetec has been developing a new concept engine that does not need the use of a crankshaft. The reciprocating force is transferred via counter-rotating three lobed cams which we call "Trilobate Cams". In short, two bearings mounted underneath a piston spread the two trilobe cams apart. One cam is mounted onto the main shaft and the other is reverse geared to provide forward driven force. This system allows us to provide a longer torque lever earlier in the stroke than is possible with a conventional engine. The torque lever can be seen in the graphic to the left. Note: The Trilobe Cams shown are a graphical representation only. As the Trilobe Cams rotate, the torque lever is maintained for a greater degree of rotation making efficient use of the BMEP peak pressure as it moved during RPM and Load changes.



How much increase is possible?

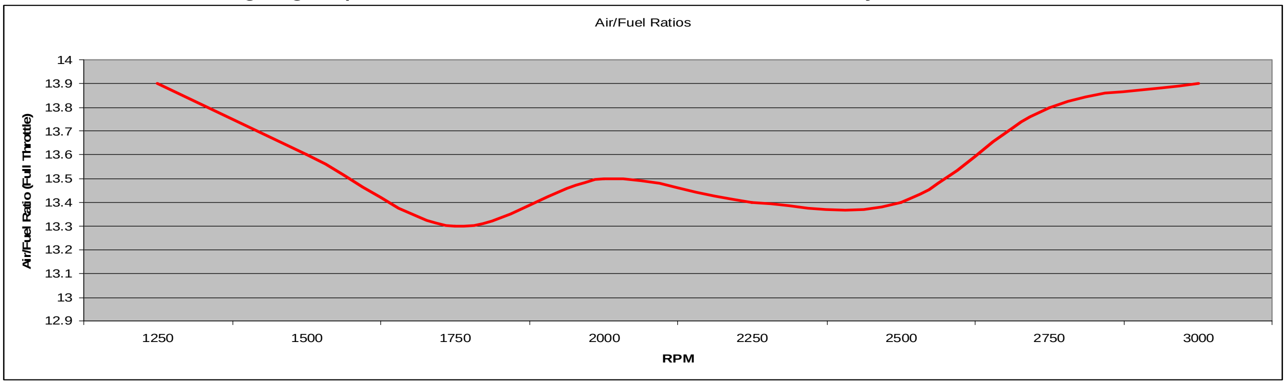
We have estimated that the potential increase in the lower RPM ranges is anywhere up to 30%. Below is a torque comparison with two engines in the marketplace. Firstly the purple torque line is the current Toyota Camry 2AZ-FE 2.4litre engine. This engine has 4 valves per cylinder, Variable Length Intake Ports and Variable Valve Timing. All features that we currently don't have. The second engine shown in blue is the General Motors LS1 engine which as a similar top end to what we are currently using. The LS1 engine is a 5.7 litre so the figures have been scaled down to 2.4 litres.



Even though we are not using VLIP, VVT and 4 valves per cylinder, we have achieved:
4.65% increase in torque @1,250rpm,
3.41% increase @1,500rpm and
3.3% increase @1,750rpm.
As a true comparison between our engine technology and a conventional engine we have benchmarked to the LS1 (Figures scaled down to 2.4 litres) and we have achieved gains of:
23.5%@1,250rpm,
20.6%@1,500rpm,
15.83%@1,750rpm,
12.5%@2,000rpm,
12.5%@2,250rpm,
8.2%@2,500rpm,
10.25%@2,750rpm and
15.5%@3,000rpm.
Not only have we increased torque over these engines in these rev ranges, we have achieved it with a piston stroke of only 65mm. The Toyota engine has a 96mm stroke.

Air/Fuel Ratios

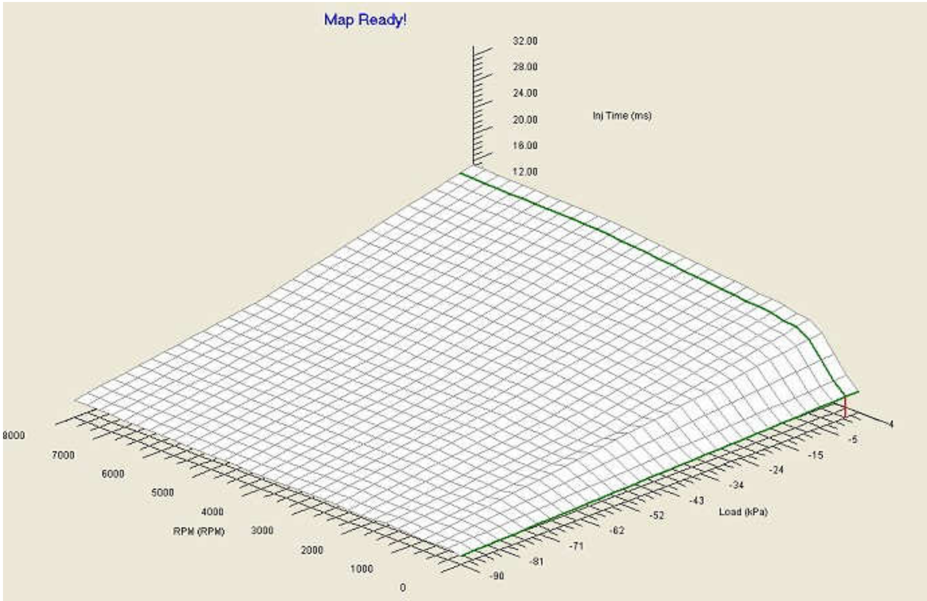
Air/Fuel ratios using high speed Lambda sensor under the above dyno test were as follows:



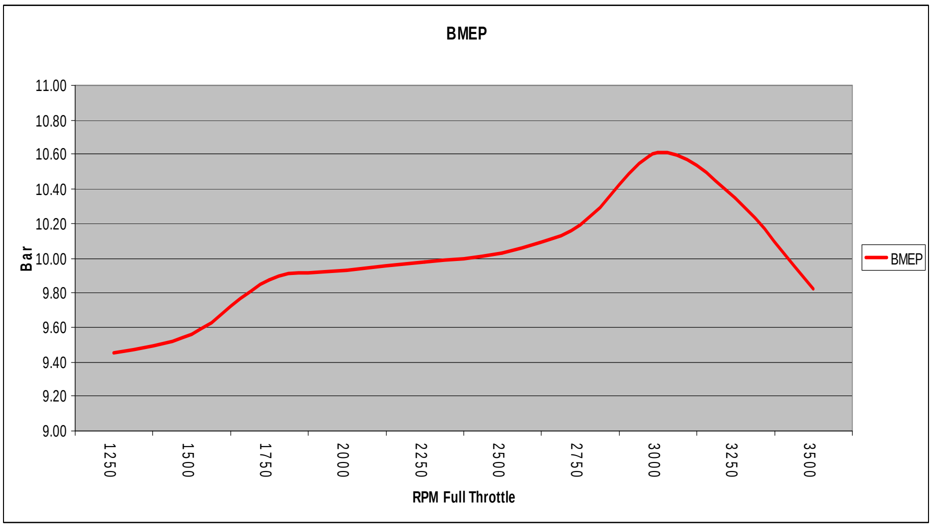
Under previous testing with Mahindra, we proved that even though the Lambda sensor was reading 14.7:1@ 2,000rpm it was also reading 14.7:1 at 4,000rpm although the fuel consumption was the same in both instances. The Lambda readings above are only a guide to the combustion process and is not an outright total fuel mixture. A design feature of the Revetec engine is extended dwell at TDC, which allows us to operate our engines at a leaner mixture, especially >2,000rpm. Further adjustments will take place over the coming week to lean the mixtures between 1,500-2,700rpm. Note: Peak Torque was produced will a full load mixture of 13.9:1. Fuel consumption figures will need to be performed in a vehicle once all programming and testing is completed.

Fuel Map and BMEP

Fuel map has been completed to 4,500rpm currently as we have designed the X4v2 as an aircraft engine operating at 2,700-3,000rpm as per the Aircraft engine stated in our Federal Government Grant. Maximum Power and Torque have been designed to peak at these RPMs for maximum performance with a propeller. Light aircraft engines usually have a top end RPM of 3,500rpm. Over the next month we are planning to modify the X4v2 further to increase the Power and Torque RPM ranges for other applications such as automotive use.



Above is the 3D fuel map used under the dyno testing performed in this report.

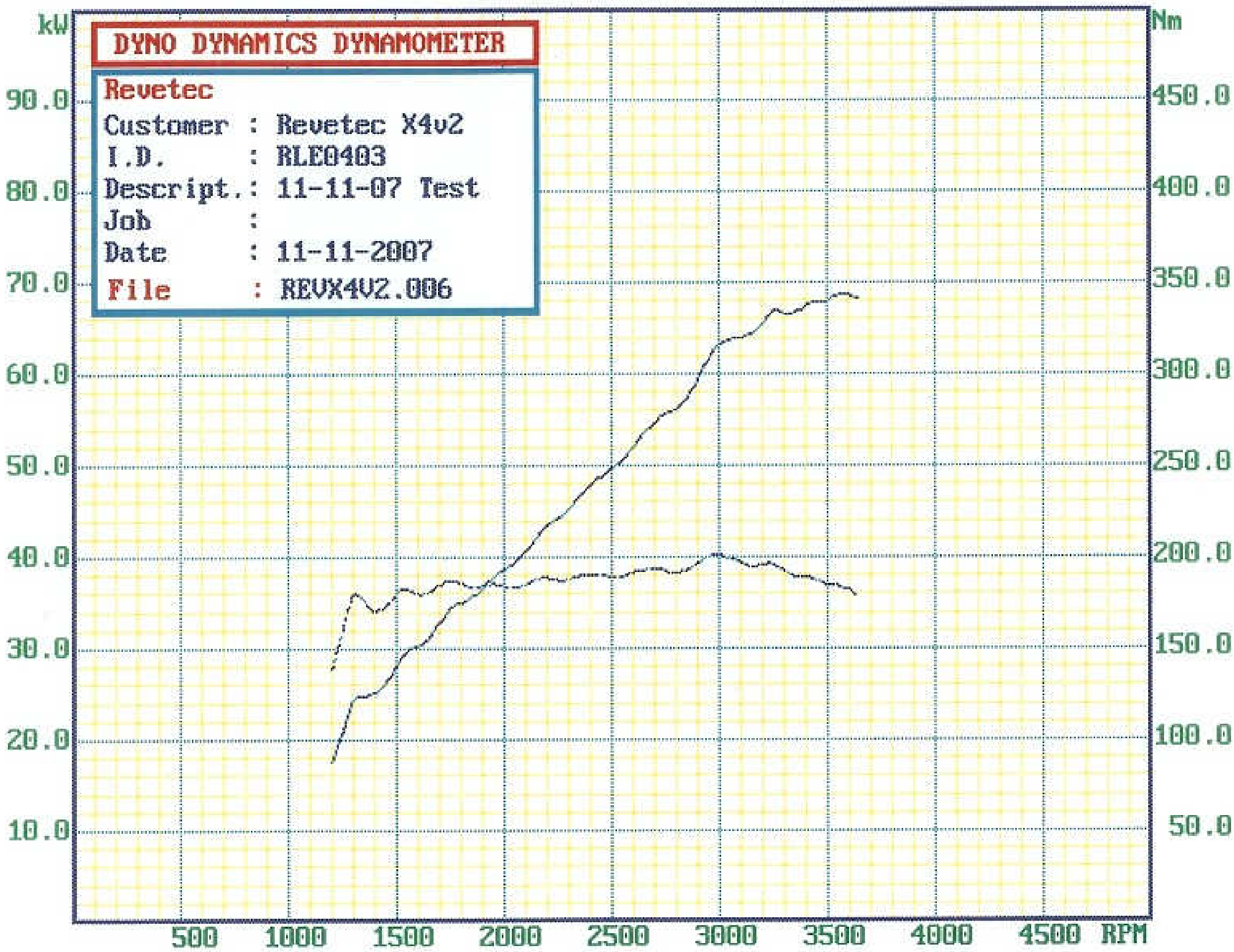


Above is a BMEP graph of the X4v2 2.4 litre engine showing at peak torque, a peak BMEP of 10.6.

This slightly exceeds an AMG Mercedes 6.3 litre V8 of 10.5Bar and exceeds the General Motors LS1 5.7 litre engine of a BMEP of 9.3Bar.

Inertia Dynamometer Ramp Test without SAE Smoothing

Below is the actual dynamometer ramp test performed on the X4v2 engine on the 11th November 2007. This dyno graph is supplied in raw form without SAE smoothing. As you can see from the graph, the engine was configured as a light aircraft engine as per our Federal Government Grant to provide maximum Torque@3,000rpm. Our next planned phase of modifications is to replace the valve camshafts and modify the piston assemblies to achieve an automotive RPM range.



Note: We have achieved a torque figure of 180Nm@1,300rpm.

Engine Specifications

Technical Data	Revetec X4v2 Prototype
No. of Cylinders	4
Engine Capacity	2382cc
Bore	108mm
Stroke	65mm
Over/Under Square Ratio	1.66:1
Compression Ratio	9.5:1
Max Power	69kW@3,600rpm
Max Torque	202Nm@3,000rpm
Induction	Normally Aspirated
No. of Valves	8
Valve Arrangement	OHV 2 per Cylinder
Valve Size	In:44mm Ex:39mm
Valve Lift	10mm
Camshaft Type	2 x Single Hydraulic
Camshaft Profile	Aircraft (3,000rpm)
Engine Management	Haltech E8
Fuel Injection Type	Sequential Multipoint
Fuel Injector Type	Subaru EJ20
Ignition Type	Dual Waste Spark
Ignition Coil Type	EC Custom
Spark Plugs Type	NGK - DCPR8E
Spark Plug Gap	1.1mm
Engine Proto. Dry Weight (dressed)	131kg
Estimated Prod. Weight (dressed)	105kg
Engine Width (dressed)	740mm
Engine Height (dressed)	550mm
Engine Depth (dressed)	460mm

Conclusion

While the X4v2 prototype is not yet fully optimised, testing on the dynamometer has proven that the Revetec design produces higher torque in the lower RPM.

We have benchmarked the X4v2 prototype against the latest 2007 Toyota 2AZ-FE engine that features four(4) valves per cylinder, Variable Length Intake Ports and Variable Valve Timing which has shown an increase in Power and Torque in the lower RPM ranges.

We have also benchmarked the X4v2 prototype engine against GM's LS1 engine showing that using a similar top end that we have achieved an increase in torque up to 23%, with an average of 15% increase in the 1,250rpm-3,000rpm range.

We have shown a 3D fuel delivery map used on the dynamometer test showing a consistent fuel map.

We have achieved a 10.6bar BMEP result at peak torque, which is better than the AMG 5.3litre Mercedes engine which has 10.5bar, and the GM LS1 5.7litre engine with a BMEP of 9.3bar.

We have provided a high speed Lambda graph from the dyno ramp test showing our air/fuel mixtures during the test of between 13.9:1 and 13.3:1. A conventional engine under full load is usually between 13.5:1 and 13.0:1.

We have supplied the raw inertia ramping graph (without SAE smoothing) of our dynamometer test showing high torque of 180Nm starts just above idle and holds reasonably flat throughout our designed RPM operating range, peaking at 202Nm.

In our forward we discussed the effects of higher torque and how they relate to city and highway driving cycles also.

Conclusively, we can say that the Revetec engine design provides substantially greater efficiency than a conventional engine of the same configuration. Further refinement and adding existing systems used in the automotive marketplace will increase efficiency further.

Kind regards

Brad Howell-Smith
Chairman
Revetec Holdings Limited