Experiments in Tuning an Automotive Engine

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Contents

1 Preface

The spectrum of settings in which an engine will run is large but there is only one set of settings that is optimal.

This document describes the techniques that were developed for optimizing the settings of an engine. This was in conjuction with the development of the Msqdev [1] system which provides an interface for automated tuning of a Megasquirt [2] based ecu.

2 Constant Idle Speed Tuning, Maximize Rpm

When an engine is at idle (with no adaptive idle control) at a constant throttle position and constant load, any change in fuel or ignition should have a direct change in engine rpm. And a higher rpm would indicate that more power being produced.
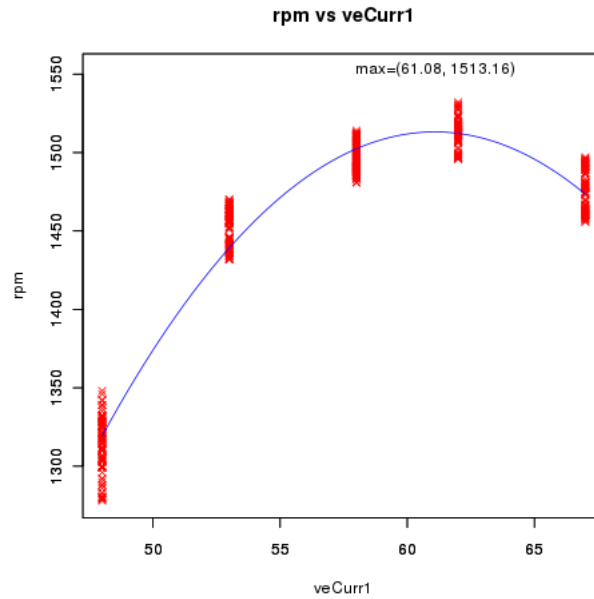
Figure 1: Varying veCurr1 vs rpm at idle.

3 Constant Road Speed Tuning, Excessive Error

It should be possible to drive a car at a steady speed (constant throttle position) while allowing the settings to be varied. And the results should provide peaks at various points through out the map.

Testing was performed by driving a car on a flat road at a steady speed and then allowing points to be varied.

Several problems appeared during testing. The first is that it is very difficult for a person to precisely position the throttle. Any slight movement will cause a disruption of the position. The second is in detecting slight amounts of acceleration. Because the amount of change from varying settings is on the order of 100 rpm even the slightests acceleration will ruin the results.

These problems did reveal a benefit of the current setting variation algorithm. Previously settings were varied from a left extreme to a right extreme. Currently settings are varied from the center to the left extreme, then back to the center and to the right extreme. The benefit of the current algorithm is that the center point will indicate if any errors occured. If no error occured the center point will be the same during both times it is tested. If an error occurs, such as acceleration, the center points will be shifted apart (see Figure 2).
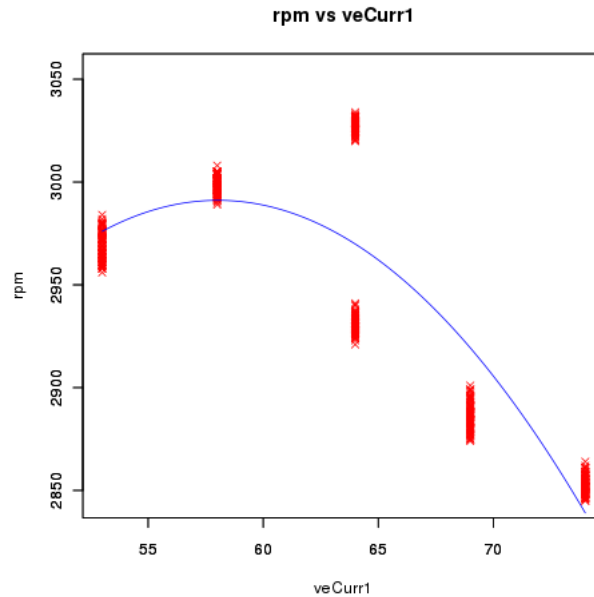

Figure 2: Constant road speed tuning with a large error (deceleration) indicated by the center left right algorithm.

4 Constant Road Speed Tuning with a Throttle Stop

To minimize the error caused by a human driver controlling the throttle (as was discussed in Section 3) rigid stops are used underneath the gas pedal to provide a fixed depressed position. The stops were cut from tubing in to various lengths and they can be substituted as approperiate for a given test. It should be possible to substitute different length stops and the engine rpm should stabilize at different points.

Testing on level ground revealed that only one of the stops, which corresponded to a very slight throttle opening, would result in a stable engine rpm. All the other stops resulted in steady acceleration of varying degrees. The throttle stops of larger openings would need an increased load, such as from an incline, in order for the engine rpm to stabilize.

The tuning results show a significant increase in precision. There was no discernable separation in the center point indicating there is a very low amount of error (see Figure 3).
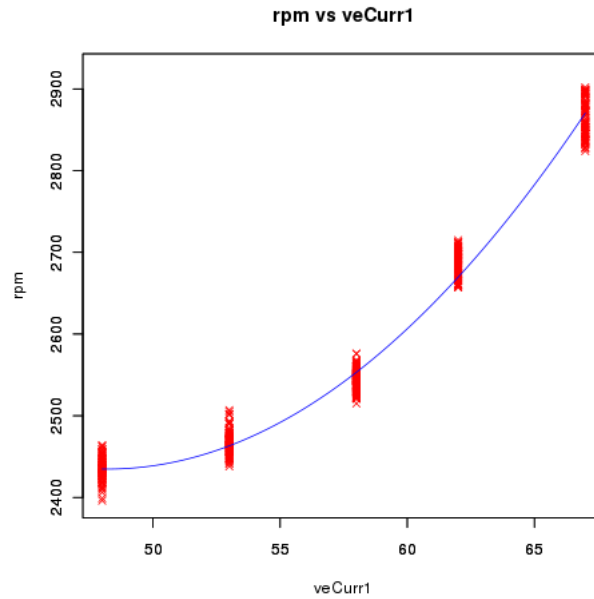

Figure 3: Variation of settings while using a throttle stop.

The throttle stop is clearly a valuable addition to steady state tuning and should be used in all testing situations.

5 Constant Road Speed Tuning Impractical

For a given load there is a single throttle position in which the rpm will stabilize and the speed will remain constant. Because the throttle stops (Section 4) are a fixed imprecise size and are not easy to adjust it is too difficult to maintain a constant speed.

Constant acceleration tuning (Section 6) should be more forgiving in this respect because it does not require stabilization and it is not depenent on any specific throttle position or load.

6 Maximizing Acceleration: Theory

Under a constant load and a constant throttle position (assuming the throttle position is such to cause acceleration) a constant acceleration should result [1].

In contrast to steady state tuning where a single setting is varied at a single point, acceleration goes through through many points and there is not enough time to vary the settings at each point. If two trials are performed under the same conditions (load and throttle position) with different settings these trials can be compared.

Because it would be nearly impossible to record two sets of data with exactly the same starting and ending points (rpm or time) it is necessary to process the data in order to make a valid comparison.

One solution is two remove data from the ends of each set of data until they span identical intervals. The starting and ending rpm ranges could be reduced to only those rpms in common for example. Depending on the amount of error in the rpm readings there will be error in which the starting and ending times are calculated. It is estimated that this could be as much as a tenth of a second. But this error should be minimized over many trials. Also, if many points in one trial are better than those in the other trial it should cause the end points to diverge which should also minimize the contribution of this error.

If optimizing for maximum acceleration using a plot of rpm versus time the settings in which an rpm interval is covered in the shortest period of time would be the more optimal solution.

Unlike steady state tuning this method does not lend it self to hill climbing. Since many variables are changed it may be better solved using Genetic Algorithms.

7 Maximizing Acceleration: Initial Results

Initial results of acceleration tuning are very promising. As is seen in Figure 4 the data points of trial 1 are lower than trial 2 indicating that trial 2 produced a greater acceleration (steeper slope, shorter time period). It is capable of

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[1] Strictly speaking the acceleration will not be constant due to changes in load and varying performance of the engine. For the purposes of this document this term will be used to refer to acceleration as opposed to no acceleration.

detecting very minute changes in power output, as in the figure which shows less than a tenth of a second time difference between the two results. It is susceptible to changes in load just like every other test but these errors can by ensuring consistent test environments and performing many trials.
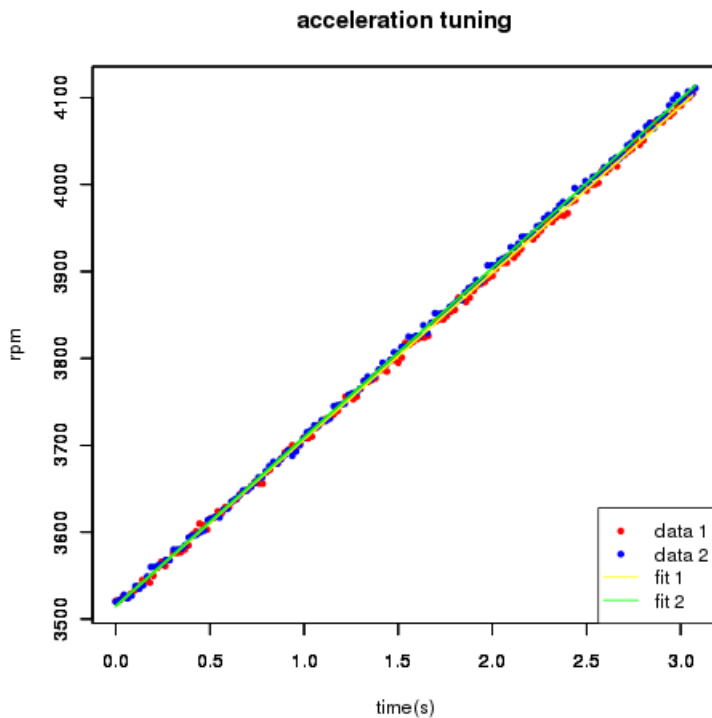

Figure 4: Comparison of two acceleration trials in 4th gear with a 52 cm throttle stop from 45 to 65 mph.

8 Throttle Response Tuning

(in development)

The biggest difficulty with tuning throttle response is producing a repeatable movement of the throttle. One possible solution is to record all the different types and then when a match is found with different settings it can be used for comparison. Another possibility is to build a mechanical apparatus using a solenoid or some other device which precisely actuates the throttle.

References

[1] J. Mahler, "msqdev: file based control of a megasquirt ecu.." `https://github.com/jmahler/msqdev`, 2011.

[2] B. Bowling and A. Grippo, "Megasquirt." `http://www.bgsoflex.com/megasquirt.html`, 2011.

[3] R Development Core Team, *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2011. ISBN 3-900051-07-0.