THE CALIBRATION AND ADJUSTMENT METHODOLOGY APPLIED TO GENERAL ENGINE MANAGEMENT SYSTEM FOR SPARK IGNITION TURBO ENGINES

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Abstract. *This work presents an experimental procedure to find the best calibration for a spark ignition engine. The ECU control allows adjustments in the ignition and fuel maps, beyond configuring the whole system according to the sensors and actuators types. The ignition dwell time and the best moment to start the injection fuel can be controlled accurately by this system. This work describes the experimental apparatus and also the methodology to accomplish the adjustments in the ECU maps, seeking to obtain the best performance. Comparison performance data for the standard engine and the proposed configuration are presented here, showing a 50% gain for an engine of 1300 cm^3, four cylinders in line, and 16 valves. The standard configuration is an aspirated engine with an original ECU developed aiming - vehicle emissions, engine power output, fuel consumption and engine lifetime in order to best meet requirements. A new configuration consists of adding the GT12 turbocompressor with the intercooler system, oil cooler and the MoTec M4 ECU also responsible for controlling the boost pressure of the turbo compressor electronically. This engine with the new configuration will be used in airplanes, so the exhaust emission is not an important parameter at this job.*

Keywords: *Turbo-compressor, boost-drive, performance, calibration, intake pressure.*

1. Introduction

Up until recently, ECU manufacturers made stand alone units for the control of engine and ABS systems. These units contained memory chips for storage of configuration information. These chips could be removed from the unit, read and then the data could be analyzed. This data was not deliberately obscure, however when downloaded it was simply a sequence of numbers and makes very little sense. Some companies (chip tuners) started to specialize in making sense of this data. Functions of small sections of this data was guessed at and then altered to see its effect on the tuning of the car. This was not satisfactory but sometimes the car went a little faster. In these early stages, there were very few cases where there was any real knowledge of what was happening within the ECU. The challenge to the chip tuners is now even greater than it was in the early days due to the increasing complexity of the ECU's and the advances made in microprocessor design. Newer ECU’s have many times more data and code than they used to. Analysis of this information is now very time consuming. As well as the ECU’s containing far more code and data as they used to, access to the information is now far more difficult. Memory chips now tend to be integrated into the microprocessor itself. This means it is no longer possible to replace the memory chip as it was before. Some companies resorted to removal and replacement of the entire processor, but this is a time consuming and expensive method. Even when the chips are removed, it is often not possible to read and rewrite the data on them. ECU manufacturers can use complex encryption algorithms to stop the internal ECU information being accessed in “ECUTEK, (2004)”. The “MoTec M4 ECU, (2004)” has been chosen for this work because it allows configuring the system to operate with any kind of internal combustion engine. The entire procedures of programming and adjusting can be done easily with this type of ECU, been a powerful tool for scientific combustion engine researches. A large application of this ECU can be found in racing teams. Some categories of racing cars use this system due to a large number of options in the program setup, the help information quality and good technical support. The additional MoTec information could be found at “MoTec M4 ECU, (2004)”.

2. Objectives

The objective of this work is to demonstrate how to configure the whole Engine Management System according to the components of the injection and ignition electronic system and also the methodology to accomplish the adjustments in the ECU maps, seeking to obtain the best performance.

3. Methodology

First of all is important to establish the expected objectives according to the engine application, so to the very light airplane category, 0.7 kW produced per kilo of the engine would be a satisfactory initial parameter. Beyond break power, a great flat torque curve is necessary. A methodology will be presented to accomplish the adjustments in the ECU maps. The performance curves of a spark ignition, gasoline fueled, 1300 cm^3, four cylinders, 16 valves FIRE engine were acquired in the bench dynamometer to characterize the initial conditions of the standard engine with the original ECU for automotive application in conformance with "NBR ISO 1585, (1996)", and presented at Fig. 1.

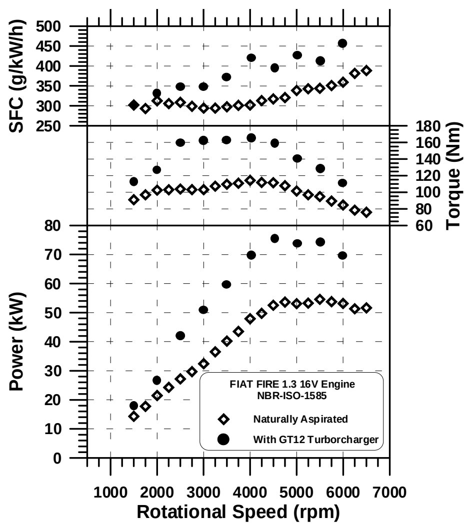

Figure 1 – Naturally aspirated and turbocharged FIRE 1.3 16V engines performances (method NBR-ISO-1585)

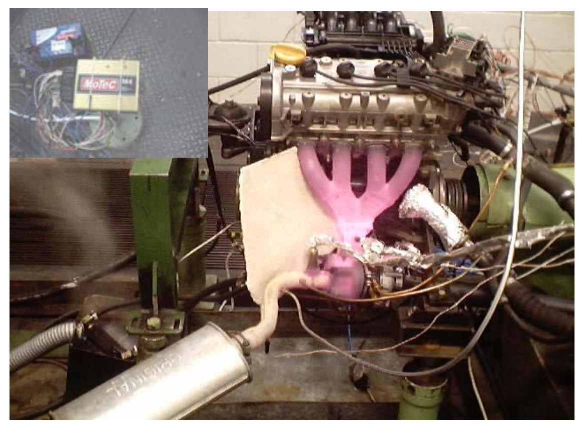

Figure 2 –Test assembly showing the GT12 turbocompressor, the FIRE 1.3 16V engine.

For the new engine configuration the compression ratio has been kept the same even with turbocompressor, but the only component changed in the combustion chamber was the spark plug due to higher temperature. The spark plug for the aspirated configuration was NGK DCPR8E-N and for the turbo version it has been changed by the BOSCH XR 5 DC to increase the dissipation of heat from the spark plug avoiding knock phenomenon. The objective of this new configuration is to use the engine without changing anything inside of it becoming the modification as cheaper as possible. A lower boost pressure must be used due to the standard compression ratio (9.5:1), but it is compensate by the modification cost. The figure 2 illustrates the modifications made in the engine to adequate it for the new application (turbocompressor, oil cooler, intake and exhaust systems, intercooler and all electronic components). Beyond the general sensors from the original system, the barometric air pressure sensor (BAP) was installed to correct the altitude, yet the engine volumetric efficiency has been determinate by the software through this correlation (MAP/BAP)*100, in percentage. The reason for this modification is the possibility to compensate the engine volumetric efficiency in altitude measuring the barometric pressure and adjusting the intake pressure boost of the compressor precisely, allowing keeping the same engine performance independent of the airplane altitude. So a drive boost electrovalve (PIERBURG Mod. 7.21493 00) was installed to control the pressure in the intake system, controlling the flow through the wastegate valve (ALLIED SIGNAL, Mod. 98-266). In order to shorten the development time it has been used the following strategy:

- To begin from the closest calibration available from another application;
- To spend the necessary time to study and to choose the best options for the main setup;
- To check all components through the diagnostic test before starting the adjustments;
- To base in the application methodology described in this work.

The figure 3 demonstrates the established stages to facilitate the understanding of the whole development process.

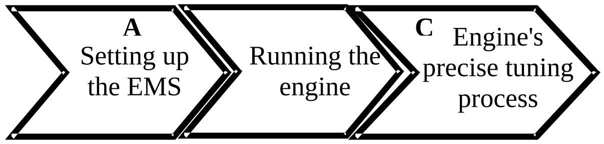

Figure 3 – Mapping procedure scheme

For the “A” stage the first step is to set the parameters of the main setup, as seen at Tab. 1.

Table 1 – Main Setup Parameters

Main Setup		
Parameter	Value	Definition
Injector scaling (IJPU)	10 ms	Pulse width corresponding to 100 % in fuel table
Injector operation	1	Group fire injection
Injector battery compensation	4	Injector battery voltage dead time compensation curve
Efficiency calc method (EFF)	2	Method for efficiency calculation
Load calc method	2	Method for load calculation
Load sites selection (LDS)	200	Selects the efficiency range of the load sites
Number of cylinders (CYLS)	mode 24	The numbers of cylinders considering the type of syncronism.
Ref sensor type	2	The type of the reference sensor (magnetic)
Sync sensor type (SYSN)	0	Type of the synchronism sensor (Not used)
Ref / Sync mode (REF)	83	The relation of missing teeth / cycle
Crank ref teeth	60	teeth number including missing teeth
Crank index position (CRIP)	95º	Missing tooth position BTDC
Ignition type (IGN)	1	Fall trigger
Number of coils (COIL)	2	Number of ignition coils
Ignition dwell time (DELL)	enabled	Coil on time
Ignition delay time	50 us	Ignition delay time from the command and when it actually fires

In order to compensate for changes in injector flow rate, injector type or fuel pressure, the IJPU parameter allows further changing the whole fuel table without adjusting all the table values. Note that lower IJPU values are required for turbo charged engines because the end injector pulse width is increased due to air density compensation. If the maximum value in fuel table falls below 60% then the IJPU setup parameter should be decreased to increase the table values. This ensures that fuel table has sufficiently fine resolution. Similarly if fuel table values reach the high levels, as 99.5%, then IJPU should be increased to decrease the table values. The injector operation (IJOP) defines the type of the injection system. In this work the group fire injection for 4 cylinders is the best option because the system doesn’t need the synchronism sensor due to the fact that the emissions in the exhaust are not relevant. In this work were used four BOSCH top-feed injectors for the standard automotive engine. The injector battery voltage dead time compensation (IJBC) is dependant of the injector type. In this work was used a built in table for a 16 ohms injector. The user could define a specific table for a new injector. The efficiency and the load calculation method (EFF and LOAD) are used as the load index for the various fuel and ignition calibration tables. In this work the engine volumetric efficiency has been determinate by the correlation EFF=LOAD=(MAP/BAP)*100. The load sites selection (LDS), selects the efficiency range and the steps of the intervals. In this work the 0 to 200% range in step of 20% was chosen due to the maximum boost pressure of the turbo compressor corresponds of 160 % of the efficiency. The numbers of cylinders (CYLS) are 4 cylinders, 4 stroke, synchronized once per revolution, since the synchronism only occurs once per engine revolution the ignition outputs are used in a wasted spark mode. The synchronism sensor type (SYSN) defines which input type the synchronism sensor is connected to and the sensor type. In this work the synchronism sensor is not required. The reference/synchronism mode (REF) determines the relation between the numbers of missing teeth and how many revolutions per cycle. In this work the injectors are fired once per revolution and the trigger type is a falling trigger. The figure 4 shows the trigger types for the 60 teeth 2 teeth fault flywheel:

Table 2 – Sensor Setup

Sensor setup	Value	Type
Throttle Position (TP)	3	Linear
Manifold Pressure (MAP)	-1	Strain Gauge
Air Temp (AT)	1	NTC
Engine Temp (ET)	1	NTC
Aux Temp (Aux T)	0	Not used
Aux Voltage (Aux V)	-4	Strain gauge
Lambda Sensor (LA)	0	Wide band

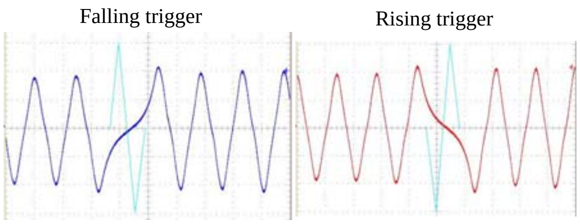

Figure 4 – Trigger types for ECU reference

The crank index position (CRIP) is used to define the position of the reference signal index tooth relative to TDC cylinder number one. The crank index position may be calculated by positioning the engine to the reference index tooth then recording the number of crank degrees the engine must rotate to reach top dead center for cylinder number 1 on the compression stroke. To set this parameter accurately the value should be adjusted until the actual ignition advance (use a timing light) is the same as the ECU advance. The ignition type (IGN) sets the trigger edge direction types which are suitable for most ignition systems. For this work the fall trigger was chosen due to use the same rotational speed sensor's configuration pin out according to the original ECU's system. The number of coils (COIL) sets the number of ignition coils directly controlled by the ECU. In this work two coils in the wasted spark mode has been used with 2 external amplification modules BKL-3BD from Magneti-Marelli. The ignition dwell time (DELL) sets the "coil on time" (coil primary circuit on time). For a effective spark generation the dwell time should be adjusted so that the ignition module almost reaches the current limit point. Longer dwell times will be required at lower battery voltages. The dwell time was set as a function of battery voltage and rotational speed. At this initial stage the dwell time table was captured from the closest calibration available from another application. After setting the "main setup parameters" the next step is to define the firing order into the software. Normally for a sequencial fuel injection and sequencial ignition mode (eg. one coil/cylinder) is necessary tells the ECU the firing order. In this work the firing order can be set "0-0-0-0" due to the fact the injection and ignition system needs to know only the rpm value and the pistons's position to command the injectors in a group fire and the coils operated in the wasted spark mode. The next step is to set the "rpm sites" properly to be used. It can be done through one table; it determines the rotational speed sites for all rotational speed dependant tables except the "FUEL MAIN" and "IGNITION MAIN" table. Then, the "sensors setup" must be defined. The objective of this step is to supply to the software the sensors type and their curves, accomplishing the calibration process and after adjusting their curves to correspond to the standard values. The table 2 presents the sensors setup table. The manifold absolute pressure (MAP) was set in the "user defined table" and the Fig. 5 shows its calibration curve.

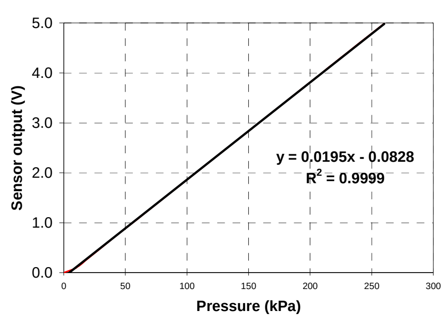

Figure 5 – MAP calibration curve

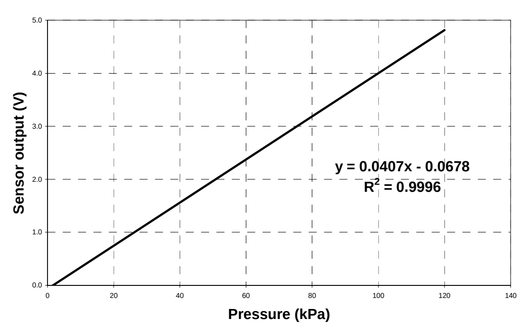

Figure 6 – BAP calibration curve

The Aux voltage was set to be a barometric air pressure sensor (BAP) and its curve is showed at Fig. 6. The lambda sensor (LA) independent of the work at this stage of the process must be off. At this stage the lambda sensor (LA) control must be turned off, because we need a stable and well know engine point of operation. Thus the closed loop should be used only in advanced stages. It's important to note that all control strategies, like auto adaptation and knock control, should be disabled to not interfere into the tuning procedure. After this, the "throttle position HI/LOW" must be recorded into the software. So adjust by moving the throttle to the fully closed position and then do the same to the opened position. The table 3 shows the values.

Table 3 – Opened/closed throttle position

Throttle Position	Value
Throttle Position Closed (TPLO)	17,1
Throttle Position Open (TPHI)	96,1

Table 4 – Cold start parameters

Cold Start	Value
Cold Warm Up Enrich	50
Post Start Enrich	120
Cranking Enrich	120
Post Start Decay	10
Cold Accel Enrich	20

Table 5 – Engine rotational speed limit table

rpm limit	Value
rpm limit	6500
rpm limit ctrl range	0
rpm limit type	2
rpm limit randomizer	75
rpm limit diag	200

The next step is to check if the “cold start” parameters are set with “typical values”, but it is very important to understand this initial step is only to make the engine running. The precise tuning of “cold start” must be done only after the engine’s warm tuning is totally concluded. The “cold start” parameters are showed at the Tab. 4. The “cold warm up enrich” is the additional fuel during cold start warm up. The amount of additional fuel reduces, as the engine warms up and has no effect above 60 °C. The “post start enrich” is the additional fuel after engine has started. The additional fuel decays to zero at a rate determined by the “post start decay”, so it is therefore temperature dependent. The “cranking enrich” is the additional fuel required during cranking period, this is reduced to zero over a number of engine revolutions. The amount of additional fuel is a percentage of the warm up enrichment and is therefore temperature dependent. The “post start decay” is the time over which the post start enrichment is reduced to zero and the “cold accel enrich” is the additional acceleration enrichment while the engine is cold. The next step is to set all the compensation tables for air temperature, engine temperature and MAP to “zero” at this initial stage. These entire compensations table influence the final value of the injector pulse width and the ignition timing, so during the arrangement of the fuel and ignition main tables these compensations must be off. The enrichment and enleanment compensation tables for the fuel during the throttle movement must be off too. After this, the value and the mode of the engine rotational speed limit must be determined; the Tab. 5 shows the parameters. The “rpm limit” is the rotational speed at which “rpm limit” will begin to control the maximum speed. The engine rotational speed cut over the range defined by the control range. The “rpm limit ctrl range” is the additional rotational speed above the rotational speed limit at which all cylinders ignition or injection will be cut. This parameter defines the intensity of the cut, from hard cut to progressive cut. The “rpm limit type” defines the type of the control limit; it can be done through the ignition, fuel or a combination of both. The “rpm limit diag” is the rotational speed above the “rpm limit” at the rotational speed limit diagnostic error will be triggered. The next step is to determine the “injection timing table”. This parameter controls the exact moment to “start” or “end” the fuel injection. Injection timing is important as it can help with fuel delivery into the cylinder and improve fuel consumption. If the injector fires at the point when the intake system air velocity is highest, all the fuel atomized will go into the cylinder. If the fuel is delivered on a closed valve it will come out of atomization and adhere to the walls of the intake system, condensing and becoming liquid fuel. At this initial stage the “injection timing table” was captured from the closest calibration available from another application and after the engine running, it will be precisely tuned. The next step is to set to the ECU the outputs to command the fuel pump relay, the ignition modules and the boost drive electro-valve for the turbo compressor pressure boost control. The fuel and the ignition main table must be imported from the closest calibration like initial procedure to run the engine. The “closest calibration” means the calibration tuned to the other similar engine with the closest configuration. For the “B” stage the first step is to check all the system components, harness, connections, engine oil level, cooler system, the dynamometer controls, fuel connections and all the tables values in the software. The check list is a powerful tool to this stage. The linear lambda sensor is essential sensor to this kind of work to ensure correct air fuel ratio and must be inserted in the exhaust system before trying running the engine. After this, try starting the engine. At this step the tuner’s experience is the most important thing, because the whole parameters during the cold start must be set to be near of the expected values without larger discrepancy. The excessive amount of fuel, a very high ignition advance or a extremely lean mixture during the cold start can cause irretrievable damage to the engine. So after to set all the “cold start” parameters to the typical values if the engine does not run, the fuel Trim table must be used to vary the mixture when trying to start the engine to determine if the engine needs more or less fuel, this ensures that the mixture is varied equally for all rotational speed and load points. After the engine has started the “C” stage can be initiated. This stage aims to adjust the initial calibration seeking the best performance. The “C” stage was subdivided in 10 stages. The methodology described in Fig. 8 shows the entire sequence adopted to the tuning process. In this work the tuning was done only until the stage “5” on the bench dynamometer and these stages will be explained in detail. Before describing the stages, is useful to understand the method the software uses to interpolate the values in the fuel and ignition main tables. So if the current engine rotational speed and load correspond exactly to a point in the table then the table value for this point is used. If the current engine rotational speed and load do not correspond exactly to a point in the table then the values of the four closest points are mathematically interpolated to arrive at an appropriate value depending on how close the current rotational speed and load are to the different points. Some tips are very relevant during the whole process and will be presented here. Use extreme caution when adjusting to ensure that the engine does not run lean at high loads. The air fuel ratio should be adjusted to suit the engine load and the desired results. At high loads the mixture should be approximate 0.89 of lambda for maximum power, on turbocharged engines a richer mixture may be required to reduce exhaust temperatures or to avoid knocking, (approximate 0.85 of lambda or less). At lighter loads the mixture may be adjusted for best emissions (lambda equal to 1.00) or best economy (approximate 1.05 of lambda). If the engine is missing for any reason (including over rich) the air fuel ratio may falsely read lean due to the oxygen in the unburned mixture. Cams with high overlap running at low speed can cause the air fuel ratio to falsely read lean due to extra air being passed through the engine. Start with a conservative ignition curve then add advance slowly until the torque stops increasing AVOID KNOCK. Too much retard will cause excessive exhaust temperature at high loads. For best idle stability set the ignition timing flat over the idle rpm range and avoid too much advance (10 to 15 degrees is good). Varying timing over the idle rpm range may cause erratic idling. During initial tuning, if large adjustments are required to a particular site ensure that the sites around it are also adjusted to a similar value so that the adjacent sites have minimal influence on the current site. Idle the engine while making these adjustments to avoid incorrect advance causing damage to the engine. When aiming MBT (maximum break torque) keep in mind the LKL (lower knock limit) sometimes can be encountered first limiting the ignition advance and consequently the maximum break torque. The exhaust temperature is another variable that can limit the torque at high rpm and load.

1) Adjusting one load row of the fuel and the ignition main tables. (Aiming Performance);
2) Tuning the dwell time table. (Aiming maximum peak current);
3) Tuning the injection time table. (Aiming the minimum “specific fuel consumption”);
4) Tuning the fuel and the ignition main tables up to the maximum efficiency point without use the turbocompressor electronic control. (Aiming Performance);
5) Tuning the superior part of the fuel and ignition main tables, through the tuning of the boost table. (Aiming Performance);
6) Tuning the air temperature, engine temperature and manifold air pressure “compensation tables” trimming the fuel, ignition and boost final values (Aiming best running, warm up and operational ability.);
7) Tuning the amount of the enrichment and the enleanment mixture due to the throttle position acceleration and deceleration;
8) Tuning the increase of the ignition advance due to the throttle position acceleration.
9) Tuning the lambda sensor table defining when the closed loop is activated and its values. (Aiming best exhaust emissions);
10) Tuning the cold start precisely. (Aiming best cold start and drive ability during warm up).

Note that there was a need of using a knock sensor and a lambda sensor at this phase. In this work was used an accelerometer and a real time spectral analysis software to detect knock. A linear output lambda sensor was used for mixture adjustments. The stage “1” consists in adjusting one load row of the fuel and the ignition main tables for all rpm sites. First adjust one site in the fuel table seeking best torque, so go to the ignition table and adjust the advance value to the same goal, come back to the fuel table and make a precise tuning and finally come back to the ignition table and make a precise tuning too. Repeat this process for all sites of this row. The stage “2” consists in tuning the dwell time table aiming to find the maximum peak current, so the ignition module almost reaches the current limit point to each site. At high rpm the ECU will ensure that the coil is off for at least 200 microseconds to ensure sufficient spark burn time, therefore the actual dwell time could be less than the table dwell time. Controlling the battery voltage value to the ECU and using an oscilloscope to check the current curve in the primary circuit of the ignition coil adjust the dwell time for all rpm sites from 10 to 14 battery voltage sites. For the others battery voltage sites proportional values have been set in this work. Figure 7 shows the dwell time curves to this application. The stage “3” consists in tuning the injection time table aiming the minimum specific fuel consumption. The SFC is the best parameter to tell the tuner if the fuel is delivered on right time or if the fuel is adhering to the walls of the intake system, condensing and becoming liquid fuel. Adjusting the injection timing may optimize engine power, emissions, economy and idle stability. In this work the injection timing was set to be a function of rpm only, so changing the injection time for each rpm site until getting the lowest SFC. Figure 8 shows the injection timing to this application.

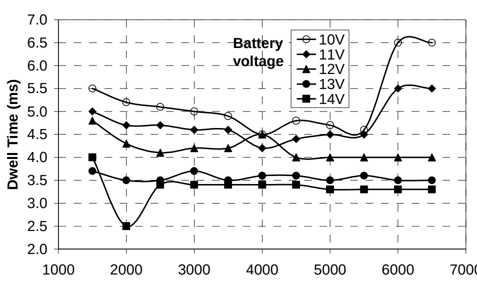

Figure 7 – Dwell time curves

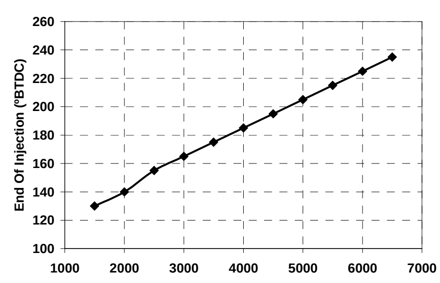

Figure 8 – Injection timing curve

The stage “4” consists in tuning the fuel and the ignition main tables up to the maximum efficiency site without use the turbo compressor electronic control aiming performance. The procedure to adjust the fuel and ignition main table is the same procedure explained in stage “1”. But is important to remember the software uses the four closest sites to mathematically interpolate and find a new value, so the values in the tables outside of the operational range of the engine (adjacent points where the engine does not run) influence the points in the operational range. Thus these adjacent points outside the operational range must be tuned to keep the desired actual values when running close to the operational range limit. The figure 12 and 13 shows the operational range limit delimited by the closed line to the fuel and ignition main table respectively. During this optimization to find the best torque, the exhaust temperature (<1000ºC) and the lower knock limit are the restriction variables. The stage “5” consists in tuning the superior part of the fuel and ignition main tables, through the tuning of the boost table aiming performance. The difference of this stage to the stage”4” is: first of all, “BEFORE RUNNING”; ESTIMATE the values for the fuel and ignition tables correctly because in high loads a large values discrapancy can damage the engine. To work in safety, start with a little more amount of fuel and lower advance than will be expected At this part of the tables. After doing this, to get a higher efficiency points the “boost limit main table” should be adjusted first. The boost value is either the desired boost pressure or the valve duty cycle depending on the control mode (PD or Duty Cycle). In this work the duty cycle control mode was set in the software using 33 Hz of frequency and the duty cycle range is from 5% to 95%. The entire closed loop procedure of tuning to this stage is similar of the stage “4” including the boost limit value in the first step of the loop. So the sequence is:

Adjusting (Boost → Fuel → Advance) → Tuning (Boost → Fuel → Advance).

The figure 9 shows the boost pressure for all rotational speed sites with 50 kPa and 100 kPa of BAP.

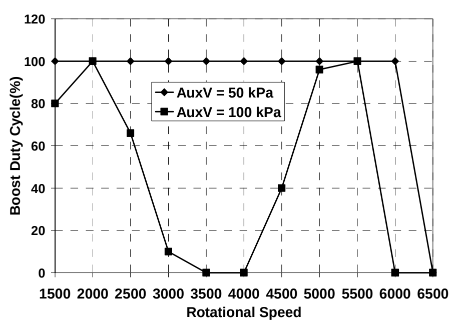

Figure 9 – Boost limit duty cycle for 2 sites of BAP

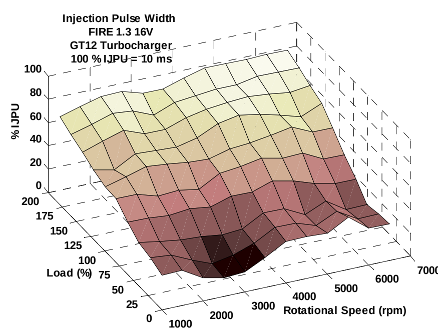

Figure 10 – The fuel main map

Note that the range from 3500 rpm to 4000 rpm is the minimum boost drive for 100 kPa of BAP as this region is the maximum torque of the engine. The performance at 50 kPa could not be accurately reproduced on bench dynamometer due to the flexible intake system tubing utilized prior to the turbocompressor did not support altitude simulations. Therefore, to the 50 kPa of BAP the maximum duty cycle has been kept at this initial step. The figure 10 shows the fuel main map after the tuning process. The figure 11 displays beyond the data of the rotation, load and injection pulse width (% IJPU), the range of the engine operation delimited by the closed line. The broken line delimits the superior part of the map adjusted with the contribution of the boost drive electro valve. The figure 11 presents the ignition main map after the tuning process. The figure 13 displays beyond the data of the rotation, load and ignition advance, the range of the engine operation delimited by the closed line. The broken line delimits the superior part of the map adjusted with the contribution of the boost drive electro-valve. Outside of the closed line there are the closest advance values that must be tuned due to the interpolation method using the four closest points from the table.

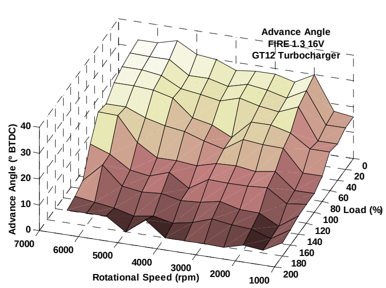

Figure 11 – The ignition main map

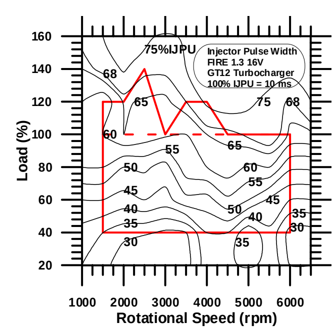

Figure 12 – The fuel main graph

4. Results

From figure 7 to 13 are presented all results of the setting and tuning methodology. At figure 1 is presented the performance data (power, torque and SFC) at WOT for the naturally aspirated engine (standard) and for turbocharged engine with GARRET GT12 turbo-compressor.

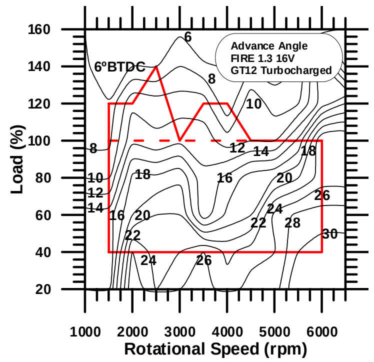

Figure 13 – The ignition main graph

Table 6 – Measurements uncertainty demanded by NBR-ISO-1585standard and verified in the used equipment

Greatness	Specified Uncertainty	Equipment Uncertainty
Torque	± 1 %	± 0.8 %
Rotational speed	± 0.5 %	± 0.1 %
Fuel Flow	± 1 %	± 1 %
Air Temperature	± 2 K	± 2 K
Barometric Pressure	± 100 Pa	± 100 Pa
Exhaustion Back Pressure	± 200 Pa	± 100 Pa
Absolute Admission Pressure	± 2 %	± 0.1 %

The Table 6 shows the uncertainty of the used equipment evaluated by recommendations of "ABNT ISO 5725, (1994)". All values were conforming to NBR-ISO-1585. The maps from figures 12 e 13 show a very complex behavior of engine into the operational envelope. The introduction of the turbocharged looks does not change the trends of injection time and advance. At figure 1 are seen the boost effect of the turbocompressor over shaft power delivered by the engine. There was a 50% of increase in maximum torque and power. The torque curve of the turbocharged engine presents a constant value between 2500 to 4500 rpm. The increase of specific fuel consumption for the turbocharged engine could be afforded to mapping procedure that looks for maximum torque. The standard engine was mapped for low emissions. This allows better combustion behavior leading to reduced fuel consumption. Another point is the need of using extra fuel to keep the exhaust temperature below 1000ºC at high loads.

5. Conclusions

This work presented a procedure to setting engine management system of a turbocharged engine. There are a lot of parameters that should be tuned to achieve an operational performance. The authors' intent it is to help people to implement a straightforward method of engine mapping. The time spent at this engine mapping was of 120 hours of two high-grade technicians and it has taken 360 liters of gasoline C fuel.

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8. Responsibility notice

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