

FlexFuel Strategy for 2-Wheeler

Erika Xavier, Ariel Bepu, Martin Leder, and Walter Arens
Robert Bosch Ltda.

ABSTRACT

Brazilian energetic matrix is based on two fuels: gasoline (E22: 78% pure gasoline + 22% anhydrous ethanol) and ethanol (E100: 93% anhydrous ethanol + 7% water).

A Flex Fuel 2-wheeler (motorcycle) engine management software strategy was developed in order to meet Brazilian market demand based on the energetic matrix mentioned above and a worldwide market forecast growth in the corresponding small engines segment.

As 2-wheeler engine configuration and electric architecture is simpler than passenger cars, a premise was established: to develop a completely new Flex Fuel system for the 2-wheeler segment with functionalities simpler and easier to calibrate than actual concept used for Flex Fuel passenger cars.

This paper presents the result of this study: a Flex Fuel system able to operate with gasoline (E22), ethanol (E100) or any mixture of both fuels with similar behavior in an easy-to-calibrate system.

CITATION: Xavier, E., Bepu, A., Leder, M., and Arens, W., "FlexFuel Strategy for 2-Wheeler," *SAE Int. J. Engines* 6(4): 2013, doi:10.4271/2013-32-9003.

INTRODUCTION

Flex Fuel is a technology that allows the engine to run on gasoline, ethanol or any combination of both. The basic principle of Flex Fuel injection solution is: a-) detection of the actual fuel mix present in the system and; b-) adjustment of the fuel injection process considering the physical properties of the mix, mainly it's stoichiometric ratio. These tasks are processed by the Engine Control Unit (ECU) according to a specific software strategy that commands engine function according to the operating conditions.

In 1975 the Brazilian government created the PROALCOOL (National Alcohol Program), which conceded tax incentives to alcohol vehicles. This encouraged the development of a 100% ethanol-powered vehicle. However in the late 1980s, with reducing oil prices, the world sugar prices increased and the interest in the program decreased. Despite of that in order to fulfill the worldwide automobile industry needs which requires products with greater energetic efficiency, the Flex Fuel technology research and development is a fact since 1985 and as a result of that the first Flex Fuel vehicle was launched in Brazil in 2003.

Since then Flex Fuel vehicles Brazil production increased steadily and currently represents about 85% of the Brazilian market (figure 1).

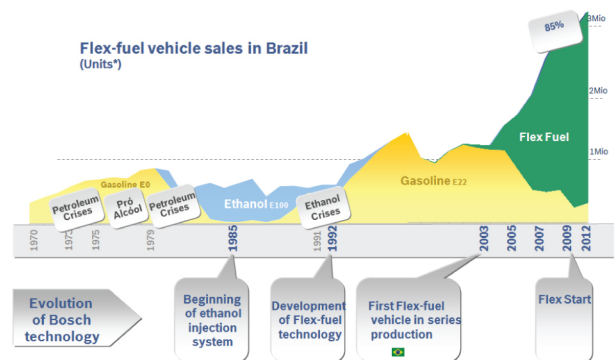


Figure 1. Flex Fuel vehicles sales in Brazil Source: Anfavea

In the meantime the Brazilian market demand and a worldwide market forecast growth in the corresponding small engines segment encouraged the development of a Flex Fuel 2-wheeler engine management software strategy (figure 2).

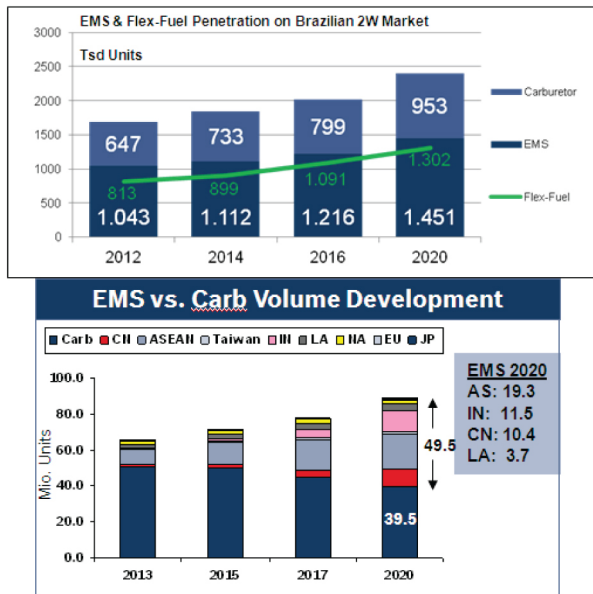


Figure 2. Brazil Production Market Volume Worldwide 2-wheeler production Source: Abraciclo/Sindipeças/Robert Bosch

In order to develop a completely new Flex Fuel system for a motorcycle, simpler and easier to calibrate than the actual concept for passenger cars, we have based the analysis on the main differences in the fuel properties for E22 and E100, aligned with the in-company experience on how these differences impact the engine functionality and consequently ECU software/calibration parameters (figure 3a and 3b).

Properties	Unit	Gasoline E22	Alcohol E100	Impact of fuel properties on engine control			
				Requires higher injection quantity up to 35%	More wall wetting	Air cooling	High knock limit
Air/Fuel Ratio		13	9	++	+	o	+
Lower Heating Value	MJ/kg	38,9	24,8	++	o	o	o
Latent Heat of Vaporization	KJ/kg	380-500	904	o	++	++	o
Octane Number	RON	> 92	108	o	o	o	++
Boiling Temperature	°C	25...215	78	o	++	o	o

Note: (++) strong relation, (+) weak relation, (o) no relation

Figure 3a. Evaluation of different fuel properties (E22 and E100) and the impact on the engine control strategy Source: Robert Bosch

	Impact on ECU SW		
	Air System	Ignition System	Fuel System
Requires higher injection quantity up to 35%	X		X
More wall wetting			X
Air cooling	X		X
High knock limit		X	
Cold start critical	X	X	X

Figure 3b. Evaluation of impacts of Engine control strategy on ECU Sub-systems Source: Robert Bosch

ECU software is comprised of many different sub-systems. Figure 4 indicates (red dots) the potentially impacted subsystems on a typical function architecture view for Flex Fuel.

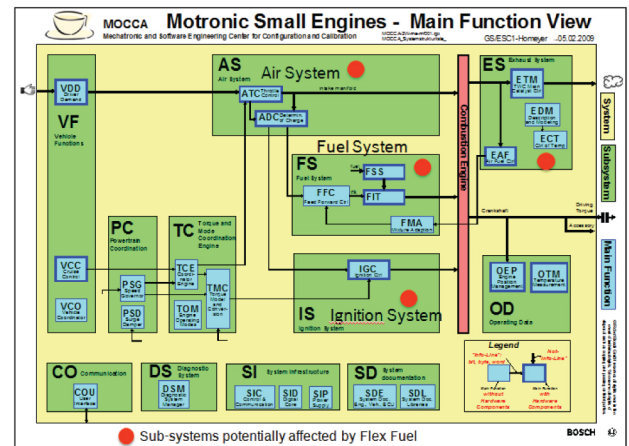


Figure 4. Main function software view (Motorcycle) Source: Robert Bosch

The sub-systems marked above (figure 4) are responsible for:

- Air system: Throttle control for idle speed and air charge determination dependent;
- Fuel system: fuel mix determination (ethanol content) correction of injection quantity/timing and lambda control/correction;
- Ignition system: Ignition angle control;
- Exhaust system: exhaust pipe/components temperature model;

This study will present the development process of this project, which motivated the changes in the previously mentioned sub-systems.

RESULTS

The project was structured as follows:

PHASE 1: Benchmarking

- Objective: define motorcycle behavior characteristics for later comparison (start quality, drivability, idle speed, fuel recognition);
- Results: characteristics were evaluated and used to define project requirements;
- Lessons Learned: the pressure pulsation at the intake manifold in a 1-cylinder engine is much bigger than in a 4-cylinder engine where individual cylinders compensate each other for pressure increases or decreases. The pulsation in the 1-cylinder engine has a big influence on mixture formation and air vaporization ([figure 5](#)).

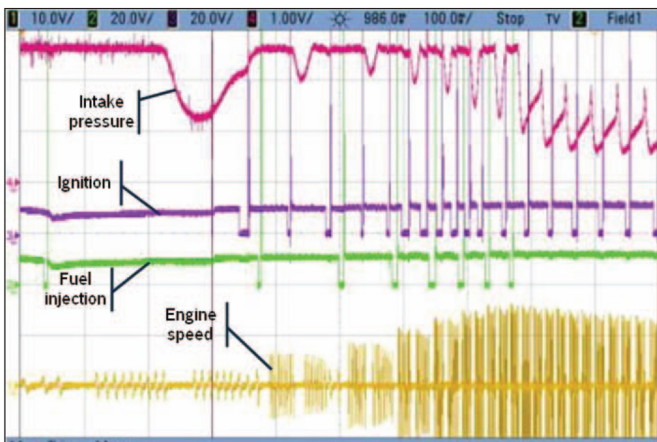


Figure 5. Intake pressure variation in a 1 cylinder engine Source: Robert Bosch

PHASE 2: Build Demonstrator and test with gasoline (E22)

- Objective: verify Bosch ECU compatibility with competitor components. Prepare a baseline calibration for E22 using an existing mono-fuel software;
- Results: Replacement of competitor lambda-sensor by Bosch lambda-sensor was made, in order to avoid rework on lambda-control strategy. Additionally software adjustments to control idle speed actuator and to adapt to the flywheel signal were made. Measurements to compare start quality, drivability and idle speed control were performed. Results showed a similar performance between OEM and Bosch system ([figure 6](#)).

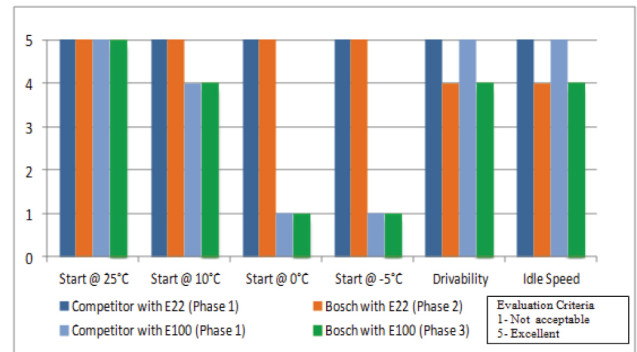


Figure 6. Performance comparison: OEM x Bosch for E22 and E100 Source: Robert Bosch

PHASE 3: Tests with Ethanol (E100)

- Objective: Prepare a baseline calibration for E100 using an existing mono-fuel software;
- Results: the measurements taken at phase 1 and 2 have been repeated and the results showed a similar trend as phase 2 ([figure 6](#)) - exception was cold start below 10°C. Due to the complexity to vaporize E100 below 10°C, a new project was established to cover this issue and will be addressed in a future paper.

PHASE 4: Flex Fuel development

- Objective: compare measurements from phases 2 and 3 and use the results to define the functional requirements for converting the mono-fuel software into a Flex Fuel system;
- Results: The following sub-systems have been identified as relevant for a more detailed study:
 - Exhaust system;
 - Air system;
 - Fuel system;
 - Ignition system.

PHASE 4a: EXHAUST SYSTEM STUDY

A comparison of the exhaust temperatures measured with E22 and E100 indicated similar values, thus leading to the conclusion that no software changes were necessary at this point ([figure 7](#)).