

Development of Flexible-Fuel Motorcycle

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ABSTRACT

A flexible-fuel motorcycle (FFM), able to be operated using gasoline, ethanol, or any mixture of the two, has been developed in order to respond to the needs of the Brazilian market. Four-wheeled flexible-fuel vehicles (FFVs) are generally provided with gasoline sub-tanks and fuel injection systems to supply gasoline to enable engine start at low temperatures, but fitting this type of additional equipment in a small motorcycle represents a challenge. This was an issue in the development of the new motorcycle. The use of a control logic that judges the ethanol concentration range of the fuel and an indicator that recommends supply of gasoline when the concentration range is not optimal for low-temperature engine starts in the Mix Fuel Injection System, developed for the new motorcycle, has enabled the realization of a simple system configuration that does away with the gasoline sub-tank. In addition, fuel system components were developed considering the characteristics of ethanol.

1. Introduction

Ethanol is produced in Brazil using the country's abundant sugar cane resource as raw materials, and the introduction of ethanol fuel has been promoted as national policy for more than 40 years. Gasoline sold as automobile fuel is mandated to contain a mixture of 20 to 25% ethanol, and 100% ethanol (hydrated ethanol containing approximately 7% water) is also sold. Brazil is said to be the most advanced country to date in the introduction of bio-ethanol, and has established a social infrastructure that enables either type of fuel to be obtained at gas station throughout the country.

Sales of four-wheeled flexible-fuel vehicles (FFVs) in Brazil began from around 2003, and Honda has also released CIVIC FFV⁽¹⁾ and FIT FFV. The flexible-fuel function enables operation using gasoline, ethanol, or any mixture of the two, which is attractive in terms of cost performance, as users can freely choose the fuel according to the fuel price. Currently, 80% or more of all new passenger cars sold in Brazil are FFV, so FFV is becoming the standard. This cost performance function of flexible-fuel is similarly demanded of motorcycles, and the release of

flexible-fuel motorcycles has been desired for some time.

Honda released the CG150 Titan (gasoline specifications), which complies with the new exhaust emission regulations, PROMOT3, that take effect from 2009. The CG150 Titan MIX flexible-fuel motorcycle was developed using this CG150 Titan as the base model. This paper introduces the technologies used in this development.

2. Development Goals

When developing a flexible-fuel motorcycle, the CG150 Titan, which is the best selling model in Brazil, was selected as the base model to make the merits available to as many users as possible. The following three items were set as development goals to realize a vehicle that matches motorcycle user needs.

- (1) Ability to operate using gasoline, ethanol, or any mixture of the two
- (2) Ability to share main components with the base motorcycle
- (3) Provided at an affordable price in accordance with motorcycle user needs

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3. Developed Vehicle

3.1. Vehicle Exterior View

Figure 1 shows an exterior view of the CG150 Titan MIX, and Table 1 lists the body specifications. The appearance is almost the same as the CG150 Titan base model. The only changes in appearance are the instrument panel, and the exchange type secondary fuel filter located inside the side cover.

3.2. Engine

Table 2 compares the engine specifications, ignition and fuel supply systems of the gasoline and flexible-fuel models, along with the 2007 model year CG150 Titan⁽²⁾ used as the base model.

Figure 2 shows an exterior view of the engine and the location of the oxygen sensor. The 2009 model year CG150 Titan assumed development of a flexible-fuel motorcycle, and was developed using shared engine specifications for both a gasoline fuel vehicle and flexible-fuel vehicle. The valve and valve seat materials were changed as a countermeasure against ethanol-induced wear.

Table 1 Body specifications

Items	Specifications
Frame type	Diamond type
Dry mass	116.4 kg
Overall length	1988 mm
Overall width	730 mm
Overall height	1098 mm



Fig. 1 CG150 Titan MIX

Table 2 Engine, ignition and fuel supply specifications

		2007 model	2009 model	
		Gasoline	Gasoline	MIX Fuel
Fuel		E20 - E25	E20 - E25	E20 - E100
Cooling system		Air	Air	Air
Bore x stroke	(mm)	57.3 x 58.84	57.3 x 58.84	57.3 x 58.84
Displacement	(cm ³)	149.2	149.2	149.2
Compression ratio		9.5	9.5	9.5
Valve train		SOHC	SOHC	SOHC
number of valves		2	2	2
Valve material	IN	SAE HNV3	SAE HNV3 (increased hardness)	SAE HNV3 (increased hardness)
	EX	LV21 - 43	SAE EV8 +Metallizing	SAE EV8 +Metallizing
Valve seat material	IN	Sinter alloy	Wear-resistance sinter alloy	Wear-resistance sinter alloy
	EX	Wear-resistance sinter alloy	High wear resistance sinter alloy	High wear resistance sinter alloy
Fuel system		Carburetor	Programmed fuel injection	Programmed fuel injection
Throttle type/Diameter	(mm)	Piston / 22.8	Butterfly / 26	Butterfly / 26
Throttle position sensor		—	On throttle body	On throttle body
Absolute pressure sensor		—	On throttle body	On throttle body
Oil temperature sensor		—	On cylinder	On cylinder
Oxygen sensor		—	Without heater	With heater
Ignition control		Engine speed table	Engine speed-throttle opening map	Engine speed-throttle opening map

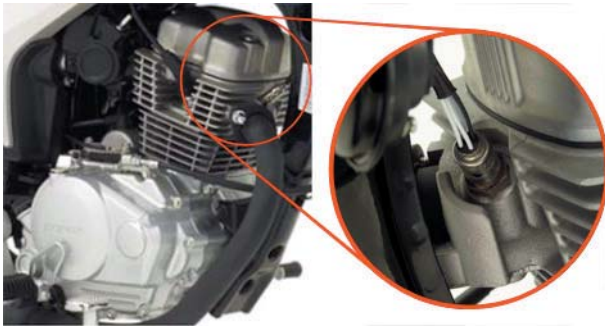


Fig. 2 Exterior view of engine and oxygen sensor

The fuel supply system was changed from a carburetor to the PGM-FI in the 2009 year model to comply with stricter exhaust emission regulations (PROMOT2, equivalent to Euro-2 → PROMOT3, equivalent to Euro-3). An oxygen sensor is located on the exhaust port of the engine head, and fuel injection amount feedback control is performed using the output signal from this sensor to enable the exhaust catalyst to exhibit sufficient purification performance. With the change to the PGM-FI, ignition timing control was also changed from that of spark advance setting, depending on engine speed, which does not vary according to the operating duty, to map control using the engine speed and throttle opening.

3.3. Output Characteristics

Figure 3 shows the engine output power performance at full throttle for gasoline (ethanol 22%) and ethanol (water content 7%). This shows that while the output

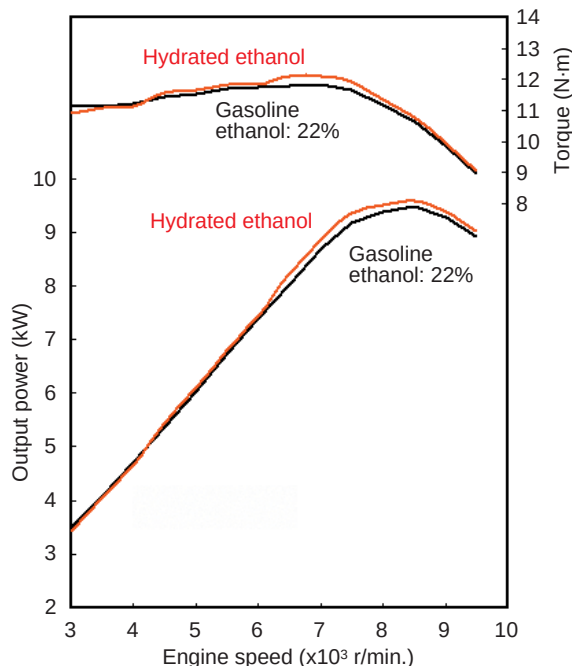


Fig. 3 Engine performance

Table 3 Fuel properties

	Gasoline	Ethanol
Specific gravity	0.73-0.75	0.79
Heating value (MJ/Air kg)	2.95	2.99
Octan number RON/MON	93/81	110/92
Stoichiometric air fuel ratio	14.6	9.0
Flash point (°C)	< -30	13
Boiling point (°C)	25-200	78
Ratio of moles before and after combustion	1.07	1.14

power is slightly higher for ethanol, it is approximately the same, and there is almost no difference in running performance according to fuel.

4. Brazilian Fuel Properties and Issues

Table 3 shows the fuel properties of gasoline and ethanol.

Commercially available motorcycle fuel in Brazil can be broadly divided into the two types of gasoline and alcohol. Gasoline fuel is not pure gasoline, and government regulations mandate that gasoline contain a mixture of 20 to 25% ethanol. Alcohol fuel is hydrated ethanol with water content of approximately 7%. Pure gasoline is not generally sold. When using ethanol as fuel, there are three main issues.

The first issue is the construction of fuel injection control for the different fuels of gasoline and ethanol. The fuel supply system of a gasoline engine measures the intake air mass and determines the fuel injection amount according to that air mass. The fuel mass ratio (stoichiometric air-fuel ratio) that results in complete combustion relative to the same intake air mass differs for gasoline and ethanol. This ratio is 14.6 for pure gasoline, and 9.0 for ethanol. When using only gasoline as fuel, the fuel mass ratio can be preset to achieve a constant air-fuel ratio, but when mixing in ethanol, the ideal air-fuel ratio changes greatly. To maintain a good engine operating state, the ethanol concentration in the fuel used should be understood, and appropriate fuel injection amount control performed accordingly.

The second issue is securing engine start performance at low temperatures. Gasoline has an ignition point of -30°C or less, but ethanol's ignition point is higher at 13°C, which makes starting under low temperature conditions a challenge when using only ethanol fuel. As a countermeasure in four-wheeled FFV, a separate sub fuel tank for gasoline is installed inside or close to the engine room for cold engine start, and a special fuel injection system is also provided. Figure 4 shows the fuel tank and fuel supply system layout in the CIVIC FFV, and Fig. 5 shows the layout of the sub fuel system for engine start⁽¹⁾. When attempting to add a similar system to a small motorcycle, it is a challenge to secure mounting space,

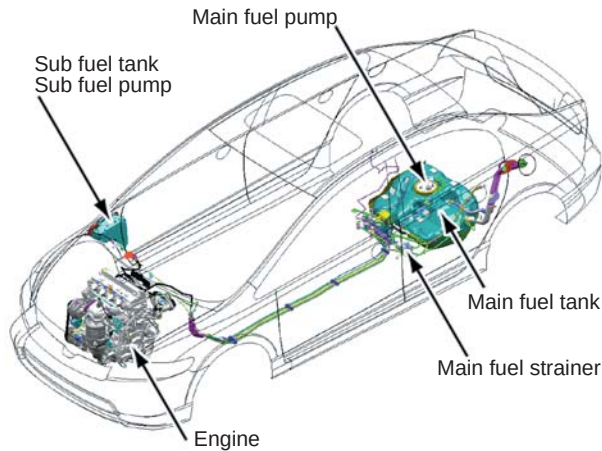


Fig. 4 Exterior view of CIVIC FFV fuel supply system

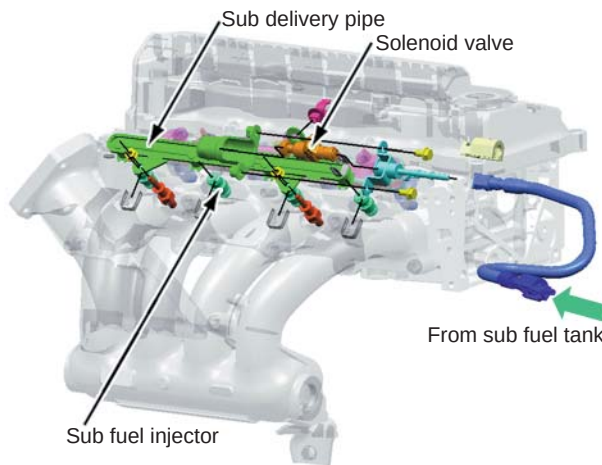


Fig. 5 Sub-fuel system for CIVIC FFV

and the vast increase in the number of components is also a major obstacle.

The third issue is that ethanol is highly corrosive to metal and rubber. This should be managed by increasing the resistance to corrosion of engine and fuel supply components⁽³⁾.

5. Fuel Injection Amount Control for Flexible-Fuel System

5.1. Issues for Fuel Injection Control

Figure 6 shows the air-fuel ratio (A/F) that results in an air excess ratio $\lambda = 1$, for the range of ethanol concentrations between pure gasoline and 7% hydrated ethanol. The A/F at which $\lambda = 1$ is 14.6 for gasoline, but 8.2 for 7% hydrated ethanol. Figure 7 shows the rate of change in the fuel injection amount at an air excess ratio $\lambda = 1$, for different ethanol concentrations relative to gasoline (ethanol concentration 22%). The fuel injection requirement increases together with the ethanol

concentration, and 100% ethanol requires a fuel injection amount approximately 1.5 times that of gasoline (ethanol concentration 22%). This shows that the fuel injection amount should be adjusted by a wide margin according to the ethanol concentration contained in the fuel. Thus, the issue for fuel injection control in a flexible-fuel system is to adjust to the ideal fuel injection amount that provides good engine performance.

5.2. Motorcycle Engine Characteristics

Most ordinary FFV use the oxygen sensor output to perform O_2 feedback control for the fuel injection amount. These results are then used to estimate the ethanol concentration, and the fuel injection amount is adjusted by applying a constant correction magnification according to the ethanol concentration estimated from a fuel injection amount map based on the reference ethanol concentration. O_2 feedback control detects whether the air-fuel ratio is rich or lean according to the oxygen concentration in the exhaust emissions, and performs control to constantly finely adjust the fuel injection amount to cancel this richness or leanness and converge

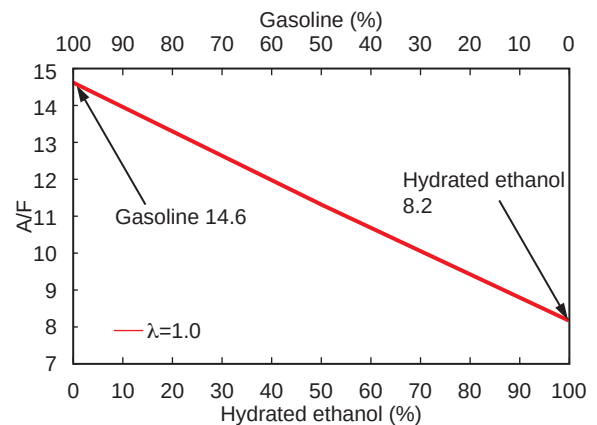
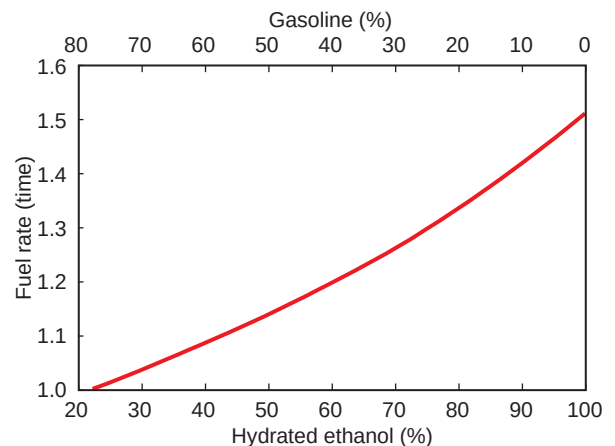
Fig. 6 Relation between A/F and ethanol concentration for $\lambda=1$ 

Fig. 7 Change in amount of injection demanded due to changing concentration of ethanol

to the stoichiometric air-fuel ratio. The adjustment magnification relative to the fuel injection amount map used as the reference for this O_2 feedback control is called the O_2 feedback correction coefficient K_{O_2} . When using only the reference gasoline fuel, only a very small K_{O_2} adjustment width is needed for O_2 feedback control. However, when ethanol is added to the fuel, the adjustment width increases. The unique correction value of ethanol concentration (K_{et}) for the fuel used can be determined by statistical processing to equalize this O_2 feedback correction coefficient K_{O_2} . The ethanol concentration correction value K_{et} is theoretically determined by only the ethanol concentration, so this enables the ethanol concentration in the fuel to be estimated. The ethanol concentration does not change until additional fuel is supplied to the fuel tank. Therefore, a good engine operating state can be secured by normal O_2 feedback control, by determining the fuel injection amount from the map obtained by applying the ethanol concentration correction value K_{et} to the basic fuel injection amount map. Figure 8 shows a schematic diagram of an FFV engine and O_2 feedback system, including the fuel injector and oxygen sensor.

Figure 9 shows the air excess ratio λ characteristics for the CG150 Titan engine when fuel injection is adjusted by the theoretical magnifications determined from the respective ethanol concentrations, when the ethanol concentration is varied using the gasoline (ethanol 22%) fuel injection amount as the reference. The same λ

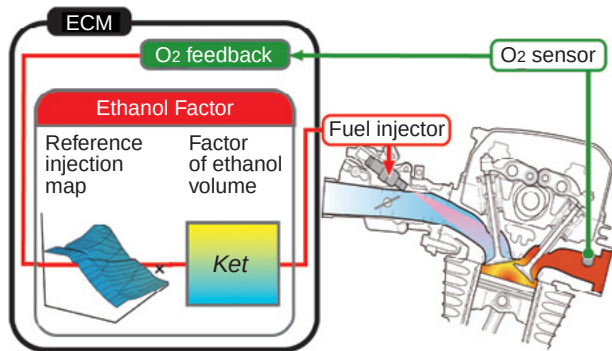


Fig. 8 Ethanol factor control diagram image of FFV

characteristics were expected regardless of the ethanol concentration, but λ varied greatly in the low load area with a throttle opening of 20 deg or less. That is to say, the change magnification for the required fuel injection amount is not constant, depending on the operating conditions, even at the same ethanol concentration. This characteristic is presumed to be due to the intake system layout peculiar to motorcycle engines, which have large valve overlaps and do not have a surge tank. This characteristic raised the issue that the appropriate amount of fuel injection cannot be supplied using the simple

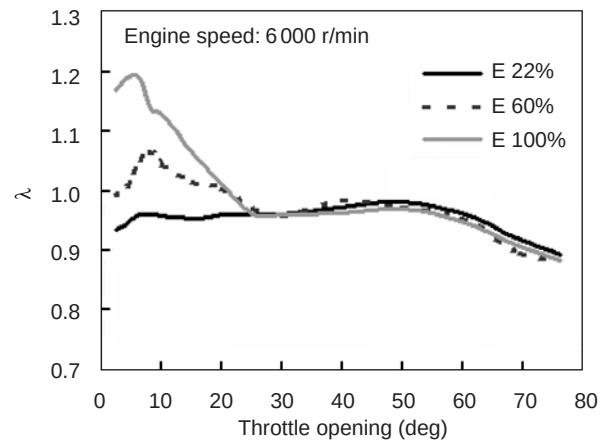
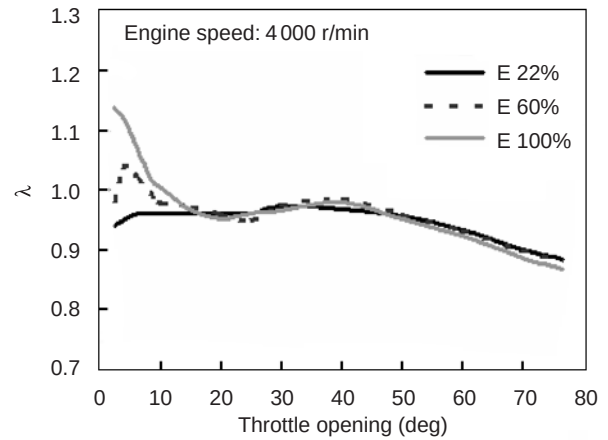


Fig. 9 λ when injection amount was multiplied at fixed rate based on difference in ethanol

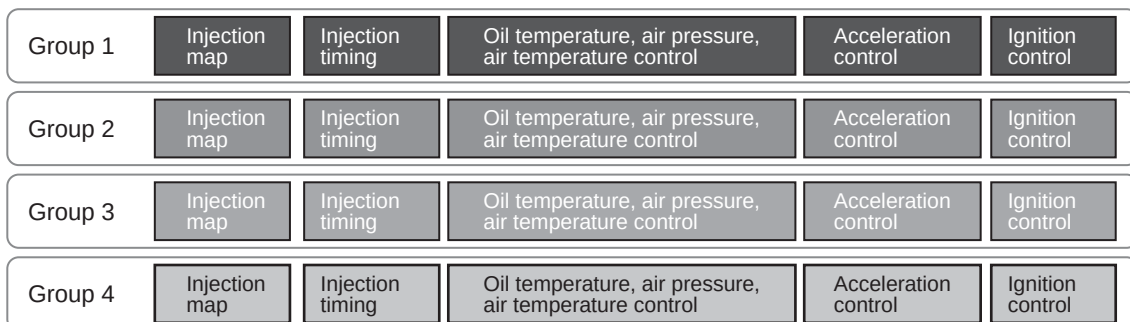


Fig. 10 Schematic diagrams of four control groups

control method of setting the fuel injection amount by adjustment using a single magnification determined according to the fuel ethanol concentration, regardless of the operating conditions.

5.3. Group Switching Control

A system that selects and switches to the appropriate fuel injection amount from among four control groups, according to the ethanol concentration, was used as the method to support the motorcycle engine characteristics. Figure 10 shows the schematic diagrams of the control groups. These control groups are packages of the various control items to be adjusted according to the ethanol concentration, and include the fuel injection amount map, injection timing, correction in start injection and engine warm-up processes, correction in transient period, ignition timing, and other control items. Four packages were prepared.

The feature of this system is that instead of directly estimating the ethanol concentration value, proper fuel injection can be performed by selecting the control group according to the set ethanol concentration range. The reference concentrations for the four control groups were spaced so that the rate of change in the magnification required for the fuel injection amount is approximately equal between gasoline (22% ethanol) and 100% ethanol. Figure 11 shows the reference ethanol concentration for each group added to the graph in Fig. 8. By dividing into four levels and setting the fuel injection amount map for each reference ethanol concentration, operation can be performed at the ideal conditions for that concentration. Correction control for other than the fuel injection amount map is also performed in the same manner. In addition, it was confirmed that even at intermediate concentrations other than the reference ethanol concentrations, the corrective effects of O₂ feedback control using the oxygen sensor output enable operation with little or no loss in performance.

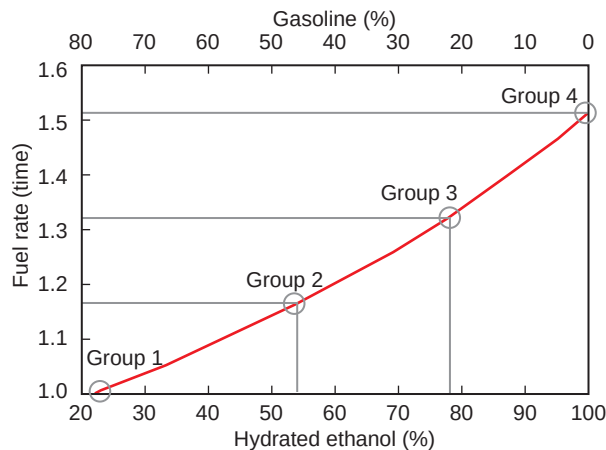


Fig. 11 Required injection multiplication based on 22% ethanol

Figure 12 shows the range of ethanol concentration for each control group. Providing areas where the concentrations overlap enabled frequent switching to be avoided, even at intermediate ethanol concentrations.

5.4. Judgment Control Using Maps

To perform the appropriate fuel injection for the fuel used, it is necessary to select the most suitable control group for the ethanol concentration. That is to say, when the ethanol concentration changes due to refueling and the control group becomes inappropriate, the control group should be switched quickly. An algorithm that selects the control group using the oxygen sensor output is used as the method of switching the control group. Figure 13 shows the group switchover concept diagram. When a certain control group is selected, typical feedback control that repeatedly alternates between rich and lean is performed by applying the O₂ feedback correction coefficient K_{O_2} to the reference fuel injection amount map based on the oxygen sensor output, so that operation converges to the stoichiometric air-fuel ratio.

When certain conditions are met, the map judgment value (K_{ref}) is continuously calculated using Eq. (1), by statistical processing to obtain the moving average of the O₂ feedback correction coefficient (K_{O_2}) for a certain time.

$$K_{ref} = \left(\sum_{i=m-n}^m (K_{O_2i}) \right) / n \quad (1)$$

K_{ref} : Map judgment value

m : Current fuel injection times

n : Fuel injection amount calculation times to be processed

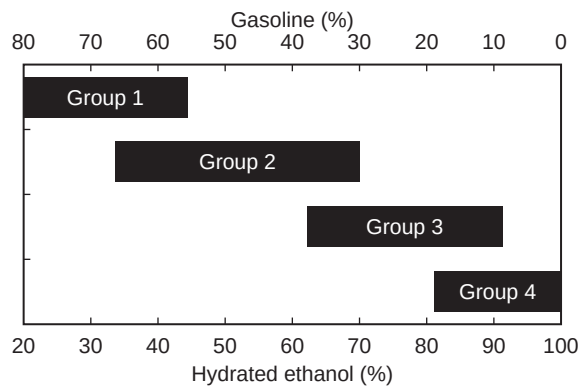


Fig. 12 Allocation of respective control groups

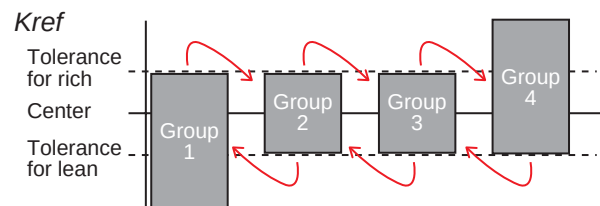


Fig. 13 Group switchover diagram

When that map judgment value (K_{ref}) is larger than the rich switching judgment value (Tolerance for rich), or smaller than the lean switching judgment value (Tolerance for lean), this means that the fuel injection amount map of the currently selected control group is inappropriate. In this case, the system switches to the adjacent control group in the direction that corrects the map offset, and operation is performed using the fuel injection amount map for that control group. When the map judgment value (K_{ref}) is still outside the tolerance for rich and lean, the system switches to the map for the next adjacent control group, and so on until the system ultimately settles on the map of the control group where the map judgment value (K_{ref}) is within the tolerance range. This type of operation to select the most appropriate of the four control groups by selecting the most appropriate fuel injection map according to the results of O_2 feedback control is called judgment control using maps. Figure 14 shows the operational schematic diagram for judgment control using maps.

This control constantly selects the ideal control group, even when the ethanol concentration of the fuel changes. Judgment control using maps is performed under various driving conditions, and achieves swift response. When the ethanol concentration within the fuel tank changes, the appropriate control group is selected within approximately 3 minutes. The most recently selected control group is

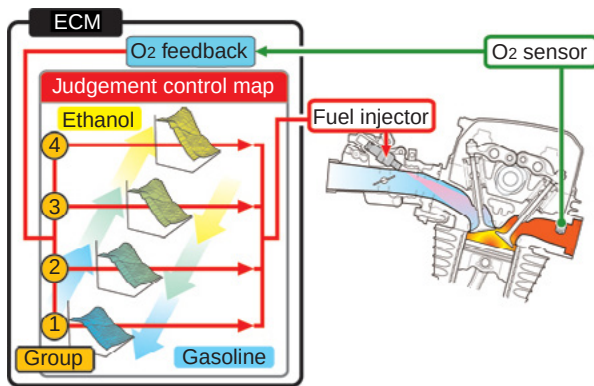


Fig. 14 Judgment control diagram map

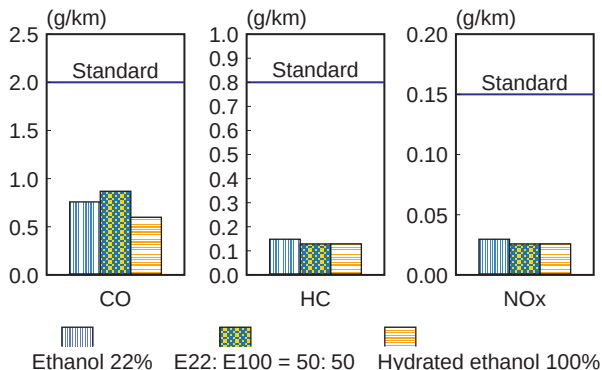


Fig. 15 Achieved exhaust emissions

Table 4 Emission standards for motorcycles

(g/km)					
Stage	Class	CO	HC	NOx	Model
PROMOT 3	$V < 150 \text{ cm}^3$	2.0	0.8	0.15	CG150 Titan
	$V \geq 150 \text{ cm}^3$	2.0	0.3	0.15	

always stored in the ECM, and is selected first during the next engine start and warm-up operation.

5.5. Exhaust Gas Performance

Table 4 lists Brazilian motorcycle exhaust emissions standards. The PROMOT3 regulations, which are on the same level as Euro-3, were implemented from 2009. In case of a four-wheeled FFV, these regulation values should be satisfied for gasoline (22% ethanol), 6.8% hydrated ethanol, and fuel consisting of an equal mixture of the two. There are currently no exhaust emissions regulations aimed specifically at flexible-fuel motorcycles, but it is thought that similar exhaust emissions performance is required.

Figure 15 shows the exhaust emissions measurement results for fuels with different ethanol concentrations. This shows that exhaust emissions 50% or less of the PROMOT3 regulation values were achieved for all ethanol concentrations, indicating that proper fuel injection and exhaust emissions processing were performed.

6. Engine Start at Low Temperatures

6.1. Startability Test Results

The issue concerning the engine start performance of ethanol fuel is that engine start performance decreases as the temperature drops. When using only ethanol, engine start is not possible at sub-zero temperatures. This is due to the fact that ethanol has a high ignition point of 13°C , and that its latent heat of vaporization is also approximately 3 times that of gasoline. However, it is a challenge for motorcycles to use the same type of sub tank system as a four-wheeled FFV, so the aim was to secure startability without a sub tank. Figure 16 shows a graph

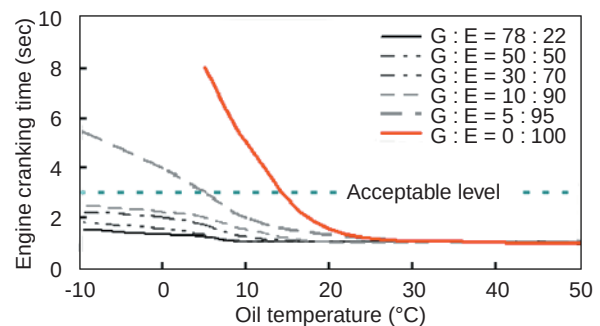


Fig. 16 Engine start time at different ethanol concentrations

comparing the cranking time until engine start for different gasoline and ethanol mixing ratios at different oil temperatures. Here, the engine was cooled completely until the oil temperature was the same as the outside air temperature. Engine startability for 100% ethanol dropped rapidly when the temperature fell below 15°C, and engine start became unlikely at temperatures below 5°C. On the other hand, when the ethanol concentration of the fuel was 90% or less, that is to say when the gasoline concentration exceeded 10%, engine start performance was found to be within the tolerable level. This indicates that when a certain concentration or more of gasoline is mixed into the fuel during engine start, stable engine start performance can be secured without the use of gasoline for engine start, even at low temperatures.

6.2. Mounting of an Alcohol Injector

If users can properly manage the alcohol concentration of the fuel in the tank according to the outside air temperature so that the engine startability does not drop, then engine startability can be secured at low temperatures, and the sub tank system can be eliminated. To achieve this, users should be able to accurately know the ethanol concentration of the fuel currently in the tank, and be able to select the appropriate fuel for refueling based on that information. An alcohol indicator consisting of the two lamps “MIX” and “ALC” was installed in the instrument panel to convey that information to users. Figure 17 shows the location of the alcohol indicator.



Fig. 17 Location of alcohol indicator

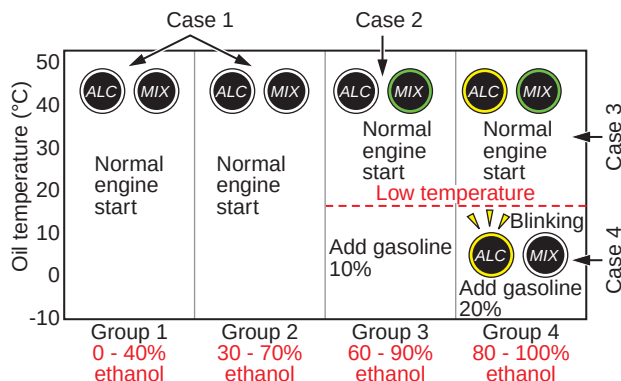


Fig. 18 Indicator functions

6.3. Indicator Display

The two lamps “MIX” and “ALC” are used in combination to indicate four different cases, to inform users of the ethanol concentration of the fuel currently in the tank, and the proper refueling method to secure good engine startability the next time the motorcycle is operated. Lamp lighting operation is linked to the control group selected as a result of map switching control, which determines the fuel injection control during operation. Figure 18 shows an overview of the indicator display.

The display contents and corresponding refueling information for each of the four cases are described below.

Case 1: Control groups 1 and 2

Both lamps off

The ethanol concentration is between 0 and 70%, and startability is good even at low temperatures.

Case 2: Control group 3

“MIX” lamp lighted

The ethanol concentration is between 60 and 90%, and startability may drop at low temperatures.

During periods when the temperature falls, additional refueling with approximately 10% or more gasoline is required when refueling.

Case 3: Control group 4

“ALC” lamp lighted

The ethanol concentration is 80% or more, and startability is poor at low temperatures. During periods when the temperature may fall, additional refueling with approximately 20% or more gasoline is required when refueling.

Case 4: Control group 4 (before engine start)

“ALC” lamp flashing

This indicates that the ethanol concentration is 80% or more and the temperature is 15°C or less, so engine start may already be unlikely.

Users can secure good startability by refueling in accordance with these indicator displays.

6.4. MIX Fuel Injection

When using gasoline and ethanol mixed fuel, the sub tank system for engine start can be omitted by performing control that secures good operability using control groups and judgment control using maps, and by mounting an alcohol indicator to help ensure a proper fuel mixture for engine start. This flexible-fuel system was named the MIX fuel injection system.

7. Fuel Supply System Components

7.1. Rust-Proofing of the Fuel Pump

One issue for the fuel supply system components is dealing with the characteristic of the corrosiveness of ethanol fuel to metal. The ethanol sold in Brazil is hydrated ethanol with water content of approximately 7%. The component most affected by this is the fuel pump, and when a gasoline-only fuel pump is used with ethanol

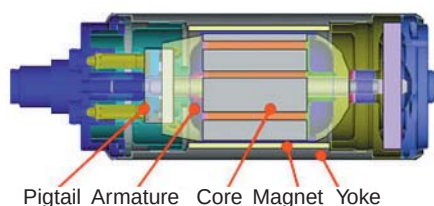
fuel, cases have been confirmed where corrosion of the metal components led to rust, resulting in malfunction. Figure 19 shows the rust-proofing performed on the various metal components of the fuel pump.

7.2. Injector

Figure 20 shows the structural diagram of the injector, and Table 5 lists the injector flow rate characteristics and materials. When using alcohol fuel, the maximum required fuel flow rate increases, even for the same engine displacement, so a larger injector flow rate range was set. In addition, the structure is the same as that for gasoline specifications, but the materials and surface treatment have been changed to increase resistance to corrosion.

7.3. Dust Deconcentration of Ethanol Fuel

The addition of ethanol is known to more finely deconcentrate the dust in the fuel. This means that the dust deconcentration in ethanol mixed fuel may promote filter



Parts	Gasoline	Flexible fuel
Pigtail	Sn plating	Sn plating
Armature	None	Resin molding
Core	None	Cu-Sn plating
Magnet	Epoxy electro-deposition painting	Epoxy electro-deposition painting
Yoke	Zn plating	Cu-Sn plating

Fig. 19 Areas of fuel pump treated with rust-preventive measures

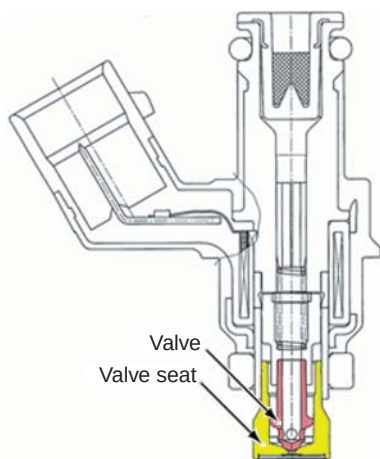


Fig. 20 Fuel injector for CG150 Titan

Table 5 Flow rate of injector and injector material of each model

		Gasoline	MIX fuel
Fuel		E20-E25	E20-E100
Fuel pressure (kPa)		294	294
Flow rate at 24 msec (mm ³ /st)		52.5	61.2
Material	Valve	S440C	S440C Passivating treatment
	Valve seat	S440C	S440C Passivating treatment

clogging. Figure 21 shows the cumulative distribution by dust particle size for gasoline and ethanol. Figure 22 shows the state of dust deconcentration in commercially available fuels. These show that ethanol contains finer dust.

7.4. Use of an Exchange Type Fuel Filter

When the existing fuel filter is used in ethanol and gasoline, the filter becomes clogged approximately three times faster with ethanol than with gasoline, and the flow rate drops. Therefore, a large capacity exchange type fuel filter was additionally installed as a countermeasure. Figure 23 shows an external view of the exchange type fuel filter. Figure 24 compares the fuel supply system with that of a conventional gasoline-only vehicle. In the system for a small motorcycle, the pressure regulator is often integrated with the fuel pump. In contrast to this,

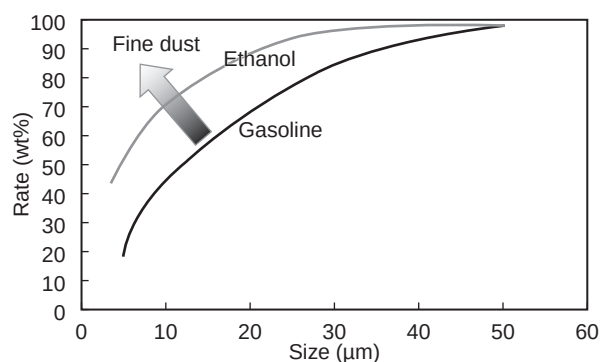


Fig. 21 Cumulative distribution of dust in fuel

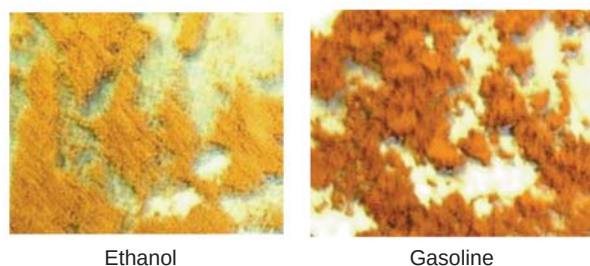


Fig. 22 State of dispersion of dust in fuel



Fig. 23 External view of stream of replacement filter

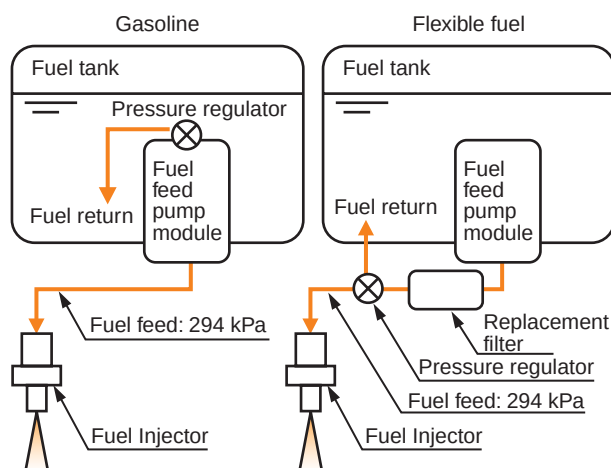


Fig. 24 Comparison of fuel feed system

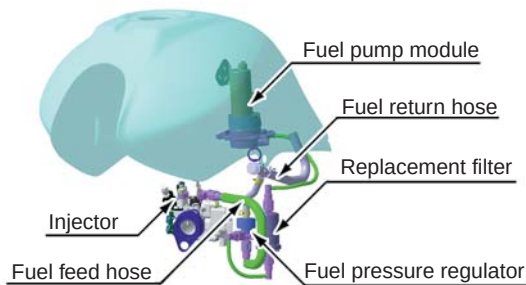


Fig. 25 Overview of fuel supply system

the pressure regulator is separate from the fuel pump in the flexible-fuel motorcycle, and is located downstream from the secondary filter. Figure 25 shows the layout of the fuel supply system components.

8. Conclusion

A flexible-fuel motorcycle was developed that matches Brazilian motorcycle user needs. The MIX fuel injection system for small motorcycles has a simple configuration

suited to the characteristics of motorcycles, and realizes flexible-fuel functions at an affordable price. The features are as follows.

- (1) Group switching fuel injection control suited to the engine characteristics of a small motorcycle is used.
- (2) An indicator is used to inform users of the ethanol concentration of the fuel and the appropriate refueling method. This eliminated the gasoline sub tank for engine start, enabling a system configuration that can be fitted to a small motorcycle.
- (3) Fuel system components that support hydrated ethanol were developed.

The CG150 Titan MIX is the first flexible-fuel motorcycle to be released in Brazil. It is hoped that the CG150 Titan MIX will delight numerous customers, and become the standard for Brazilian motorcycles in the same way that FFV have become the standard for four-wheeled vehicles.

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