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Streszczenie: Silniki spalania wewnętrznego są najpowszechniejszymi napędami pojazdów na całym świecie. Normy emisji, które stają się coraz bardziej restrykcyjne z roku na rok – powodują rezygnacje z napędu pojazdów przy użyciu silników wewnętrznego spalania. Z tego powodu stosuje się regulowane układy sterowania silnikami (ECU) do testowania nowych technologii w silnikach zasilanych bio-paliwami (eko-paliwami).

Słowa kluczowe: silnik spalania wewnętrznego, silnik, spalanie, sterownik silnika (ECU), elektroniczny układ sterowania

ENGINE CONTROL UNIT FOR ADVANCED COMBUSTION ENGINE TECHNOLOGIES AND SUSTAINABLE SOURCES APPLICATION

Summary: Internal combustion engine are most common used drives in many vehicles around the world. Emission norms which are getting strict nearly every year are pushing internal combustion engines away from vehicles. Due to this fact adjustable engine control units (ECU) are used to test new combustion technologies together with biofuels.

Keywords: internal combustion engine, engine, combustion, ECU, electronic control unit

1. Introduction

Engines with internal combustion currently represent a source of driving force for transport technology, but they also find significant use in the energy industry. In general, however, they are advantageously applied where it is necessary to generate a large amount of mechanical work with small demands on built-up space, weight of the drive unit, fuel tank, etc. A critical condition of the current modern era is the ability

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to meet the growing demands for energy production in the long term, where the vast majority are still made up of exhaustible fossil fuels [1,2].
A part of every means of transport is a drive unit. The combustion engine has become the most used drive unit for means of transport. The four-stroke internal combustion engine is the most widespread drive unit in vehicles due to the mentioned advantages. Over several decades of intensive development, the designers and engineers managed to fine-tune the mechanical parts of the engine, and the electronics have already taken over further development [3].
Manufacturers of means of transport offer a wide selection of assortments, which are distinguished by e.g. dimensions, driving comfort, fuel consumption but also speed. The mentioned characteristics are largely influenced by engine performance. Nowadays, the motorcycle is becoming a popular means of transport. The motorcycle is especially useful in cities, which have crowded roads every day, which is associated with traffic jams and waiting. The single-track means of transport is used not only in transport, but also in sports, hobbies or tourism. When increasing the output performance parameters of a single-track means of transport, a problem arises with maintaining its reliability and service life. The world's motorcycle manufacturers are looking for various ways to increase performance at the lowest possible cost [4,5].
The subject of the article is an approximation of the engine control system (ECU) of the motorcycle with four – stroke engine, which controls the operation of the engine and the combustion cycle itself. The parts of the control unit described in this article are used both in series-produced motorcycles and in motorsport. The software of the control unit can be adjusted for the needs of the user, such as for achieving maximum engine performance while maintaining the longest possible life.
The focus on the control unit of the four-stroke power unit is due to the fact that it is currently preferred mainly due to lower fuel consumption and less wear of individual structural segments. Other advantages of the four-cycle work cycle include more perfect combustion, which is associated with lower emission production [6].

2. Engine control system actuators

Today's racing motorcycles use fully electronic ignition and fuel injection, which has displaced carburettor systems. Such fully electronic control consists of various sensors, control unit, etc.
All processes of the internal combustion engine control are dependent on a constant supply of input data, which the ECU control unit then evaluates and creates control actions for the engine management actuators. The mentioned sub-chapter briefly provides information about the control elements and functional members of the ECU control unit, which controls and optimizes the combustion process.
By increasing the efficiency of the combustion engine, it is possible to achieve higher output performance parameters and also reduce emission values. Nowadays, electronic control units are an integral part of every internal combustion engine, not only of a car, but also of a motorcycle [7,8].

3. Technical elements of the ECU electronic control unit

The electronic control unit should be seen as a specific microcomputer that is very important in controlling and optimizing the combustion process of the engine. The control unit receives input data obtained through sensors that sense various physical values during engine operation. Subsequently, the control unit processes the distributed operational information recorded by the aforementioned sensors. Based on the pre-programmed functions, the control unit then creates control signals for the engine management actuators. The amount of fuel injected, as well as the moment of ignition of the mixture, is made based on the input data of the given data fields. Such a system controls and optimizes the combustion process of the engine during all its modes.
During the operation of the combustion engine, the following operating modes arise, which must be evaluated and subsequently optimized by the control system:

- engine acceleration mode during its start-up,
- engine idling mode,
- engine cold start mode,
- maximum power mode.

Figure 1. RACING ECU control unit module

Important control data is located in ROM (ReadOnlyMemory). These main control data are essential for the ECU unit's operation itself. The data fields of the microprocessor are read precisely through the given memory. Current data on the operation of the combustion engine is stored using the RAM (Random Access Memory) module.

The EEPROM module ensures the distribution of current data as well as their subsequent deletion and re-uploading. Uploading data fields to the unit's ECU consists of several important operations. This kind of operation requires specific software equipment, on the basis of which it is possible to modify the data fields of the unit's ECU.
The connection between the ECU unit and the PC is realized via the CAN/BUS communication interface. Today's ECU units contain a standardized OBD socket.
The sensors through which the ECU unit obtains current data during the operation of the combustion engine work on the basis of analog mode. The ECU unit, as mentioned above, works with data in digital form and therefore the A/D analog-to-digital converter is extremely important.
The A/D converter transforms data obtained through various sensors that record important data, such as throttle position, amount of air sucked into the intake tract, exhaust gas temperature, engine temperature, etc. Subsequently, the ECU unit processes and evaluates the given data [7,8].

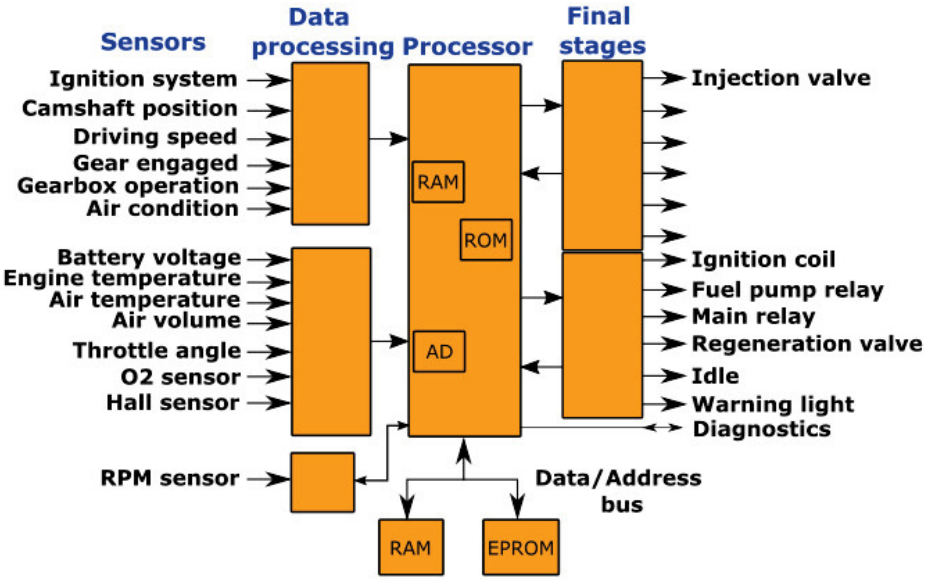

Figure 2. The ECU unit operation block scheme

4. The combustion engine operational data sensing and recording

Sensors are among the most important elements of the engine control system. They record important physical parameters during its operation. In the technical solution of the sensors, the main emphasis is placed on the accuracy of their measurement and service life. The basic sensors used in the engine control system include:

- impulse sensors,
- pressure sensors,

- volumetric sensors,
- temperature sensors.

The priority engine management sensors include a pressure sensor that detects the pressure in the intake manifold of the combustion engine, the so-called MAP (Manifold Absolute Pressure) sensor. The engine load can be expressed on the basis of the vacuum created in the intake manifold during the operation of the combustion engine. Current MAP sensors are also able to define the value of atmospheric air pressure. The ECU unit subsequently optimizes the fuel injection data field together with the ignition advance angle data field based on the atmospheric pressure value. This correction is extremely important when changing altitude.
The IAT is a temperature sensor that detects the temperature of the intake air or is also referred to as MAT. The air temperature has a significant effect on the optimal operation of the drive unit, as a result of which the content and volume of oxygen changes. If there is a given ECU change, the unit creates a correction between the air/fuel ratio. The correction is implemented by changing the amount of injected fuel. The position sensors include the throttle position sensor and the accelerator position sensor. In technical terminology, it is referred to as a TPS sensor. The operation of this sensor is based on a resistance potentiometer system. If there is a change in the position of the moving member, in our case the throttle, resistance transformations occur. Position sensors are among the most important members of the internal combustion engine control system.

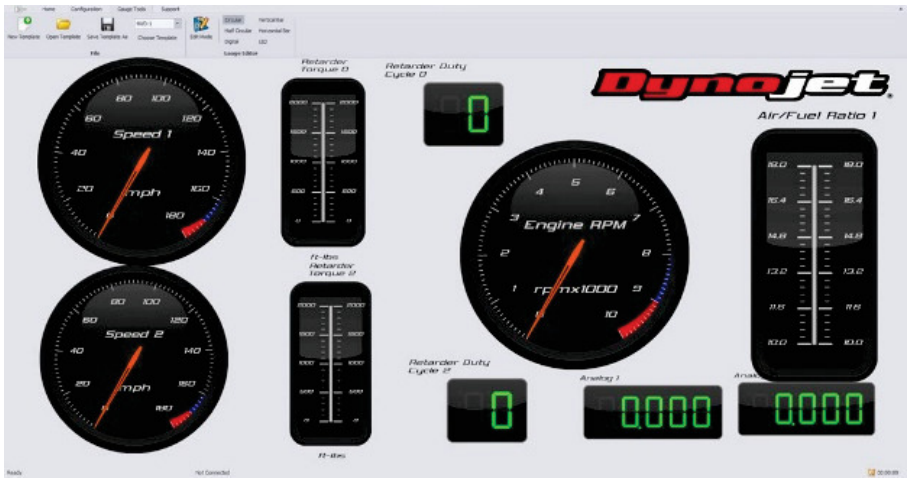

Figure 3. Sensor output data in the interface

For the engine management system to work properly, the functionality of the crankshaft position sensor is necessary. The aforementioned sensor for induced voltage uses the passage of a conductive object through the working field. This sensing method works on the principle of the Hall effect, which uses an optical or magnetic sensing method. There is a protrusion on the flywheel of the crankshaft that serves to excite the impulse. The camshaft position sensor works on a similar principle.

When optimizing data fields, it is extremely important to know the composition of exhaust gases during various dynamically changing engine loads. It is the lambda probe that defines the given composition.

Engine performance is determined by the amount of energy obtained by burning fuel, while the correct combustion process requires an optimal mixing ratio. For four-stroke spark-ignition combustion engines, the ideal mixing ratio is 14.7:1. In lean engine mode, the lambda ranges from 1.07 to 1.17. For engines that are the drive unit of racing specials, the lambda ranges from 0.80 to 0.97. The lambda value also depends on the construction of the combustion engine itself, but also on the quality of the gasoline used. Exceeding the mentioned lambda values can cause a decrease in the efficiency of the combustion process.

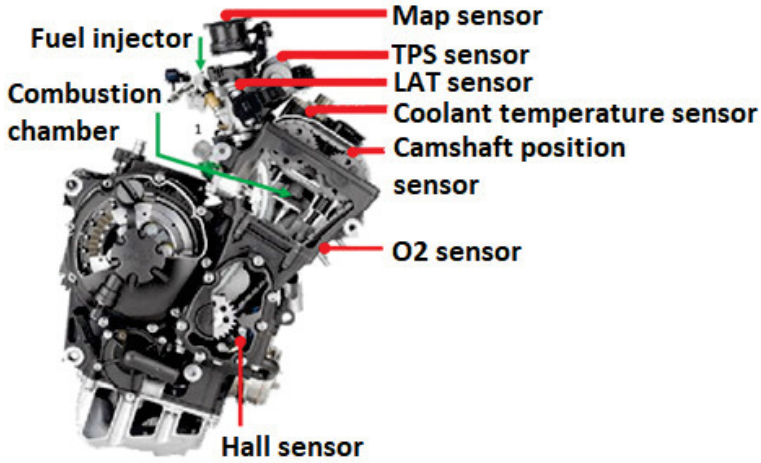

Figure 4 . Location of engine management sensors on the motorcycle engine

5. Elementary and additional tasks of the engine control system

The basic task of the ECU unit is to receive and process data obtained through sensors. After their processing by the ECU, the unit performs regulatory and control tasks. Engine management of an internal combustion engine ensures two elementary tasks, which are the determination of the necessary volume of dosed fuel and the specification of the advance angle of the ignition of the working mixture in the engine's combustion space.

Determining the fuel dose

The basic dose of fuel depends on engine speed and load. If these quantities are combined together, we get the so-called fuel map. Specific data can be obtained on the basis of measurements performed on a performance dynamometer or during testing on a racing circuit using datalogin. The basic fuel dose is corrected on the basis of external influences in order to ensure a constant composition of the mixture.
Main quantities:

- engine temperaturę,
- intake air temperature,
- air pressure,
- on-board network voltage.

The ECU unit also enables fuel enrichment at maximum load or sudden acceleration of the engine. The moment of injection time is corrected by revolutions, load, intake air temperature and other parameters.
Currently, there are a large number of injection systems for internal combustion engines, and therefore, when modifying the ECU of the unit, it is necessary to define the type of injection of a specific power unit. For example, group fuel injection is used in engines that do not have such high demands on the output performance parameters. A power unit with such an injection system does not need to be equipped with a camshaft position sensing element.
The second system is simultaneous injection, which is used to ensure even distribution of the mixture. The given system works with the possibility of injecting all injectors at the same time.
The so-called dual fuel injection system is used for power units intended for motor sports. This injection system is specific in that it contains two independent injectors. The first injector is located before the throttle and the second before the intake valve of the combustion engine. The given injection system ensures the engine's quick reaction ability and flexibility in rapidly changing load conditions on racing circuits.

The working mixture ignition moment determination

The basic parameters for determining the ignition advance angle are engine speed and load. When correcting the pre-ignition map, other parameters are also taken into account, such as engine temperature (an engine with a higher temperature is more prone to detonation combustion, which is undesirable), intake air temperature, throttle opening position and speed, exhaust gas temperature and composition , pressure in the suction pipe, etc. In general, a long ignition advance leads to thermal and mechanical stress on the engine, and conversely, a low ignition advance causes a decrease in performance characteristics. In some cases, a low ignition advance is desirable, for example, for faster heating of the catalyst to operating temperature.
The accuracy of the moment of ignition of the mixture is of great importance, especially for high-speed spark-ignition combustion engines. When solving pre-ignition maps, various simulation programs are used.

6. Conclusion

Mentioned adjustable engine control unit makes possible to use and test new technologies in an internal combustion engines which can lead to maximizing engine performance and also to reduction of fuel consumption and minimizing emissions levels that are produced by the internal engine during operation. Emission norms are getting very hard to reach for many vehicle producing companies and because of that usage of fully adjustable ECU can test dual fuel technologies (application of biofuels

and alternative fuels) which in many tests done by various scienties show emission reduction while maintaining or even increasing the engine performance.

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