COMPUTER SIMULATION POSSIBILITIES IN MODELLING OF IGNITION ADVANCE ANGLE CONTROL IN MOTOR AND AGRICULTURAL VEHICLES

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Summary. The purpose of the present article is to present a computer simulation model of the ignition advance angle in ZI engines. The opportunities associated with the use of LabView software package have been presented on the basis of individual functional blocks in order to create the simulation program. The methods of basic data entry into the program and the opportunities in the scope of their reading depending on the setups of correspondingly defined modules have also been illustrated. Therefore such a model can be used for the didactic or industrial purposes e.g. for the designing of modern motor vehicles controllers.

Key words: computer simulation, spark ignition, motor vehicle controller, simulation model, ignition map, ignition advance angle.

INTRODUCTION

The last two decades have been characterized by very dynamic development in the field in electronics, particularly in the scope of semi-conductive and microprocessor systems. At the moment the microprocessor devices are used in every kind of electronic equipment encompassing the wide range of specialized equipment used both in industry and household appliances. Their task is to perform the control and diagnostic functions for the specific equipment. The changes occurred also in the automotive technology. Many new circuits have already been and still are created to increase the driving comfort and safety. Furthermore the new technical solutions have also been applied in the agricultural vehicles being actually controlled by means of micro-controllers. Therefore the circuits controlling ZI engines operation are completely different from those applied several decades ago.

The modifications occurred among others in the scope of air – fuel mixture ignition control. The optimal time of the air – fuel mixture ignition is determined by means of the introduced spatial bitmap of the ignition advance angle vs. engine speed and its load. This time is corrected depending on current engine operation parameters i.e. crankshaft speed, load, cooling medium temperature. The controller is provided with data inputs supplied by the sensors and the set values selectors and determines the ignition advance angle in accordance with the established algorithm. The correct time of the air – fuel mixture ignition is essential for the fuel consumption, exhaust gas composi-

tion, achievable torque and the service life of the engine (knock combustion) [10]. Owing to the developed control circuits and the requirements in the scope of functioning reliability, the permanent control of the control devices is required as early as in their designing phase. Therefore the efforts are continued to find the next new research methods in order to answer the questions in the scope of reliability and correct operation of these elements in various conditions. One of possible solutions consists in the application of the computer simulation techniques.

The simulation is defined as the testing of the performance of specific object in various operating conditions. The introduction of the computer techniques makes it possible to create the simulation models using the adequate programming languages in a relatively fast and easy manner in order to eliminate the laboratory (physical) models which are frequently complex and rather difficult to build.

THE USE OF LABVIEW SOFTWARE AS SIMULATION ENVIRONMENT

LabView software has been created by National Instruments as a tool on the basis of the graphical programming environment in G language in order to enable the designing of the simulation models and to support the designers. It consists in the appropriate combination of icons representing the elements of the system (sensors, control data, actuators etc.). Their interrelations are illustrated in the form of diagram i.e. by adequate connection of the defined icons together.

Therefore the program operation is almost intuitive and the capabilities of the program are comparable with high level languages. Even extremely sophisticated systems or circuits can be created and simulated in an easy manner. Furthermore, the simulated input elements (sensors and set values selectors) and output elements (actuators) can be replaced by the real subassemblies by means of appropriate extension cards [4] when LabView software is used. In such a case the computer becomes a test and measurement device with comprehensive measurement capabilities. Therefore, to change the function of specific block or any controlling/recording element, its parameters should be changed in the program only. The purchase of any other measurement devices as in the case of physical models is unnecessary.

Owing to its several advantages and opportunities, this environment has been used by the authors of the present study in order to create the computer simulation model of ignition advance angle control.

ASSUMPTIONS OF SIMULATION MODEL

The front panel created by the authors for the computer simulation model of ignition advance angle control in a combustion engine has been illustrated in Fig. 1 showing the knobs simulating the inputs from the sensors for: crankshaft speed, throttle position or the manifold pressure and cooling medium temperature. The output elements (incorporated on RH side) are the sensors for: ignition advance angle, manifold pressure, MIL control light.

The program enables the ignition advance angle control versus:
– engine crankshaft speed;
– manifold pressure,
– cooling medium temperature.

Furthermore it is possible to simulate the typical ignition control defects (by means of corresponding switches) encompassing the following:

– lack of the engine crankshaft speed input
– damaged sensor of cooling medium temperature
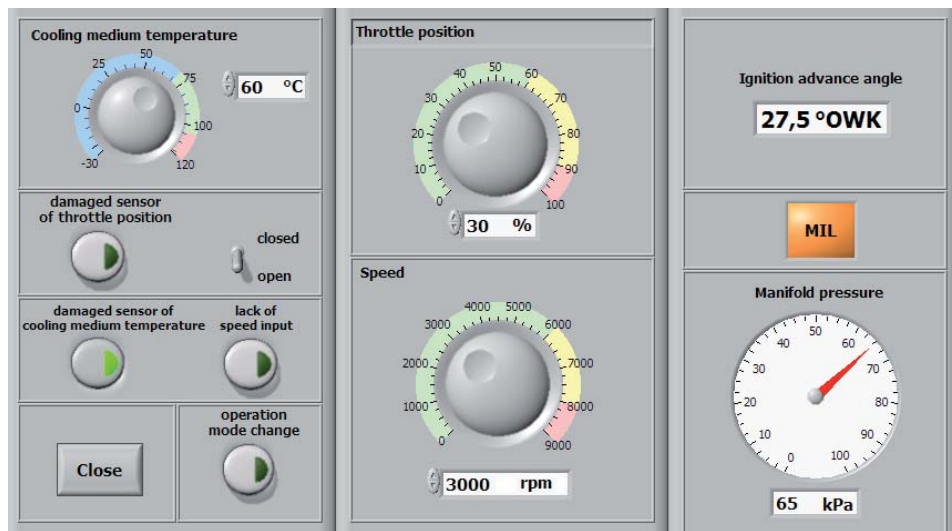– damaged sensor of throttle position.

Fig 1. Front view of the Program Front Panel

DESCRIPTION OF INDIVIDUAL BLOCKS AND DIAGRAMS OF THE PROGRAM

The input and output elements are simulated in the program by means of correspondingly defined icons (Fig. 2 and 3). The input data illustrate the functions performed by the sensors and set values selectors. The signals values can be changed within correspondingly defined limits by means of sliders and switches. The indicators displaying the controlling values of the control system have been used as the output elements. Owing to the program structure they can be replaced by the real actuators.
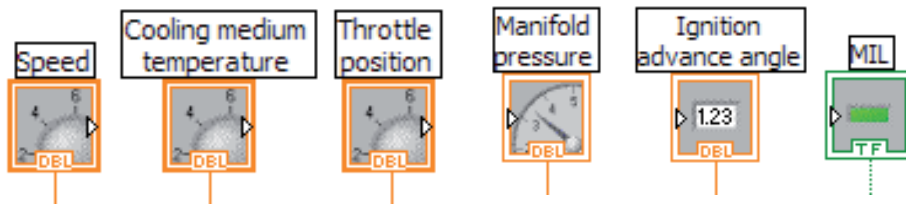
Fig. 2. Icons representing the input data

Fig. 3. Icons representing the output data

The value of the ignition advance angle is read by means of specially created subroutine „mapa.vi" (Fig. 4) with inner structure illustrated in Fig. 5.
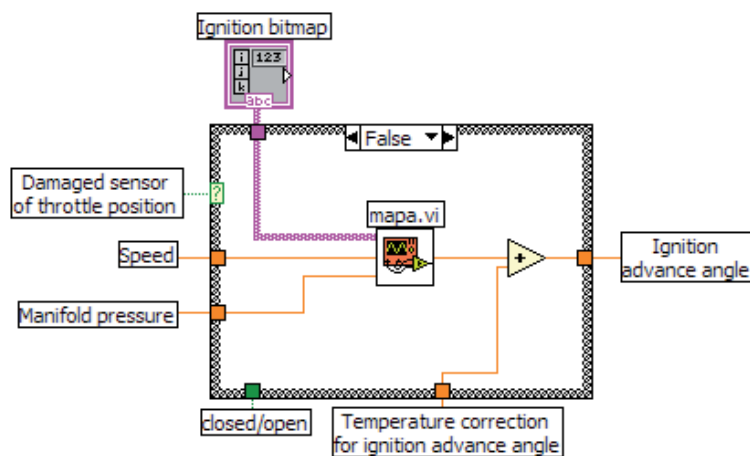
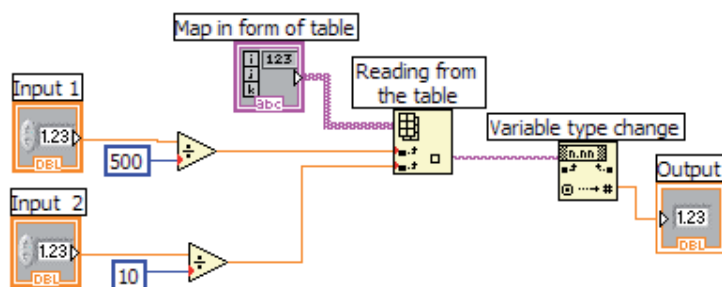Fig. 4. Realization diagram for the ignition advance angle reading from a bitmap

Fig. 5. Inner structure realization diagram for "mapa.vi" subroutine

Owing to the concept of its use, the additional function block ("mapa.vi") can be used in other parts of the program for reading of other tabulated data i.e. manifold pressure as described hereinafter.

The basic value of the ignition advance angle is recorded in the ignition map and depends on the engine crankshaft speed and on the pressure in intake manifold. It is entered into the program in the form of Table (Fig. 6).

Fig. 6. Fragment of a sample ignition map entered into the program in the form of Table

The bitmap illustrated above has been presented as an example of planar and spatial data – curves introduced to the program. The manifold pressure value are represented on X-axis and engine crankshaft speed values on Y-axis. The value of OWK ignition advance angle is read from individual table field in accordance with these parameters.

In case of damage of the throttle position (simulated by means of corresponding pushbutton), the controller will be switched over to emergency operation mode to one of two emergency curves. MIL control light will go on simultaneously. In such a case the ignition advance angle is determined on the basis of the engine crankshaft speed and depends on the idle speed contactor position ("closed / open" position; Fig. 7 and 8).
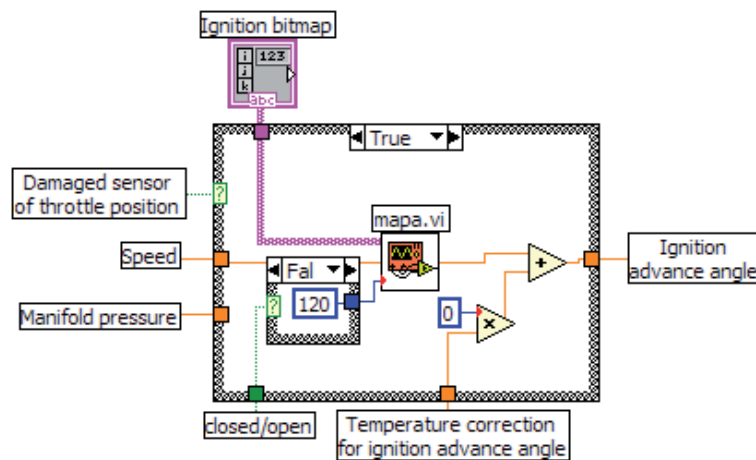
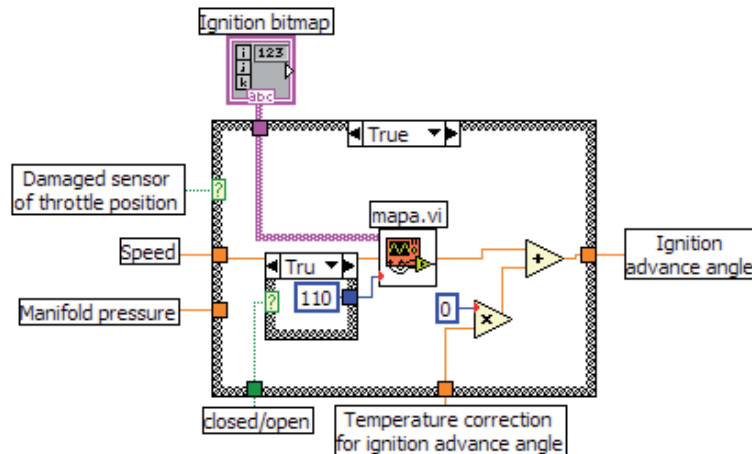Fig. 7. Realization diagram for throttle position sensor damage ("open")

Fig. 8. Realization diagram for throttle position sensor damage "closed"

The emergency curves are recorded in the ignition bitmap table and are read in accordance with determined algorithm illustrated in the diagram. If such a situation takes place, the temperature correction is disabled (the value is multiplied by 0).
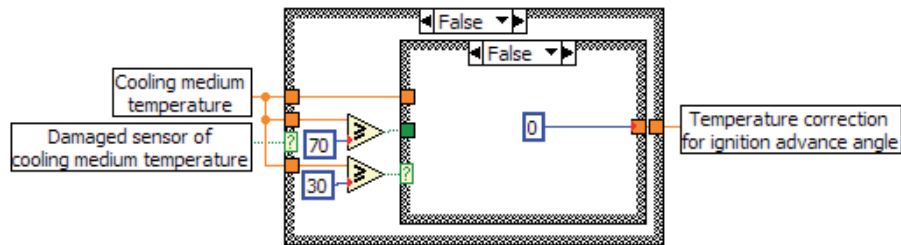
Fig. 9. Realization diagram for the ignition advance angle correction vs. engine cooling medium temperature
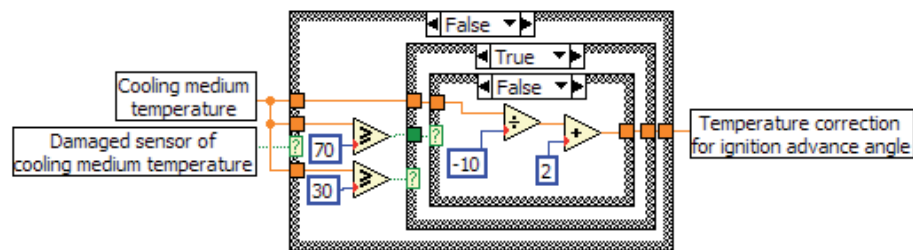(under 30°C)

Fig. 10. Realization diagram for the ignition advance angle correction vs. engine cooling medium temperature
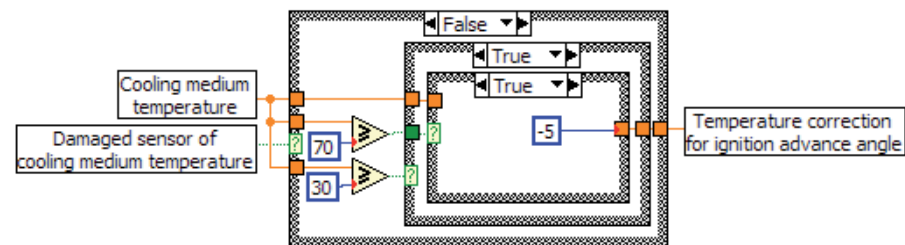(30–70°C)

Fig. 11. Realization diagram for the ignition advance angle correction vs. engine cooling medium temperature
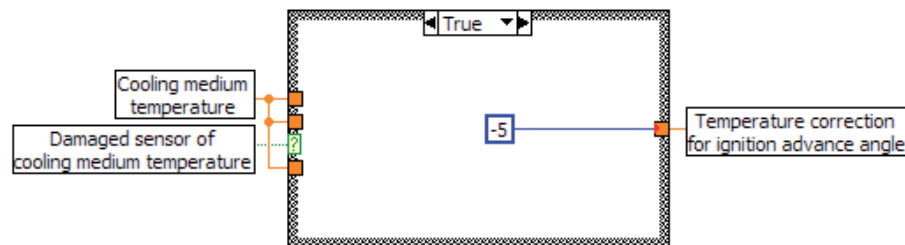(above 70°C)

Fig. 12. Realization diagram for the ignition advance angle correction in case of damaged sensor
of engine cooling medium temperature

The realization diagrams for the ignition advance angle correction vs. cooling medium temperature are illustrated in the Fig. 9 – 11. There is no correction for temperatures under 30°C. In case of temperature increase above this value, the angle is reduced by 1°OWK per every 10°C up to the temperature of 70°C. Above the latter, the constant correction value of -5 °OWK is achieved. The same value of ignition advance angle correction is used if the temperature sensor is applied (Fig. 12).

The pressure in intake manifold is determined on the basis of the throttle position angle or of other engine load parameters. The throttle position can be controlled by means of a created simulation program. The diagram of this functional block is illustrated in Fig. 13. The pressure values depend on the crankshaft speed and on the throttle position angle and are entered into the program in tabulated form (Fig. 14).
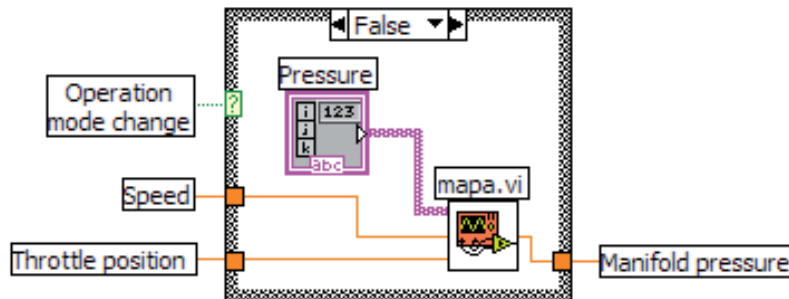
Fig. 13. Realization diagram for the pressure control in the intake pressure

Fig. 14. Sample table field representing the pressure reading

The function of the throttle position angle control key can be changed to the direct pressure control in the intake manifold by means of the selector "Operation mode change" (Fig. 15)
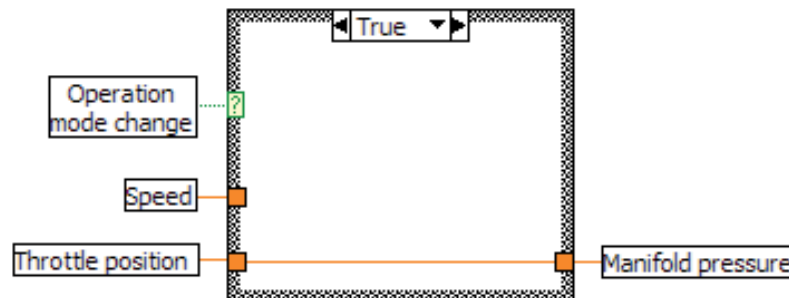
Fig. 15. Realization diagram for the direct pressure control in the intake pressure

The ignition advance angle α_z in the program presented herein is the sum of the value of the angle reading from the ignition bitmap and temperature correction. This relationship is represented by the formula:

$$\alpha_z = \alpha_z^m + \alpha_z^T,$$ (1)

where:
α_z – calculated ignition advance angle,
α_z^m – ignition advance angle reading from the ignition bitmap,
α_z^T – ignition advance angle correction vs. engine cooling medium temperature.

The created computer simulation model makes it possible to determine and to verify the correct functioning of the ignition bit maps as well as corrective and emergency curves which were entered into the program in a tabular form. The examples of emergency curves determined in the program are illustrated in Fig. 16.
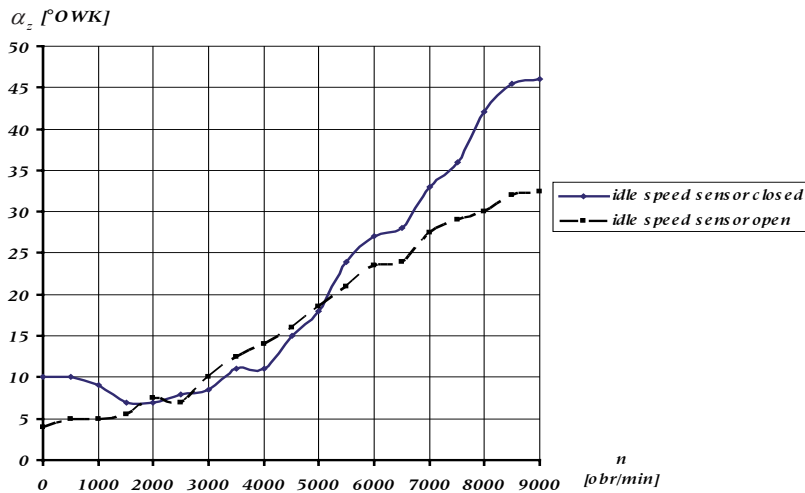

Fig. 16. Sample curves of the ignition advance angle with damaged throttle position sensor

In case of corrective curve of the ignition advance angle vs. cooling medium temperature, one should assume that there is no correction at the temperature under 21 °C. Individual points can be calculated from the formula:

$$\alpha_z^T = \alpha_z - \alpha_z^{20},$$ (2)

where:
α_z^T – ignition advance angle correction vs. temperature,
α_z^{20} – ignition advance angle correction at the temperature of 20 °C,
α_z – ignition advance angle reading.

Fig. 17. illustrates the corrective curve of the ignition advance angle vs. engine cooling medium temperature.
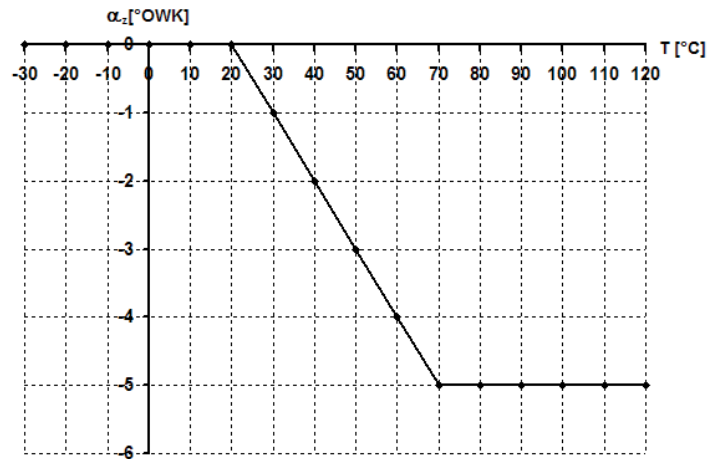

Fig. 17. Sample curve of the ignition advance angle correction depending
on the engine cooling medium temperature

CONCLUSIONS

The created computer simulation model for ignition advance angle control represents the operation of the real combustion engine operation control system and makes it possible to verify the basic control map and the correction curves. The user can easily introduce his own ignition bitmap in order to eliminate the defects and failures and to check their operation correctness. The system can be also expanded in form of new circuits as well as the simulated sensors and actuators can be replaced by real elements by means of additional extension cards. Owing to such solution the computer becomes a test and measurement device with comprehensive capabilities in the scope of extension and functions. Therefore the tests of prototype sensors and actuator are possible for their verification.

The program makes it possible to change the basic model parameters in an easy and quick manner and to simulate various variants of the engine operation. Furthermore it is possible to simulate the defects of individual elements and to monitor their impact on the operation of the whole system. Therefore such a model can be used for the testing of parameters in emergency cases which is useful in case of design of new solutions for the controllers or in case of checking of the new maps and control characteristics in the motor vehicles engines with spark ignition.

Owing to its transparent structure, the model can be used to simulate other microprocessor control systems in modern technical equipment.

Another possible application consists in the use of such simulation model for didactic and training purposes, in order to familiarize the attendants with the working principle of the computer control system and its structure. In contrary to the physical models, their inner structure is accessible to students, who are able to perform corrections and check the impact of such changes onto the operation of the whole control system.

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