Simulation Tests of Injection System Reliability

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Abstract

During the operation of automotive combustion engine a very important role is played by its durability. Knowledge of engine working time facilitates not only planning the strategy of operation of the vehicle, but also allows for early planning services or repairs. Durability of the automotive engine is bound up with durability of electronic injection assembly. This assembly determines engine power losses and in case of engine damage, can increase considerably cost of repair. Electronic ignition has been subjected to significant changes during the last few years owing to the rapid pace of development in the field of electronics. In addition, by linking them with other electronic systems in the vehicle an overall engine-management system becomes possible, as well as the joint optimisation of the individual systems. The paper presented results of simulation tests of injection system.

Keywords: Injection system, Automotive engine, Simulation test

1. Introduction

The process of controlling the fuel dose in injection petrol systems consists in influencing the time of opening the electric valve; the time of opening is to some extent linearly connected with fuel injected mass (volume). Both the time of injector opening and the moment of injection start in relation to engine crankshaft position can be subject to influence. The latest achievements in constructing injectors capable of precise high-pressure injecting have made the development of GDI (Gasoline Direct Injection) systems possible. Systems injecting fuel to the inlet system – single point injection (SPI) to the throttling valve and multi point injection (MPI) in front of inlet valves - reached high level of development. In each of the injection systems, there is a λ probe making it possible to solve the problem of mixture ratio stabilization (by measuring oxygen contents in exhaust gases).

The system of injection control is designed in such a way that necessary fuel is supplied with proper pressure in the fuel system (proper fuel mass and degree of fineness). Successive injections are synchronized with the working process. The controlling signal (time of injector opening) is a pulse of certain time length. When the pulse is longer, the injected fuel dose is increased.

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On the grounds of engine operating conditions, the determined value of the coefficient (sucked air mass to fuel mass ratio) is chosen. Then, the controller determines sucked air mass on the basis of measurement sensors indications. The correction of injection time according to power voltage is carried out.

The procedures of control in injection systems are stored in microprocessor memory as three-dimensional characteristics.

2. Simulation Tests Carried Out on the Stand of Honda PGM-FI Injection System

The aim of tests is to verify the functionality of the stand for testing Honda PGM-FI DPI injection system for chosen failures.

The program of tests:

1. Testing the change of fuel injection time depending on variable operating conditions of the injection system.
2. Testing the change of fuel injection time for the system in which the alternator failure is simulated.
3. The simulation of injection system sensors failures and their influence on the change of fuel injection time.
4. Testing the efficiency of injectors depending on variable operating conditions of the system.

In Honda PGM-FI injection system, a method of determining mixture composition on the basis of absolute pressure (load) and engine speed was used. On the grounds of those values, the electronic control module determines the basic injection time. The system is equipped with a device shutting off the fuel during engine breaking and a device limiting engine speed. In the circuit of air feed, apart from typical parts, there are:

- throttling valve body on whose shaft there is a throttling valve position sensor (TP) which transmits signals about the degree of throttling valve opening to the control module (ECM);
- electromagnetic valves for stabilizing the idle run (IAC valve) and a valve of fast idle run which delivers the programmed amount of air while electric equipment receivers are being switched on and off unless the cooling agent reaches 40°C.

The electronic control module receives signals from correction sensors and transforms them into fuel injectors opening pulse which is dependent on time. Optimum, basic injection time, according to the pressure in the suction manifold and engine speed, is programmed in the control module memory as a three-dimensional characteristic in function of air pressure in the suction manifold and engine speed. A sensor mounted on the suction manifold is used for determining pressure; TDC/CKP sensors are used for determining engine speed. Besides, the following functions are programmed in the control module memory:

- controlling the injected fuel dose while starting the engine,
- controlling the fuel pump,
- adaptation mode,
- self-diagnostics,
- trouble service.

In that injection system, there are the following sensors:

- sensor of pressure in the suction manifold - MAP,
- crankshaft position sensor – TDC/CKP,
- atmospheric pressure sensor – PA,
- sensor of cooling agent temperature – ECT,
- sensor of sucked air temperature – IAT,
- throttling valve position sensor – TP,
- λ probe – oxygen sensor.

Fuel pressure is maintained by the controller set on 255kPa. The fuel pump is controlled by the relay. Honda PGM-FI (DPI) injection system
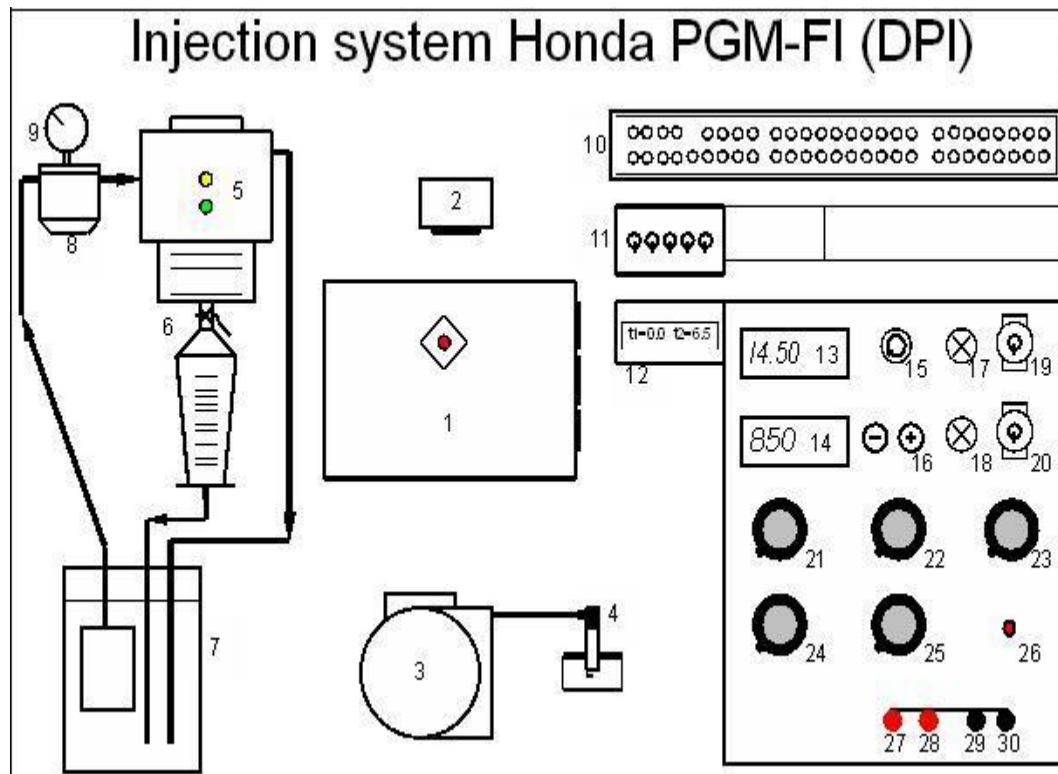

Fig.2.1. Diagram presenting the stand for testing PGM-FI (DPI) injection system.

1. Electronic control module (ECM). 2. Main relay. 3. Timer-distributor. 4. Sparking plug. 5. Body of throttling valve and injectors. 6. Measuring cylinder. 7. Fuel tank with fuel pump. 8. Fuel filter. 9. Manometer. 10. Edge card connector. 11. Switch-keys of failure simulations. 12. Digital voltmeter. 13. Digital rev-counter. 14. Potentiometer of voltage adjustment. 15. Push-buttons of rotational speed controller. 16. Control lamp of switching on voltage in the system. 17. Control lamp of switching on the adjustment of time-distributor rotational speed. 18. Switch-key of supplying voltage. 19. Switch-key of time-distributor rotational speed adjustment. 20. Simulation of engine temperature (ECT sensor). 21. Simulation of inlet air temperature (IAT sensor). 22. Simulation of throttling valve opening (TP sensor). 23. Simulation of pressure in suction manifold (MAP sensor). 24. Simulation of oxygen sensor. 25. Push-button of erasing errors. 26,27. Test stand clamps. 28,29. Power supply clamp. 30. Display of the system measuring fuel injection time.

2.1 Simulation tests of fuel injection time change depending on variable injection system operating conditions

Tests of fuel injection time change depending on negative pressure values in the suction manifold.

The test $t_w = f(p_d)$ was carried out for the following established conditions:
- cooling agent temperature: $T_s = 60°C$;
- temperature of air in the inlet system: $T_p = 20°C$;
- voltage of λ probe signal: λ=500mV, (λ=1);
- power supply voltage : $U_A = 14V$.

The tests were carried out for values of negative pressure in the suction manifold ranging from 600mmHg to 0 mmHg, with a jump every 100 mmHg.

The measurement was carried out for constant engine speed n=800rpm (+/- 50 rpm) – the throttling valve is completely closed – $\alpha_p = 0\%$. The measurement was repeated for engine speeds n=1400, 2000, 2600, 3800, 4400, 5000, 5600, 6200, 6800 rpm and corresponding throttling valve openings $\alpha_p = 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 \%$.

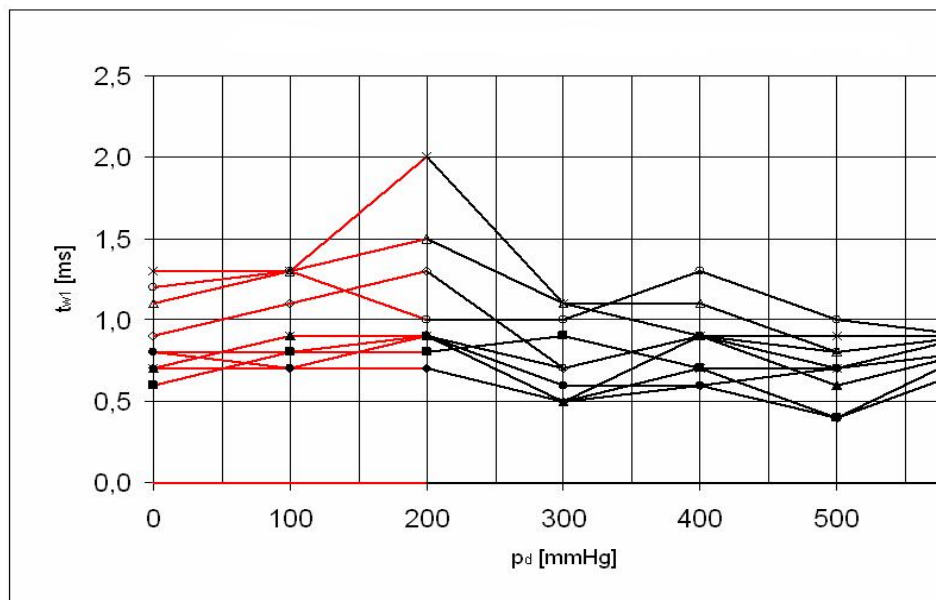Test results have been graphically presented in Fig. 2.2 to 2.6.

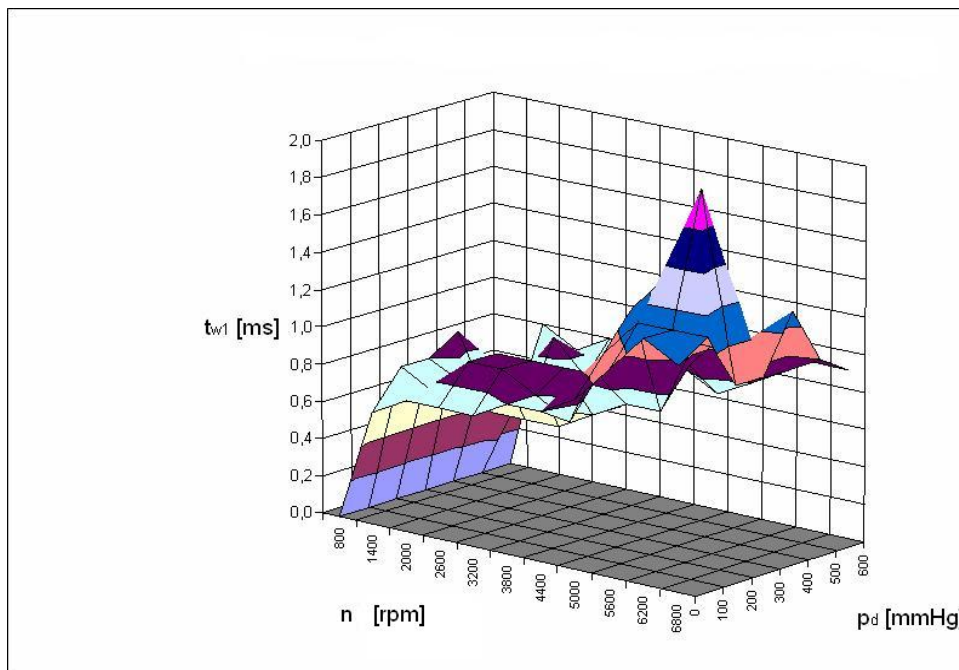Fig.2.2 Change of fuel injection time $t_{w1} = f(p_d)$ for the main injector

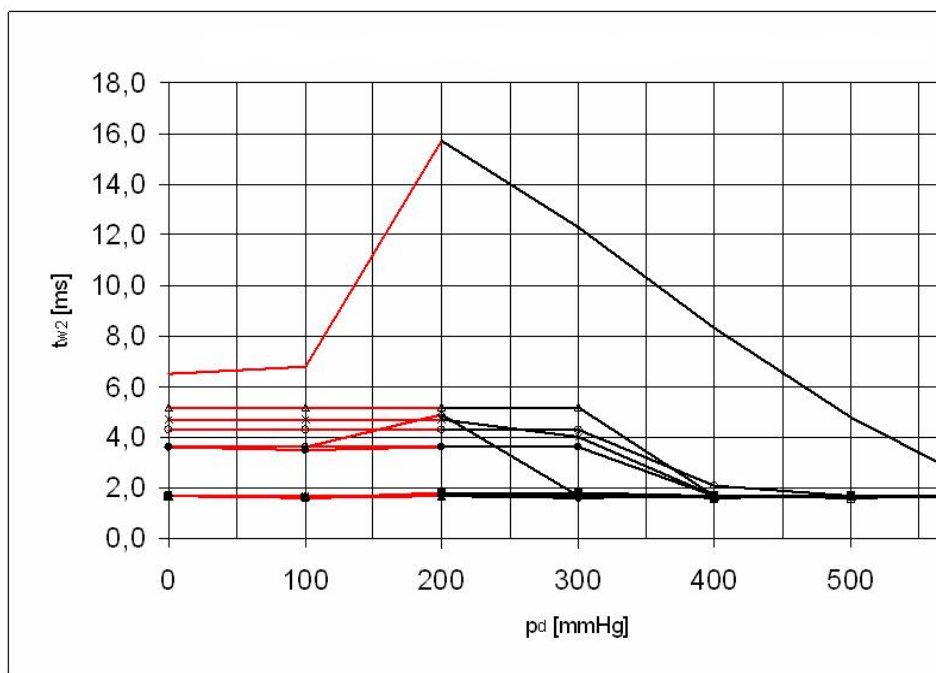Fig. 2.3 Change of fuel injection time $t_{w1} = f(p_d)$ for the main injector

Fig. 2.4 Change of fuel injection time $t_{w2} = f(p_d)$ for the supportive injector
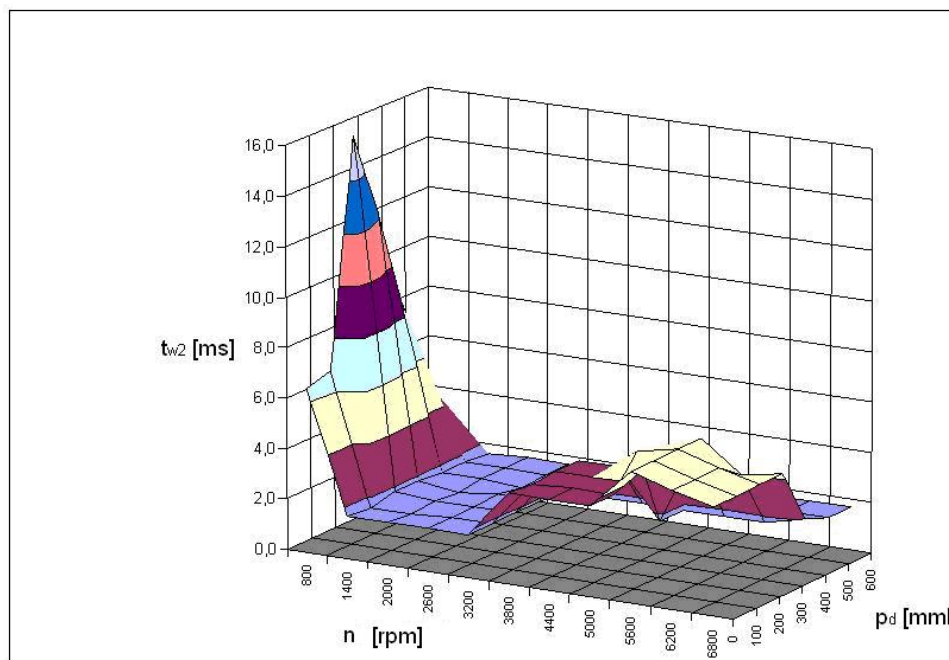
Fig. 2.5 Change of fuel injection time $t_{w2} = f(p_d)$ for the supportive injector
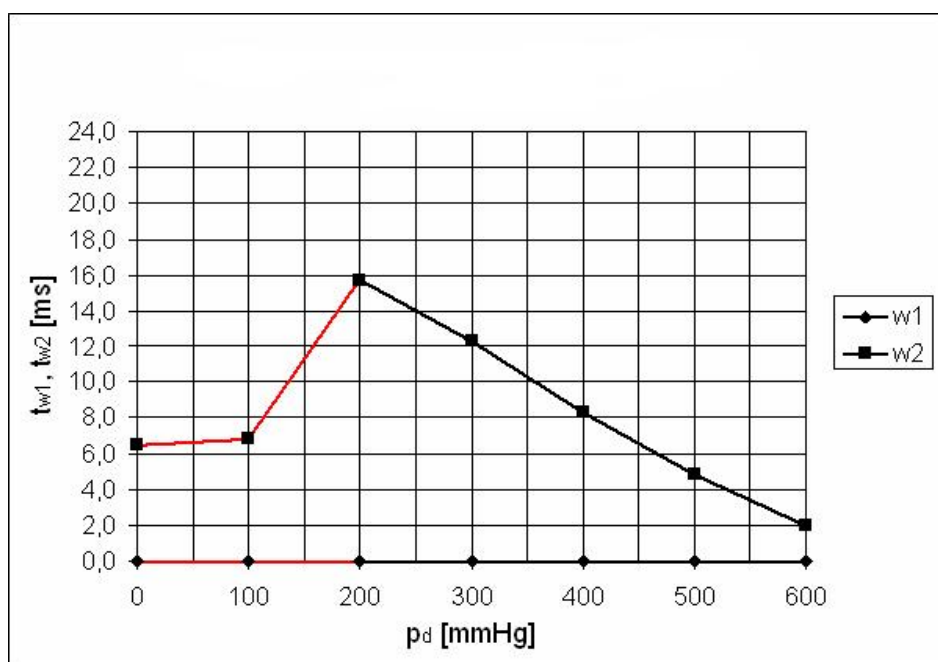

Fig. 2.6 Change of fuel injection time $t_w = f(p_d)$ for n = 800 [rpm]

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Tests of fuel injection time change depending on voltage of λ probe signal.

The test $t_w = f(\alpha)$ was carried out for the following established conditions:
- cooling agent temperature: $T_s = 60°C$;
- temperature of air in the inlet system: $T_p = 20°C$;
- voltage of λ probe signal: $\lambda=100mV$ to $\lambda=1000mV$;
- power supply voltage : $U_A=14V$.

The measurement was carried out for constant engine speed n=800rpm (+/- 50 rpm) – the throttling valve is completely closed - $\alpha_p = 0\%$. The measurement was repeated for engine speeds n=1400, 2000, 2600, 3800, 4400, 5000, 5600, 6200, 6800 rpm.

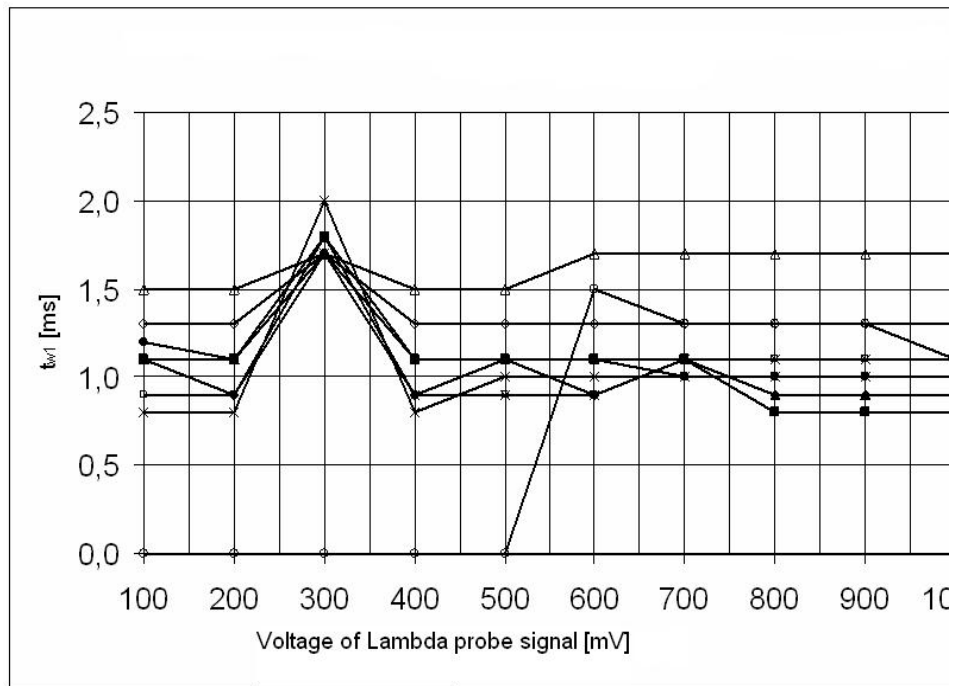Test results have been graphically presented in Fig. 2.7 to 2.11:

Fig. 2.7 Change of fuel injection time $t_{w1} = f(p_d)$ for the main injector
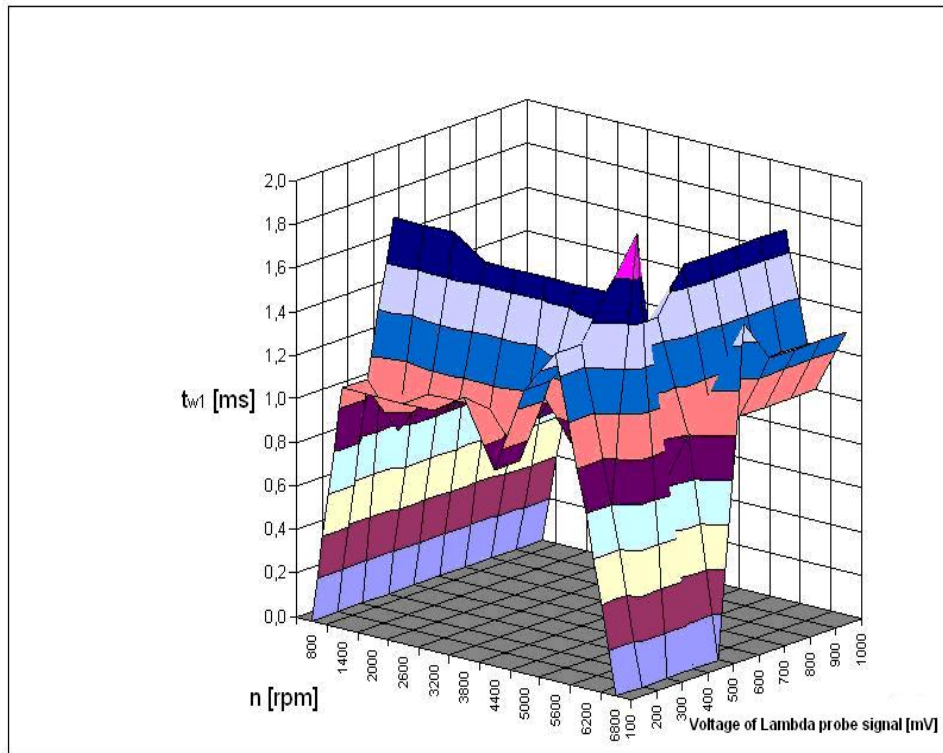
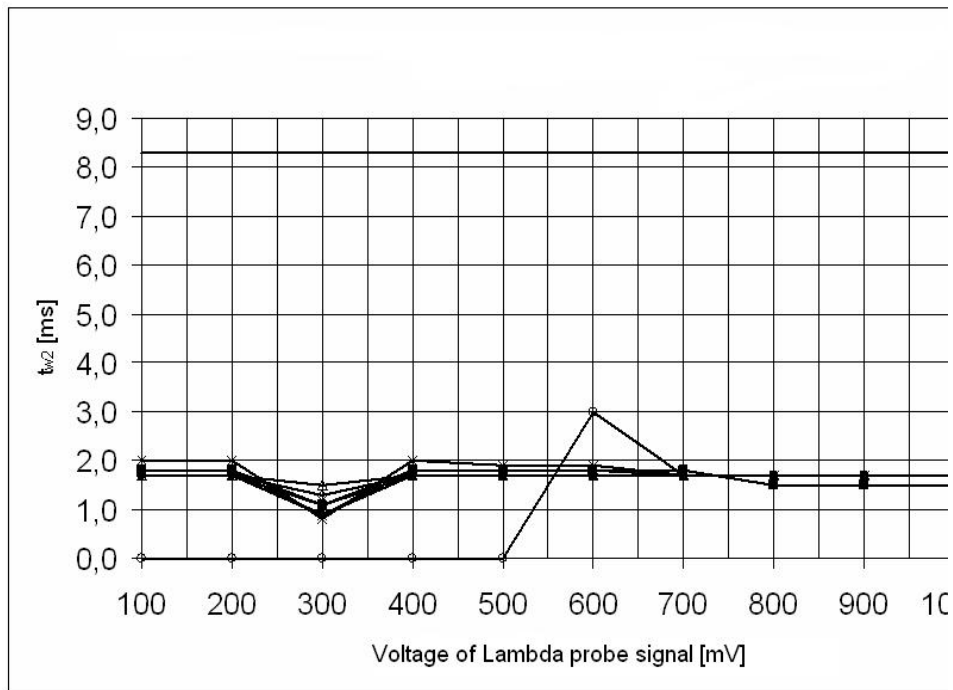Fig. 2.8 Change of fuel injection time $t_{w1} = f(p_d)$ for the main injector

Fig. 2.9 Change of fuel injection time $t_{w2} = f(p_d)$ for the supportive injector
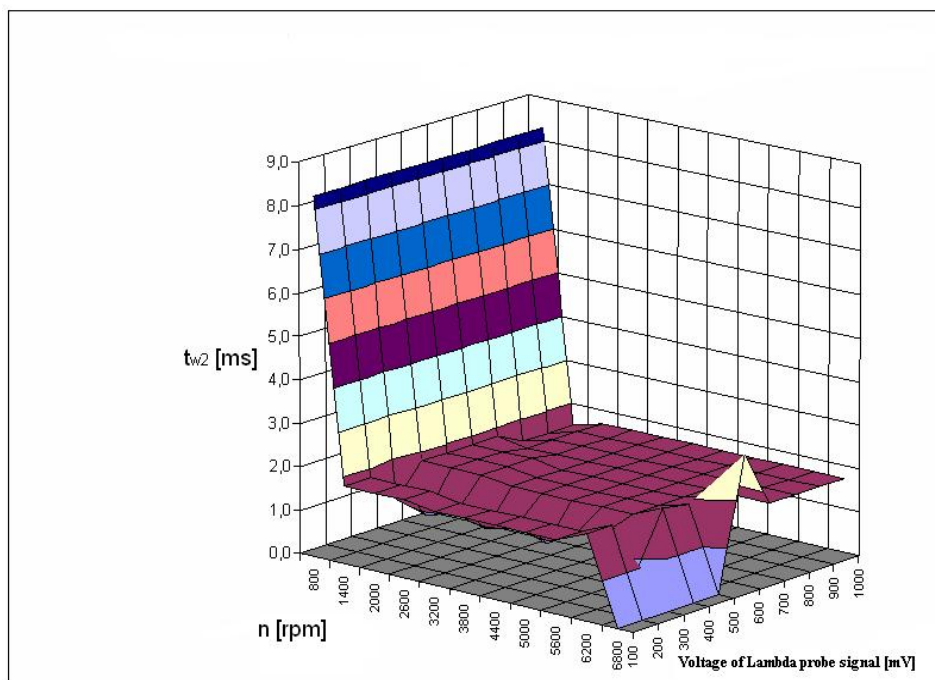
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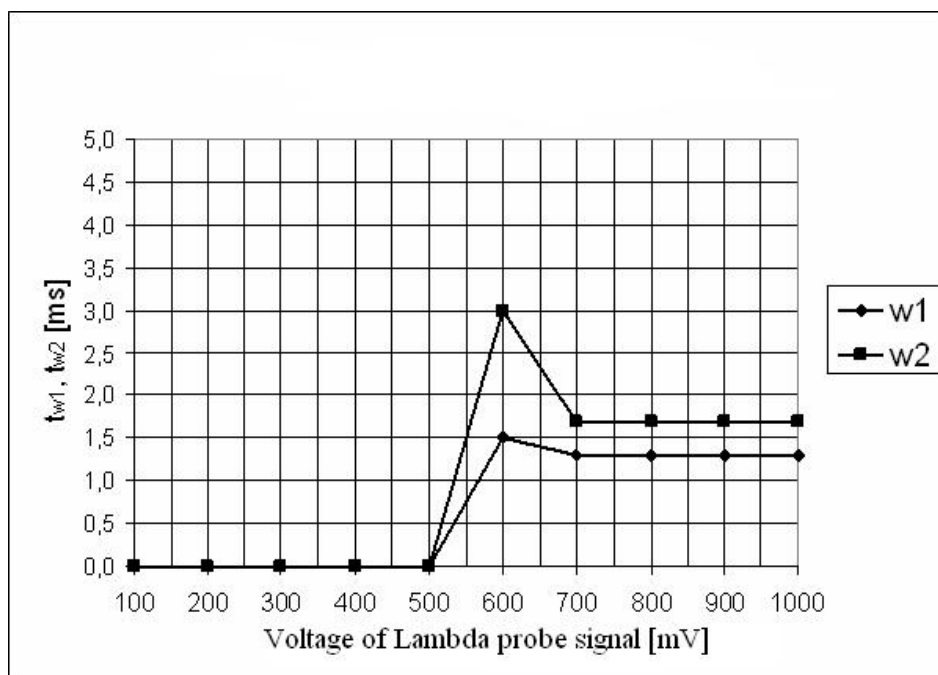Fig. 2.10 Change of fuel injection time $t_{w2} = f(p_d)$ for the supportive injector

Fig. 2.11 Change of fuel injection time $t_w = f(p_d)$ for n = 800 [rpm]

Conclusions

In the diagram of fuel injection time change $t_w = f(p_d)$ of the main injector (w1) and the supportive one (w2) for constant engine speed (n = 800 rpm) has been presented.

On the basis of the presented diagram, it can be stated that for the main injector t_{w1}=0 [ms] in the whole measurement range. In the case of the supportive injector, the increase t_{w2} in the range from 600 to 200 mmHg is observed.

In real conditions, such a situation takes place when you want to drive up the hill without stepping on the gas. The engine speed decreases then, and the control system enriches the mixture in order to counteract the decrease.

As injectors operating conditions are known and it is known that the system compensates fuel injection time in case of the decrease of pressure in the suction manifold, it can be stated that the simulation of negative pressure sensor in the suction manifold has been carried out correctly.

References

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