INVESTIGATIONS OF IGNITION SYSTEMS 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 ignition 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 the passive statistical experiment. The diagnostic set worked out by the author, is meant for the analysis of diagnostic signals coming form the electronic ignition and the identification of fault type.

1. Introduction

The ignition system must function perfectly for the engine to function correctly. Veraiable ignition timing allows the ignition to respond to variations in engine speed and load factor. On simple systems, timing is adjusted by a centrifugal advance mechanism and a vacuum control unit. Manifold vacuum provides a reasonably accurate index of engine load. Semiconductor ignition systems also allow for other influences of the engine e.g., temperature or changes in the mixture composition. The values of all ignition timing functions are linked either mechanically or electronically in order to determine the ignition poit. The energy storage device must be fully charged before the actual ignition poit. This requires the formation of a dwell period or dwell angle in the ignition system. The energy is generally stored in an inductive storage device, and, in rare cases, in a capacitive storage device. High voltage is generated by disconnecting the primary inductor from the power supply followed by transformation. The high volatge is applied to the cylinder curently performing the working stroke. When an ignition distributor is used, the crankshaft position information required for this is provided by an appropriate mechanism via the ignition distributor drive. In the case of stationary voltage distribution, an electrical signal from the crankshaft or the camshaft provides the position signal. The connecting elements (plugs and high-tension cable) convey the high voltage to the spark plug. The spark plug must function reliably in all engine operating ranges in order to ensure consistent ignition of the mixture. The excess-air factor λ and the cylinder pressure which is determined by charge and compression have, together with the spark-plug electrode gap, a crucial influence upon the required ignition voltage and , thus, upon the required secondary available voltage of the ignition system. Approximately 0.2 mJ of energy is required per individual ignition for igiting an air-fuel mixture by electric spark, providing the mixture has a stoichiometric composition. Rich and lean mixtures require over 3 mJ. This amount of energy is but a fraction of the total energy contained in the ignition spark, the ignition energy. Is insufficient ignition energy is available, igition does not occur; the mixture cannot ignite and there are combustion misses. This is way adequate ignition energy must be provided to ensure that, even under worst-case external conditions, the air-fuel mixture always ignites. It may suffice for a small cloud of explosive mixture to move past the spark. The cloud of mixture ignites and, in turn, ignites the rest of the mixture in the cylinder, thus initiatinng fuel combustion. Good induction and easy access of the mixture to the ignition spark improve the ignition characteristics as do long spark duration and a long spark or large electrode gap. Intense turbulence of the mixture also has a similarly favourable effect providing that adequate ignition energy is available. The spark position and spark length are determined by the dimensions of the spark plug. The spark duration is determined by the type and design of ignition system and the instantaneous ignition conditions. The spark position and accessibility of the mixture to the spark plug influence the exhaust gas, especially in the idle range. Particularly high ignition energy and a long spark duration are favourable in the case of lean mixtures. This can be demonstrated using an engine at idle.

Fouling of the spark plug is also an important factor. If spark plugs are badly fouled, energy is discharged from the ignition coil via the spark-plug shunt path during the period in which the high voltage is being built up. This shortens the spark duration, thus affecting the exhaust gas and, in critical cases (if the spark plugs are badly fouled or wet)may result in complete misfiring. A certain amount of misfiring is normally not noticed by the driver but does result in higher fuel consumption and may damage the catalytic converter.

The ignition angle α_z or the ignition poit has an important influence on the exhaust-gas values, the torque, the fuel consumption and the driveability of the spark-ignition engine.

2. Analysis of reliability

Failures of ignition systems in vehicles is a very important notion in the theory of reliability. Each reliability test, both reliability analysis and reliability synthesis, should have strictly defined notions of failure, conforming with the specification of the tested ignition system. Ignition system is a random event in witch at least one or more features of the ignition system, measurable or non-measurable, cease to comply with imposed requirements, i.e.

$$C_{Mi} < \underline{C_{Mi}} \text{ or } C_{Mi} > \overline{C_{Mi}} \text{ and } C_{Nj} = 0$$

for all or some indexes i=1, ..., n; j = 1, ..., k.

The ignition system can be classified in one of the two states:

S_0 – ability state, when

$$\underline{C_{Mi}} < C_{Mi} < \overline{C_{Mi}}, \; i = 1, 2, 3, \ldots, n \qquad (1)$$

and

$$C_{Nj} = 1, \; j = 1, 2, 3, \ldots, k$$

S_1 – disability state, when

$$C_{Mi} < \underline{C_{Mi}} \quad C_{Mi} > \overline{C_{Mi}} \quad \text{i } C_{Nj} = 0 \qquad (2)$$

A transition from ability state to disability state $S_0 \rightarrow S_1$ is referred to as failure of an item. The ignition system can get damaged as a result of constant slow irreversible wear-out and ageing processes proceeding in its components. Failures can be divided into so called natural failures and so called random failures occurring as a result of sudden rapid changes in ignition system features.

Ignition system reliability is the probability of its correct operation in determined maintenance conditions in required time period and can be written down as the probability of an event:

$$R(t) = P\{\tau \geq t\}, \qquad (3)$$

Where:

R(t) – reliability,

τ - operating time up to the failure,
t - required operating time.

Determining ignition system reliability function R(t) by means of an experiment consists in testing N identical ignition systems in time t and in stating the number of damaged ignition systems n. Reliability R(t) can be determined as n/N ratio for high values of N.

$\frac{n}{N} \rightarrow R$ high N ($N \rightarrow \infty$ with probability close to 1)

$$R_N(t) = \frac{n(t)}{N}; \tag{4}$$

$$R_N(t) = R(t)$$

Failure rate $[\lambda(t)]$ – is a probability of conditional failure occurrence in the moment t on condition that the ignition system operated properly up to that moment.

$$\lambda(t) = -\frac{R'(t)}{R(t)} \tag{5}$$

Statistically estimated failure rate of ignition system is equal to the number of failures which occurred in time unit against the number of ignition system with no failures. Empirical failure rate has the shape of a step curve, approximated to a full line, which is divided into three intervals:

a) the first interval, where ignition system failure rate is a decreasing function, is the initial period of maintenance in which elements of lower reliability are eliminated,
b) the second interval, in which $\lambda_N(t)$=const, so called period of normal maintenance,
c) the third interval, where failure rate is an increasing function, in which wear-out and ageing failures begin to dominate.

3. Reliability statistical test of ignition system

The aim of studies was to gather data about the reliability of ignition system. Tests were carried out at Auto-Volt, Bosch Service in Lublin. On the grounds of data bases obtained from service stations, passive statistical experiment was carried out 100 cars of four makes were chosen for tests (Fig.1. and Fig.2). In the course of research, statistical distributions of ignition system and statistical distributions of failures, calculated on the grounds of data results sheets from mentioned above service station, were determined. With the aid of the computer program "Statistica" and with the use of λ-Kołmogorow test of goodness of fit, reliability models of ignition system were made (Fig. 3 to Fig.6.).

4. Ignition system stand testing

For testing the ignition system of engine Opel C20 NE, a laboratory stand was used. The measurement stand is presented in Fig. 7. and Fig. 8.. Tests of ignition system without failures and ignition system with some elements(e.g. spark plug, ignition coil, high tension wire) disassembled for the purpose of simulating typical mechanical and electrical failures were carried out. The process of technical state assessment cosist of three basic tasks:

1. Measureing diagnostic parameter value and comparing it with nominal value.
2. Analysis of deviation character and causes.
3. Stating probable value of ignition system efficient running measure.

Signals sent from sensors to the controller and signals sent from the controller to executory elements were registered by means of KTS500 diagnostic device (Fig. 7 and Fig. 8.).

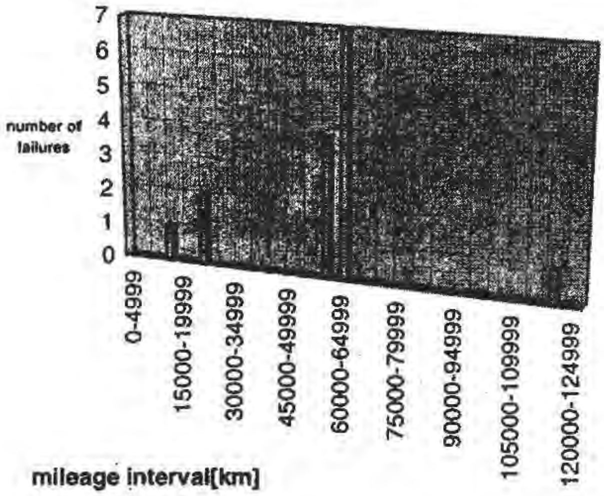

Fig. 1. Number of failures as function of mileage interval for spark plug of maker car 1

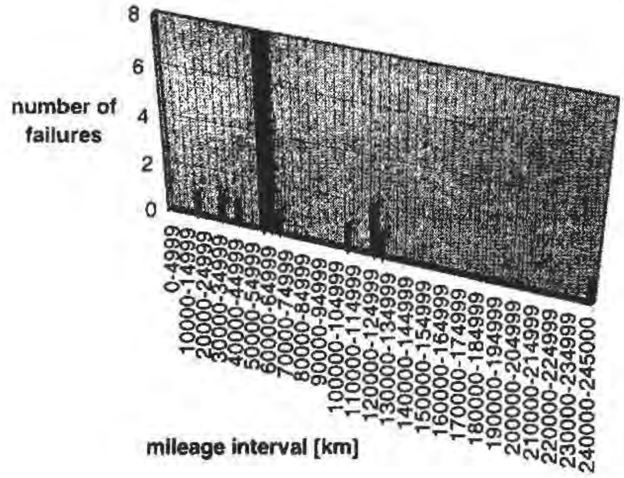

Fig. 2. Number of failures as function of mileage interval for spark plug of maker car 2

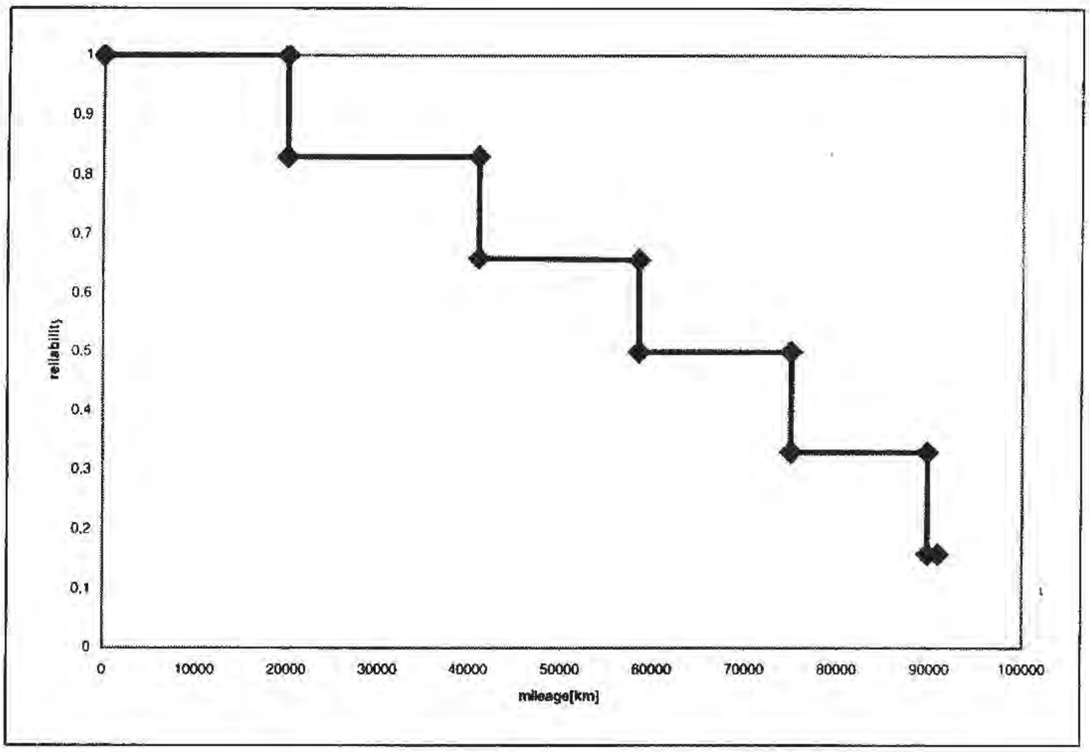

Fig. 3. High-tension wire empirical reliability function

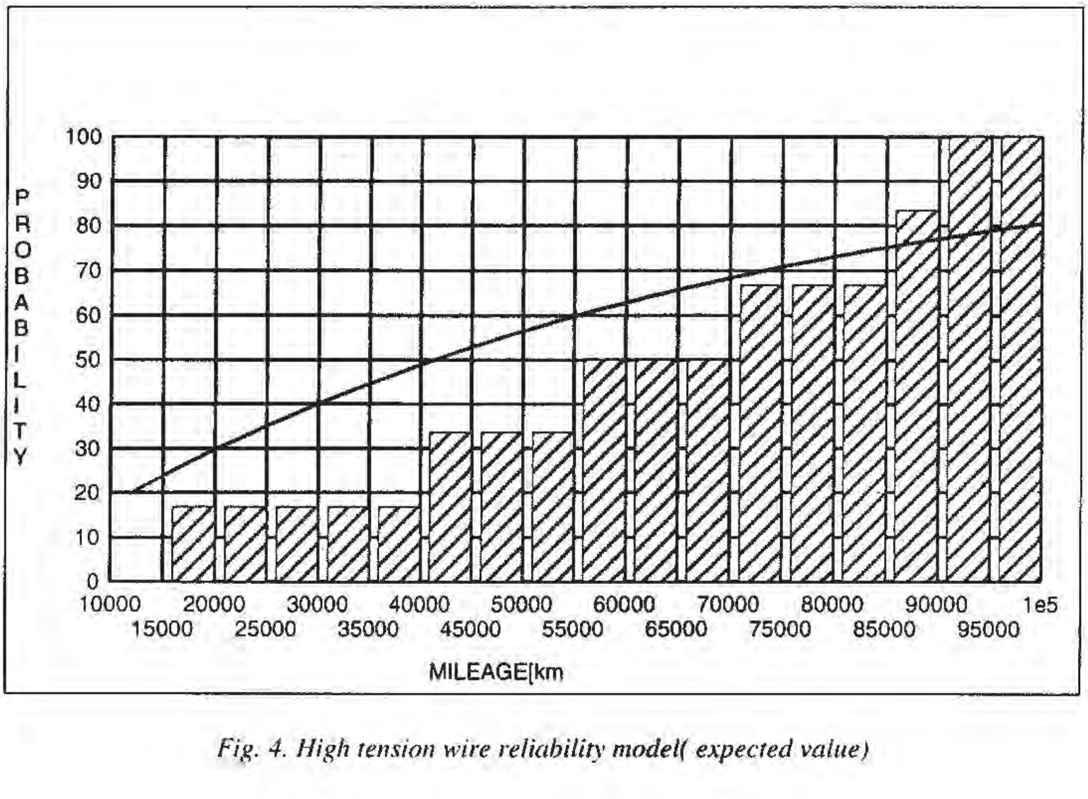

Fig. 4. High tension wire reliability model(expected value)

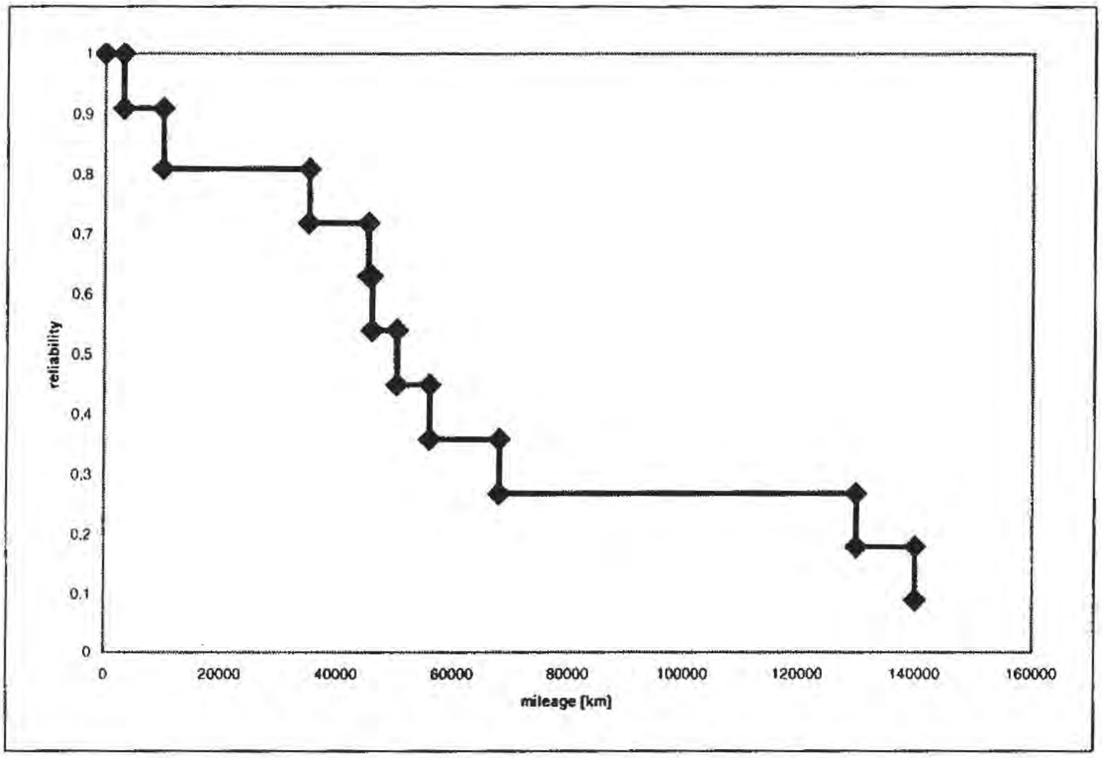

Fig. 5. Trigger box empirical reliability function

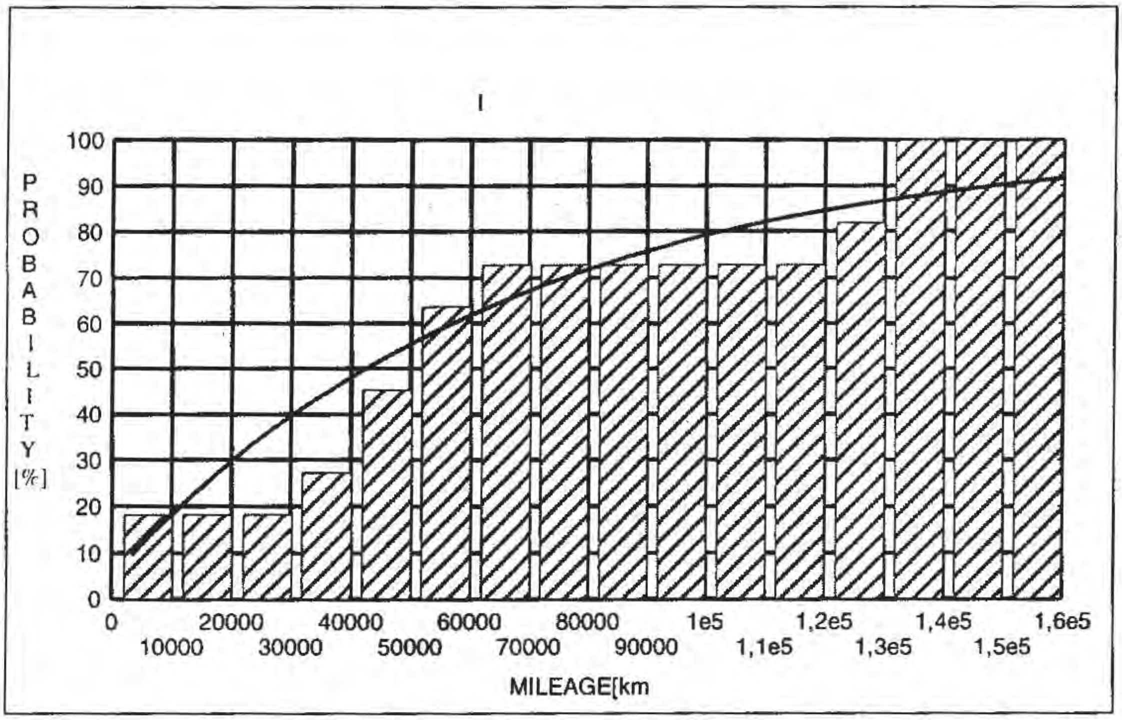

Fig. 6. Trigger box reliability model(expected value).

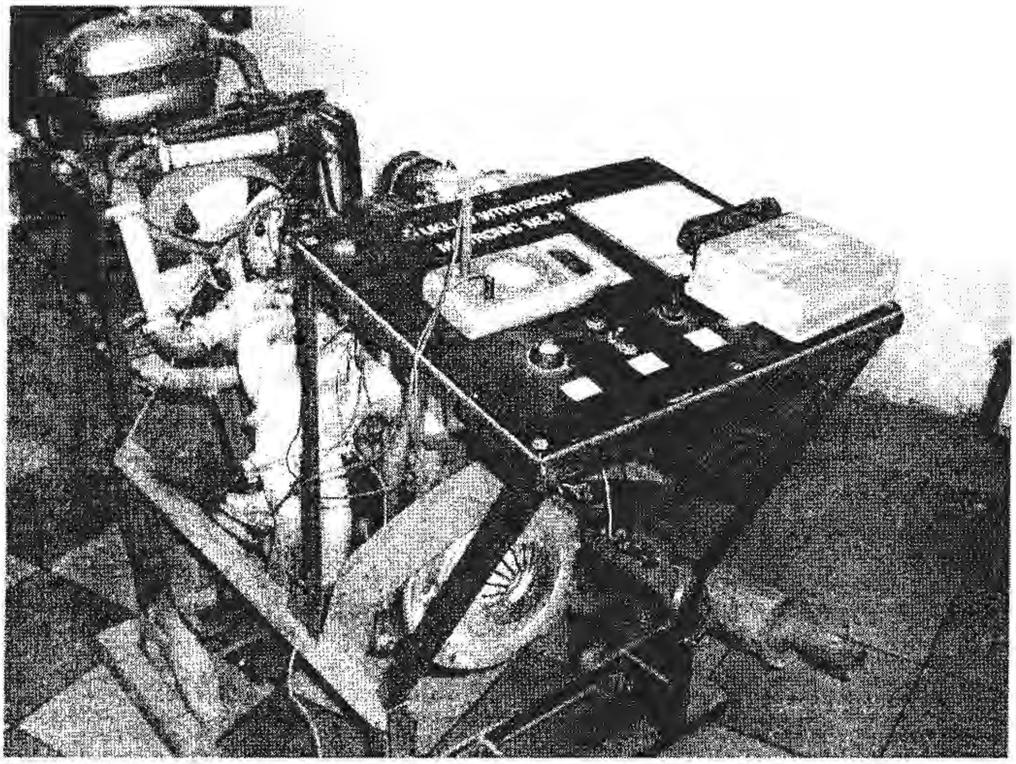

Fig. 7. Engine measurement stand

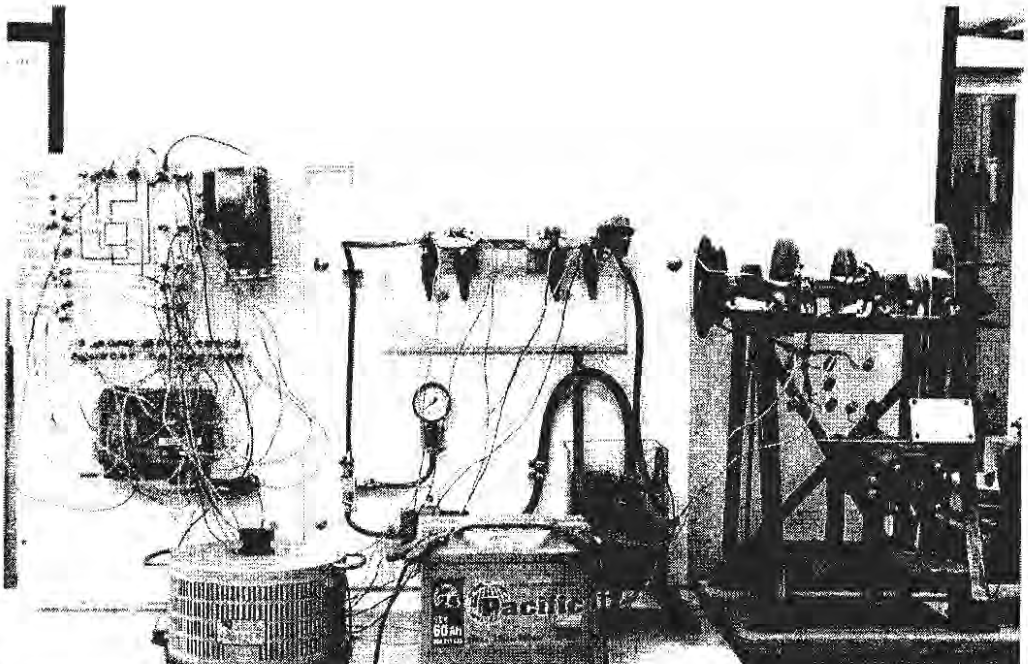

Fig. 8. Electronic ignition system stand

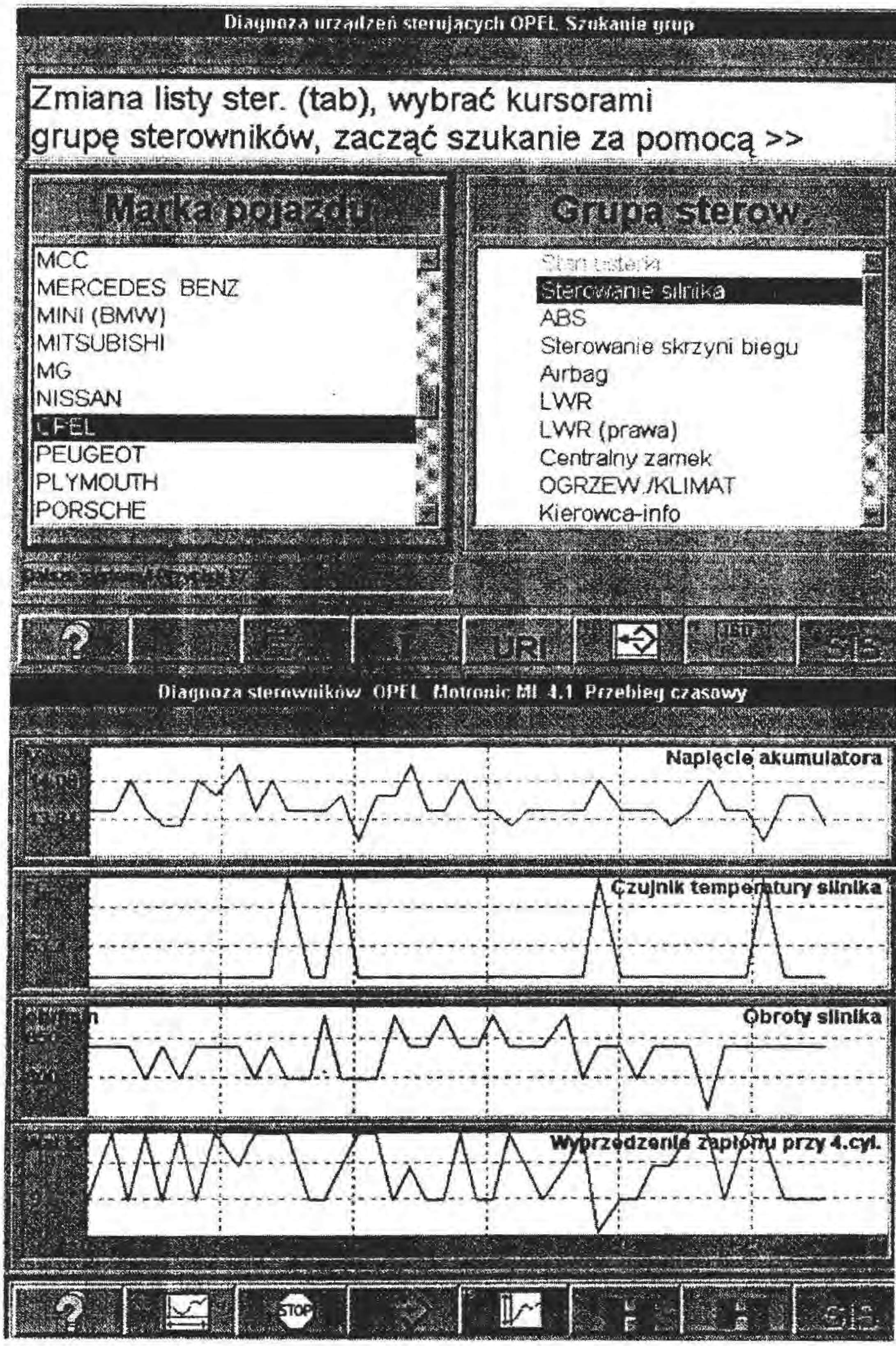

Fig. 9. Example of measured battery voltage and temperature engine, speed engine, ignition angle

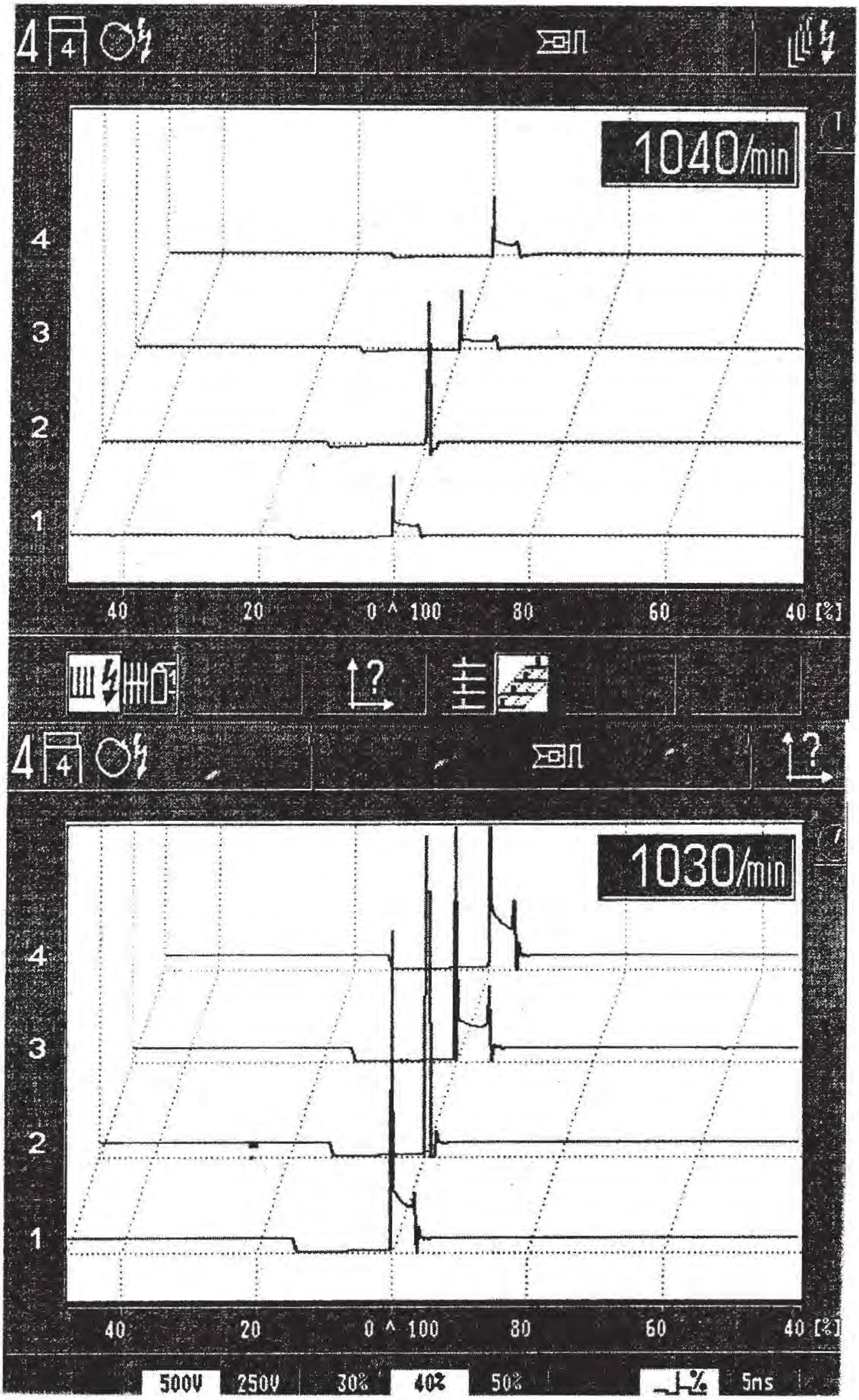

Fig.10. Example of measured high-tension voltage

5. Conclusion

Gathered information about reliability, parameters and failures of ignition system particular components makes it possible to state requirements for construction and changes of functional and diagnostic parameters of a given ignition system type.

The analysis of time up to the failure occurrence (or the number of covered kilometers together with test conditions) makes it possible to establish and identify failure causes and to assess the possibility of selecting and improving ignition system particular components.

The analysis of ignition system reliability provides a wide range of development possibilities in computer modelling of recovery processes and reliability diagnostics.

Stating that ignition system technical state is dependent upon structure parameters values and is determined by them is crucial for explaining the essence of diagnostics. However, it is not sufficient in practice because generally it is impossible to measure object structure parameters without its disassembly. It must be added that output parameters course is dependent upon ignition system technical state.

A model of reliability can be created for ignition system being characterised by optional structure. This method basing upon analysis of effect of failure (failure of operating) of a subsystem selet determines the consequences of such failures for operation of whole system and determines conditions resulting in each type of failures.

References

[1] Dziubiński M.: *Elektroniczne układy pojazdów samochodowych*, Wyd. Naukowe G.B., Lublin 2003, p.128, ISBN 83-89263-05-X

[2] Dziubiński M.: *Koncepcja diagnostyki wyposażenia elektrycznego samochodu*, Polskie Naukowe-Techniczne Towarzystwo Eksploatacyjne, Eksploatacja i Niezawodność, Warszawa 2002, nr 2, p. 39÷47. ISSN 1507-2711

[3] Liscak S.: *Spolahlivost v prevadzke cestnych vozidiel*, Vydala Zilinska univerzita v Ziline, 2003, p.195, ISBN 80-7100-969-51

[4] Merkisz, J., Mazurek, St. :*Podkładowe systemy diagnostyczne pojazdów samochodowych*. Wyd. WkiŁ, Warszawa, 2002, ISBN 83-206-1457-0.

[5] Niewczas A. - Koszałka G.: *Niezawodność silników spalinowych* , Wydawnictwa Uczelniane PL, Lublin, 2003, p. 173, ISBN 83-89246-31-7

[6] Niżiński, St., Michalski, R.: *Diagnostyka obiektów technicznych*. Wydawnictwo i Zakład Poligrafii Instytutu Technologii Eksploatacji, Radom, 2002, ISBN 83-7204-290-X.

[7] Oprzędkiewicz J. – Stolarski B.: *Komputerowe monitorowanie niezawodności samochodów*, Wyd. Naukowe PWN, Warszawa-Kraków, 2000, ISBN 83-01-13356-2

[8] Walusiak S. - Dziubiński M. - Pietrzyk W. - Sumorek A.: *Badania niezawodności elementów wyposażenia elektrycznego samochodów*, Teka Komisji Naukowo-Problemowej PAN o/Kraków, zeszyt 26-27, Kraków 2003,p. 499÷506, ISSN 1642-1639

[9] Żółtowski, B.: *Podstawy diagnostyki maszyn*. Wyd. Akademii Techniczno-Rolniczej w Bydgoszczy, Bydgoszcz, 1996, ISBN 83-900853-9-9.