Overdruk uit „TNO-Nieuws" 22 (1967) 65-69

An electronic ignition system for automobiles

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Samenvatting

Een schakeling voor het elektronisch ontsteken van automotoren is ontwikkeld. Het ontwerp is gebaseerd op het ontladen van een capaciteit. Naast de bekende eigenschappen van dit type ontsteking heeft deze het voordeel bruikbaar te zijn, ongeacht welke pool van de accu aan de massa is verbonden. Tevens wordt de standaard bobine toegepast.
Vermogens- en verbruiksmetingen, uitgevoerd aan twee automobielen, met zowel de conventionele ontsteking als de ontwikkelde elektronische ontsteking, vertoonden geen verschillen.

Summary

A circuit for the electronic ignition of automobiles has been developed. It is based on the capacitor discharge principle. In addition to the known properties of this type of ignition, this circuit has the advantage of being serviceable for both polarities of the battery with respect to ground, while the normal high tension coil is used.
Measurements of power and consumption, performed at cars with conventional ignition and at cars with this electronic ignition did not show significant diferences between these systems.

1. Introduction

Since semi-conductors became available, many publications have appeared on electronic ignition systems for automobiles [1, 3-10]. Most of these suggest that increased power, possibly combined with less fuel consumption, is obtainable [3, 6, 8] the arguments in these publications are mostly subjective and unverifiable. Therefore, an electronic ignition on the basis of capacitor discharge was developed at the Central Laboratory TNO, and a rather comprehensive programme of tests was performed on this new system, using a roller testing stand [1]).
In addition to the features of the conventional system, this ignition has the advantages that (a) it can be applied with either polarity of the battery with respect to ground (chassis) and that (b) the standard high voltage coil is used. The programme of tests, consisting of power and consumption measurements, was carried out on a Morris 850 standard and a Fiat 850 coupé, each provided with the conventional as well as the electronic ignition. The first car has the positive pole of the battery to ground, the second the negative one.

2. Description of the circuit

The principle of the circuit is not new. A voltage source charges a capacitor connected in series with the primary side of the high voltage transformer, the coil. Parallel to this combination, a switching element, such as a thyristor or silicon controlled rectifier, is connected. The thyristor controlled by the circuit breaker shortens the capacitor over the coil, resulting on the secondary side of the coil in a high voltage pulse of some microseconds directed to the spark distributor.
The design philosophy was to build a circuit with few and commercially available components, that is suitable to either polarity of the battery, easily interchangeable for conventional ignition, reliable and safe at all normally occurring temperatures (—40 to +80 degrees Celsius).
The capacitor of $\approx 0.3\ \mu F$ used in the conventional system has to be disconnected. See Fig. 1.

The circuit (See Fig. 2) can be split up into three parts:

(a) the D.C. to D.C. converter from battery (12 V) to high voltage (250 V);

(b) the trigger;

(c) the thyristor unit.

The converter is the well-known magnetic coupled astable multivibrator. The frequency of oscillation is 100 c/s for no load, and 250 c/s for full load. The battery currents are respectively 1 Amp. and 3 Amps. The maximum power converted is 50 Watts. The built-in overload protection becomes active for a peak average current of 150 mA at a peak voltage of 250 Volts.
A silicon bridge rectifier and a small capacitor,

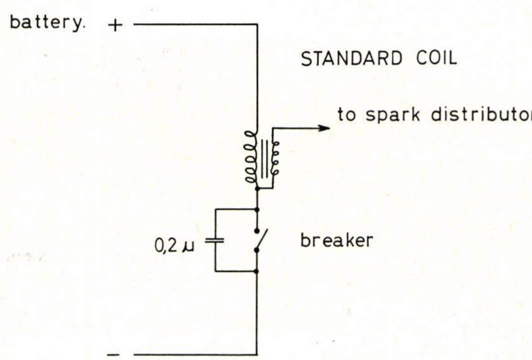

Fig. 1. Conventional ignition circuit.

1) This stand was available by courtesy of the „Autotechnische School" at Apeldoorn, Holland.

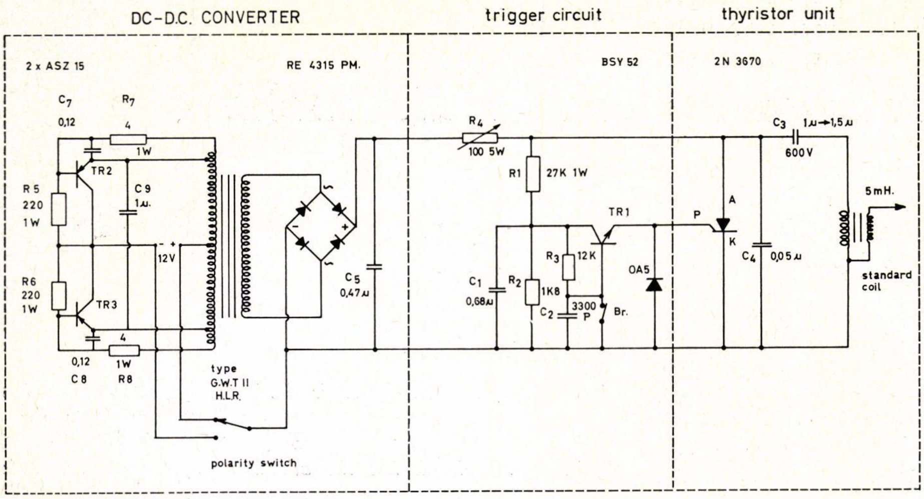

Fig. 2. Ignition circuit.

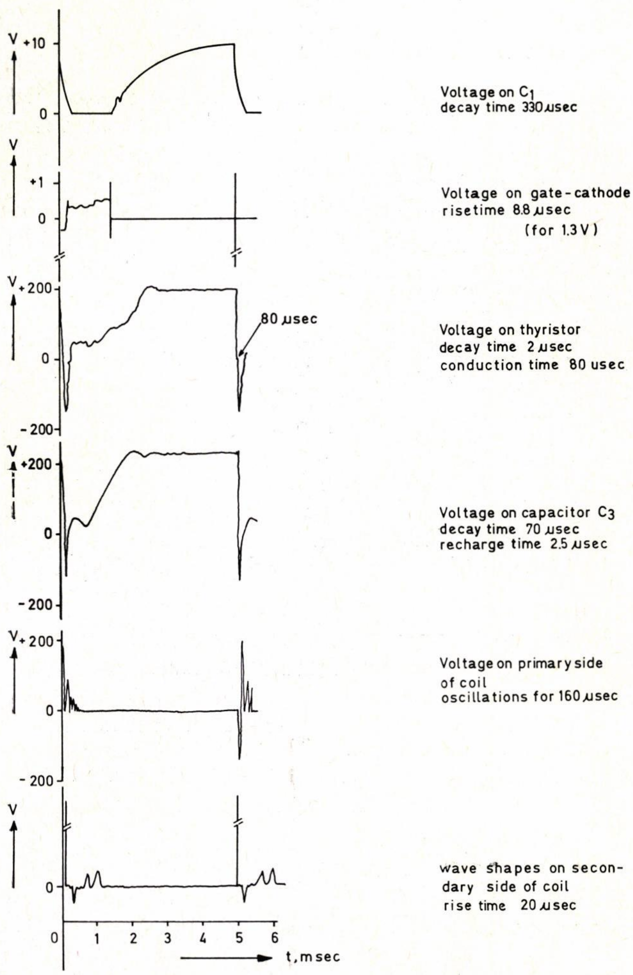

Fig. 3. Wave shapes for 200 c.p.s.

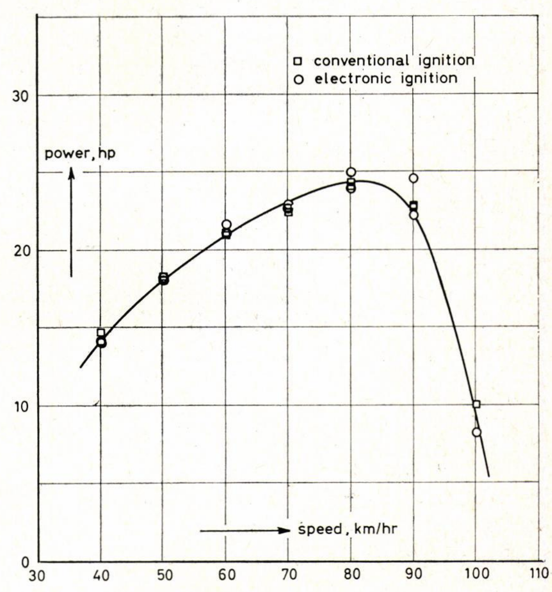

Fig. 4. Power in hp as a function of the speed in km/h for the Morris 850 standard.

also filtering transients, convert the square voltage to a D.C. one of about 250 Volts, depending on the battery. For a range of 8 to 15 Volts, the converter operates normally.
The trigger circuit is connected to the 250 V D.C. by a resistor, R_4. This resistor acts as a current limiter, and as a time delay for the power supply on delivering a voltage to the thyristor during and after the discharge period, preventing it to stay in the conducting state.
After R_4 follows a high ohmic voltage divider R_1, R_2, with a capacitor, C_1. C_1 is connected to a silicon switching transistor (TR_1) which,on breaker action, becomes conductive and so opens the thyristor gate. The breaker periodically disconnects the base of TR_1 from ground and, through resistor R_3, the base gets the potential of C_1 (collector voltage). The gate current has to be more than 0 mA with ≈ 2 Volts with respect to ground, lasting at least 2 μ seconds.
The time constant of the circuit R_1, R_1, C_1 is ≈ 5 m sec. which is necessary for suppressing the converter spikes. The charge of C_1 is sufficient to deliver the thyristor gate current for correct operation up to 12,000 r.p.m. in a four-stroke four-cylinder engine.
A diode protects TR_1 for negative going transients which occur when the thyristor gate opens. The time constant, R_3C_2, is 40 μ sec. and has no influence on the trigger speed. C_2 serves only as a suppressor for fast contact bounce of the breaker.
The thyristor unit contains, apart from the „consumer" thyristor [2]), a capacitor for high voltage (600 V) and the ignition coil (12 V, 5 mH). The thyristor blocks the high voltage on the capacitor until the gate is triggered, thus causing the thyristor to conduct within 10 μ seconds. For 20 μ sec. a strong change of magnetic flux occurs in the coil, giving a voltage peak of approximately 25 K Volts to the distributor. The capacitor energy, $\frac{1}{2}$ CV^2, for 1 μ F is 31 mJ. The conventional coil energy, $\frac{1}{2}$ LI^2 for 5 mH is 22 mJ, oscillating for 100 μ sec. By contrast, the electronic system does not oscillate because the thyristor conducts only for part of a period.
The thyristor comes in its non-conducting state when the holding current and voltage drop to zero due to the discharge of C_3 and the oscillation of the coil, C_3 recharges within 2.5 m sec. to converter voltage. For wave-shapes see Fig. 3.
The whole circuit was built in an aluminium box of approx. 8 x 9 x 12 cm. with an aluminium cooling strip as a cover. Mounted on this strip are the two power transistors, the thyristor and resistor R_4. The wires to battery, coil and breaker are provided on a connector.

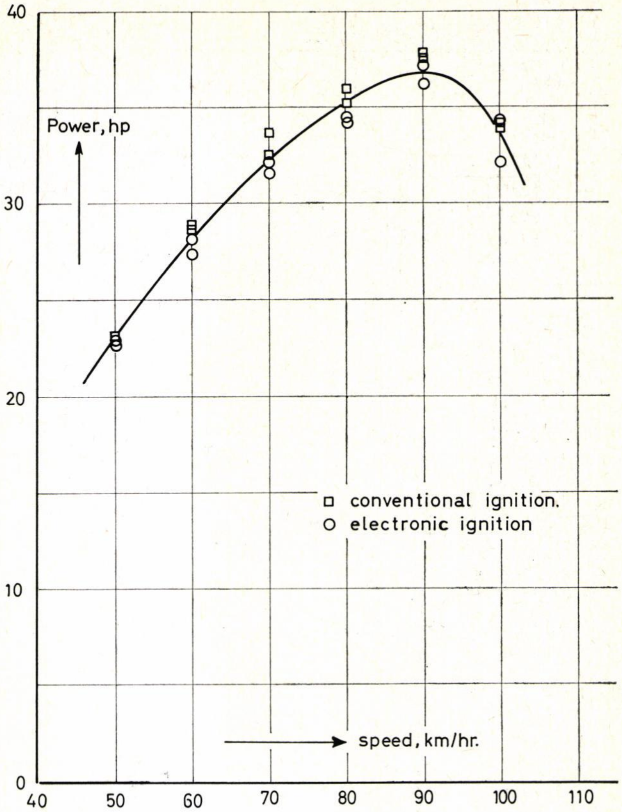

Fig. 5. Power in hp as a function of the speed in km/h for the Fiat 850 coupé.

3. Power [3]) measurements

On the roller testing stand, two series of tests were carried out on two cars: a Morris 850 standard, compression ratio 8.3: 1, and a Fiat 850 coupé, compression ratio 9.3 : 1.
Fig. 4 gives the power (Hp) as a function of speed (km/h) for the Morris 850. Measurements were made in the third gear at full throttle and going from high to low speed. One series for the conventional and electronic ignition was done without changing the carburetter or the ignition timing; the other after optimalizing, in this sequence, both ignitions at a speed of 80 km/h (4750 r.p.m.). In the figure, where squares mark the conventional and circles the electronic system, these two series could not be indicated separately. A negligible difference in power is found for both ignitions. The accuracy is not better than 5% (The equilibrium conditions for the engine are not always fulfilled).

In the first series of tests Shell SAE-30 motoroil was used, in the second one we used Castrol 20-W50 [4]) oil. Although a strong impression was gained that the engine was running more smoothly in this second series, and that the water temperature at the same atmospheric conditions dropped about 5 degrees Celsius, an increase of power could not be distinguished.
Fig. 5 shows the results for the Fiat 850. Measurements were done in the third gear at full throttle, after optimilization of both ignitions at a speed of 90 km/h (5800 r.p.m.). Each series was done twice, going from high to low speed. The figure

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[2]) R.C.A. type 2N3670, 400 Volts, t_{on} = 1,25 μ sec., t_{off} = 20 μ sec. for full load.

[3]) Power is defined as the power measured on the drive shafts under the assumption that the central gear shaft rotates frictionless.

[4]) Supplied by courtesy of Castrol Nederland N.V., Voorburg, Holland.

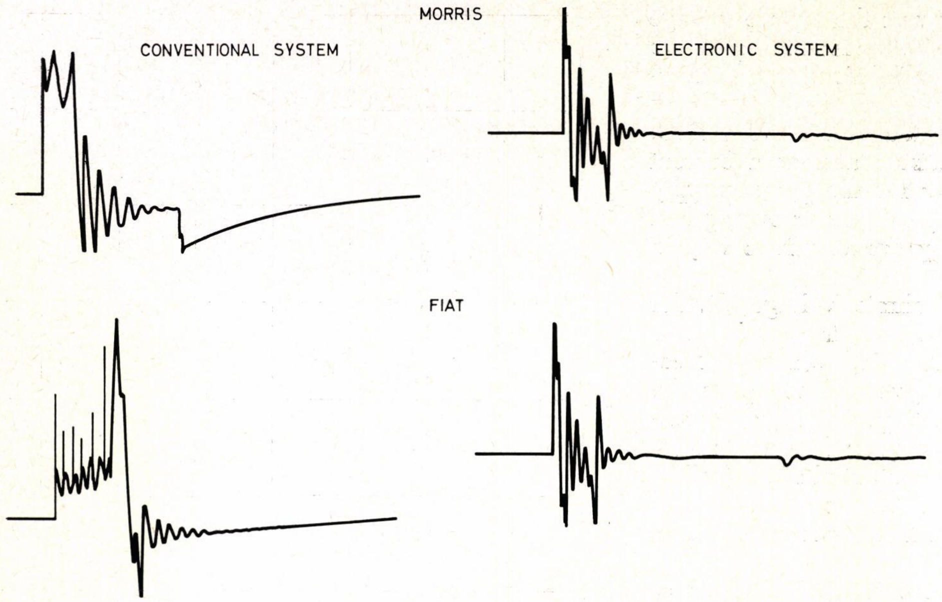

Fig. 6. Wave shapes on secondary side of the coil.

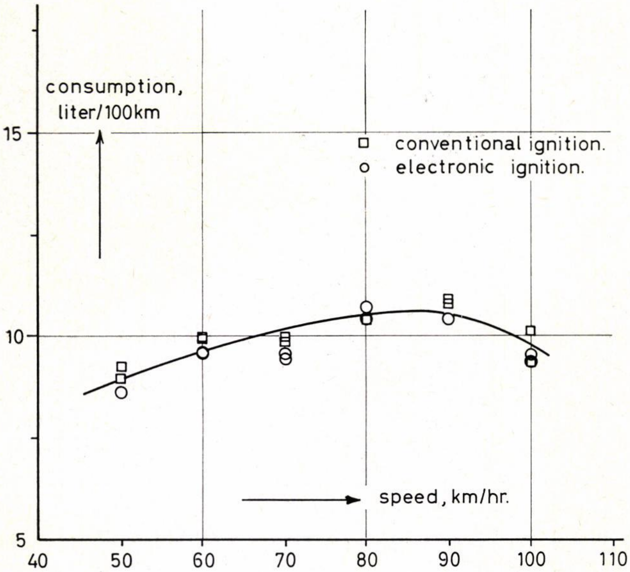

Fig. 7. Consumption in liter/100 km as a function of the speed in km/h.

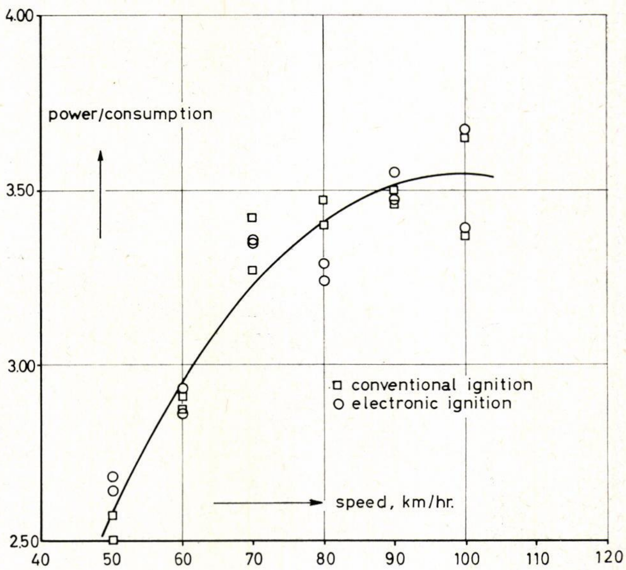

Fig. 8. The ratio of the power to consumption as a function of the speed in km/h.

does not show a significant difference between the systems.
Fig. 6 gives a copy of the wave shapes on the secondary side of the coil.

4. Consumption measurements

Together with the power measurements of the Fiat, the fuel [5]) consumption is specified for both ignitions. A difference could not be indicated. The consumption was measured with the aid of a balance and a stopwatch, accuracy 0.5 grams and 0,5 sec.
Fig. 7 gives the specific consumption, in liters per 100 km, as a function of the speed.

[5]) Mobil super petrol.

Fig. 8 shows the quotient of the power and the fuel consumption.

5. Conclusions

An electronic ignition, using the normal contact breaker and the standard high tension coil, has been constructed. The resulting spark has a character which differs from the normal one in that oscillations in the primary circuit of the coil do not occur. Under normal atmospheric conditions the system works, without failure, at rates up to 6500 r.p.m. Under the test conditions as described in the present paper, no significant difference in power or fuel consumption could be established.
Several modifications are still possible. The breaker giving difficulties under severe cold, because

of ice formation on the contact points, can be replaced by an optical or magnetic triggering. Then the system is also accessible for fast running engines where the normal breaker tends to float. Further the spark intensity might be increased by altering the output voltage of the converter; then the spark gap can be made wider. According to Kumagai and Kudo [2], this is one of the necessities for improvement of especially the high speed engine.

6. Acknowledgements

The authors wish to thank Mr. P. Klaver, of the department of gasturbines and combustion engines, Technological University, Delft, for his help, and intermediary in making the testing stand available to them, and Mr. Ter Steeg, teacher at the Autotechnische School, Apeldoorn, in particular for his co-operation and the pleasant way in which he has carried out the measurements.

7. References

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