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Comparative study on fuel injection process of vegetable and hydrocarbon fuels

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The paper presents results of investigations on the influence of physicochemical properties of hydrocarbon and vegetable fuels on parameters of the fuel injection process. The following parameters have been determined: fuel pressure in delivery pipe, rate of pressure rise, total dynamic delivery C.A., C.A. of injection duration, stability of injection needle opening. The essential physicochemical properties of applied fuels have been given.

1. Introduction

The paper presents results of investigations on fuelling the direct-injection engine AD 3.152 (under license of Perkins) with various hydrocarbon and vegetable fuels. As far vegetable fuels are concerned, the following ones were applied: rape (RO), soybean (SO) and sunflower (SFO) oils; hydrocarbon fuels were: standard diesel fuel (DF), Ekodiesel (EDF), diesel fuel for urban transport (DFUT). It has been showed that wide differences in physicochemical properties of these fuel groups positively influence the rate of pressure rise in delivery pipes and lift processes of the injection needle.

These parameters determine the values of:

- maximal fuel pressure in delivery pipes,
- residual fuel pressure in delivery pipes,
- needle stability at its full opening,
- dynamic delivery, C.A.,
- total injection duration C.A.,
- needle closing C.A.

The above-mentioned parameters of a fuel injection process of engine fuelling with vegetable fuels influence the combustion process. Changes of control parameters of injection equipment in relation to standard settings have to be done in order to attain the most favourable combustion parameters.

2. Selected physicochemical properties of investigated fuels

Table 1 contains chosen elementary physicochemical properties of investigated fuels.

T a b l e 1. Elementary physicochemical properties of investigated fuels

Property	Vegetable fuels			Hydrocarbon fuels		
	RO	SO	SFO	EDF	DF	DFUT
Density ρ [g/cm³]	0.914	0.917	0.916	0.851	0.839	0.817
Kinematic viscosity at 40°C ν [mm²/s]	34.56	31.98	31.54	3.60	2.84	1.83
Surface tension $\sigma \cdot 10^{-2}$ [N/m]	3.38	3.22	3.22	3.64	3.71	3.47

Among the above-mentioned physicochemical parameters of applied fuels, their viscosity has the greatest effect on parameters of the fuel process. Viscosity of investigated vegetable fuels is about 10 times higher than of hydrocarbon fuels.

3. Block diagram and description of the test stand

Fig. 1 shows a block diagram of the test stand for measurements of high-speed parameters. The parameters are: fuel pressure in a cylinder $p_c = f(\alpha)$, fuel pressure in

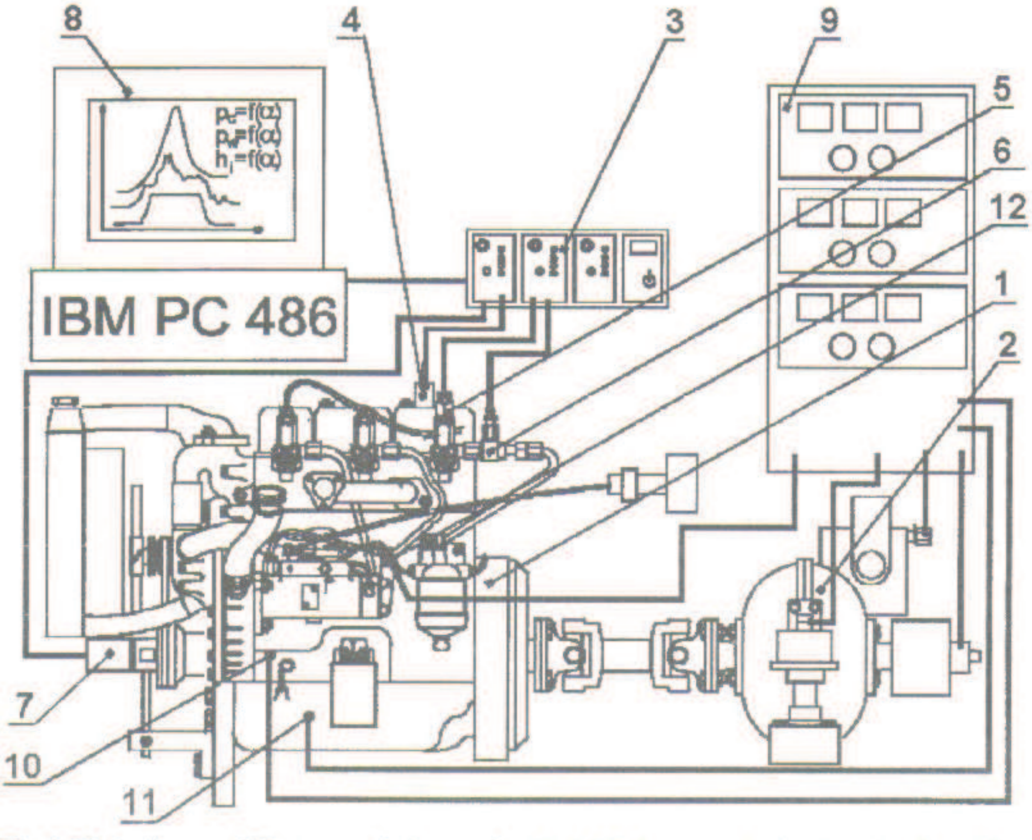

Fig. 1. Block diagram of the test stand: 1 — engine AD 3.152; 2 — water brake; 3 — signal amplifier; 4 — combustion pressure sensor; 5 — needle lift sensor; 6 — sensor of the fuel pressure ahead of the injector; 7 — angle transmitter; 8 — computer with a measuring card; 9 — control cubicle; 10 — water temperature sensor; 11 — oil temperature sensor; 12 — fuel temperature sensor

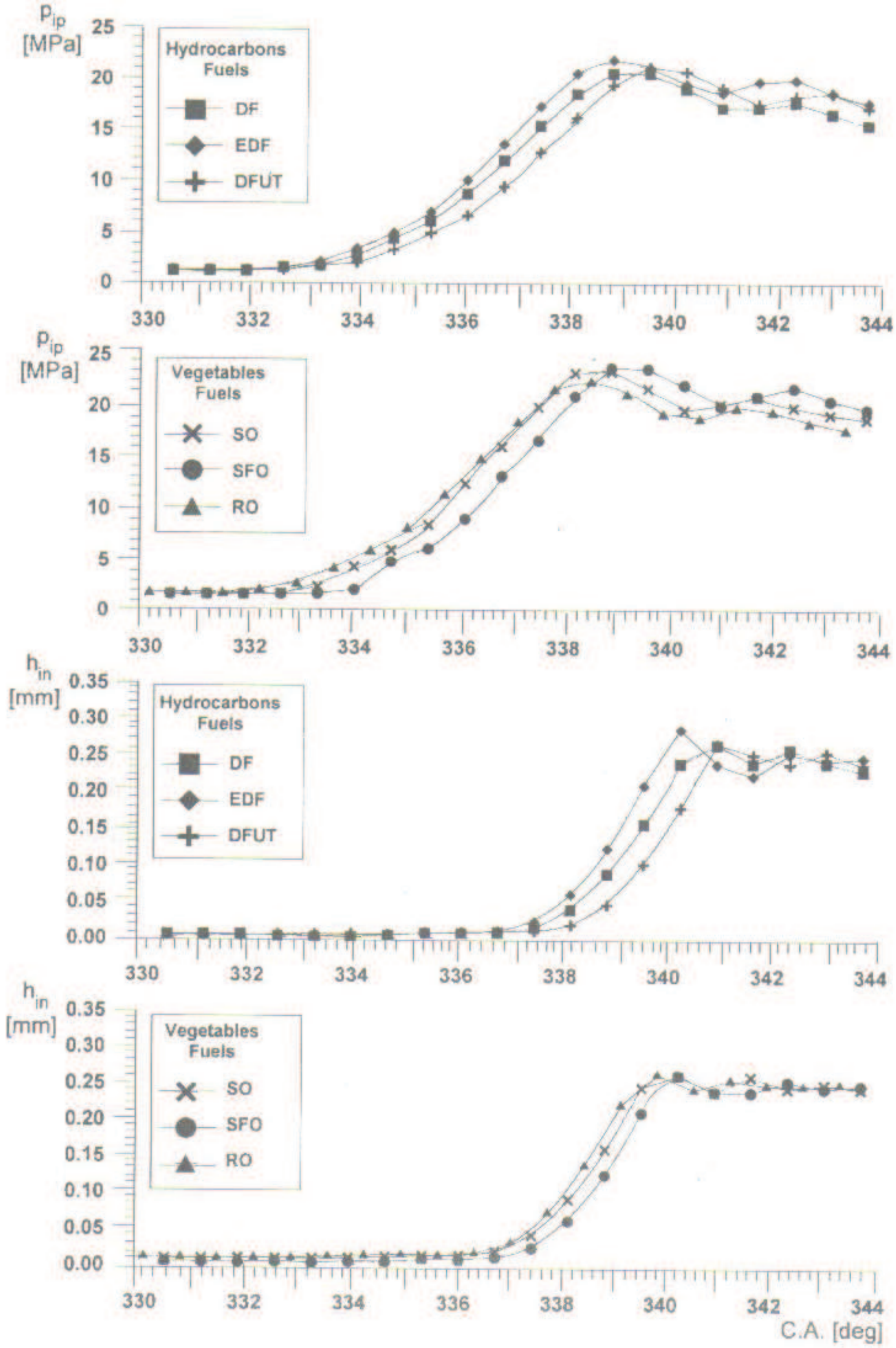

Fig. 2a. Diagram of fuel pressure course in a delivery pipe $p_{ip}=f(\alpha)$ and injection needle lift $h_{in}=f(\alpha)$ for vegetable and hydrocarbon fuels

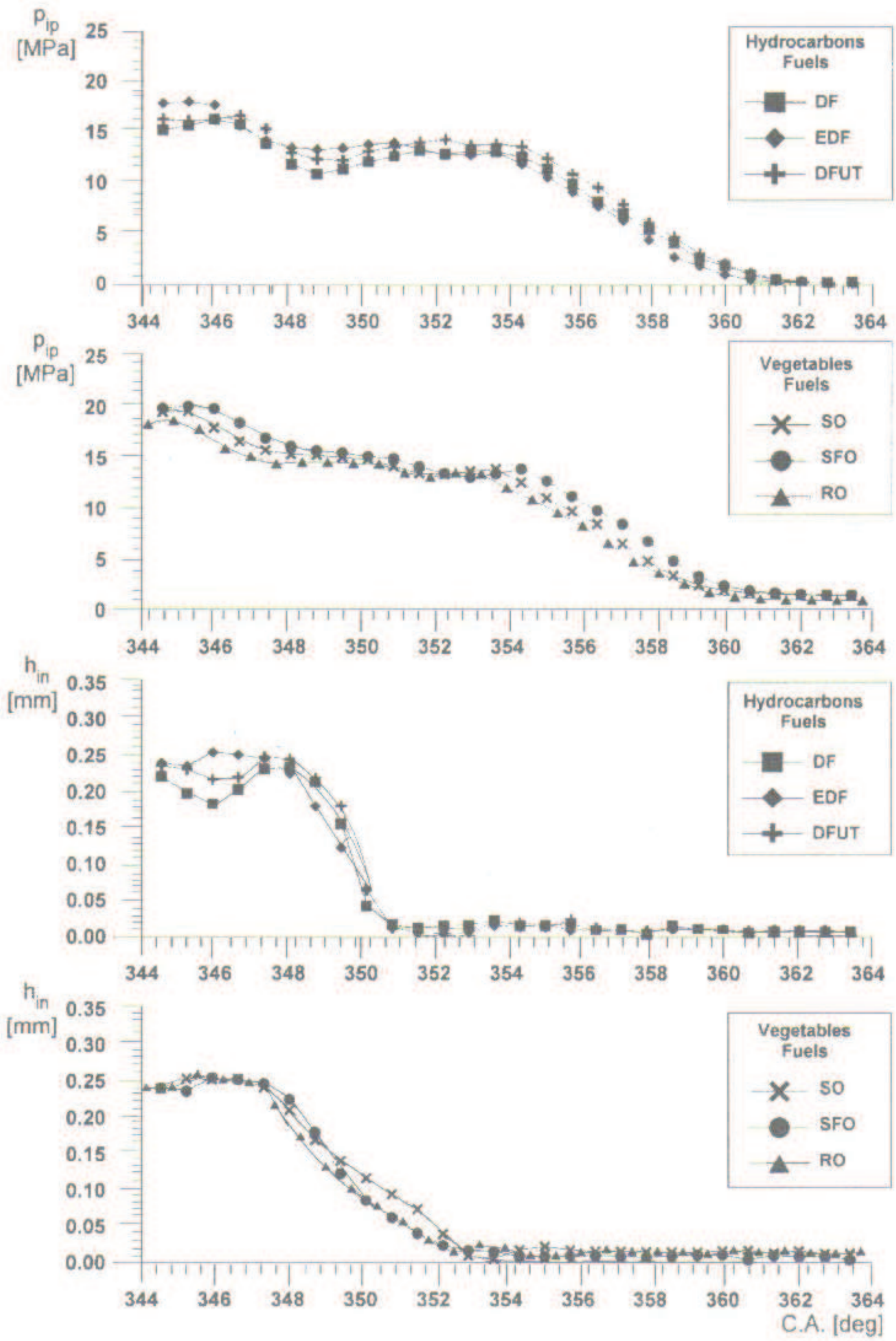

Fig. 2b. Diagram of fuel pressure course in a delivery pipe $p_{ip} = f(\alpha)$ and injection needle lift $h_{in} = f(\alpha)$ for vegetable and hydrocarbon fuels

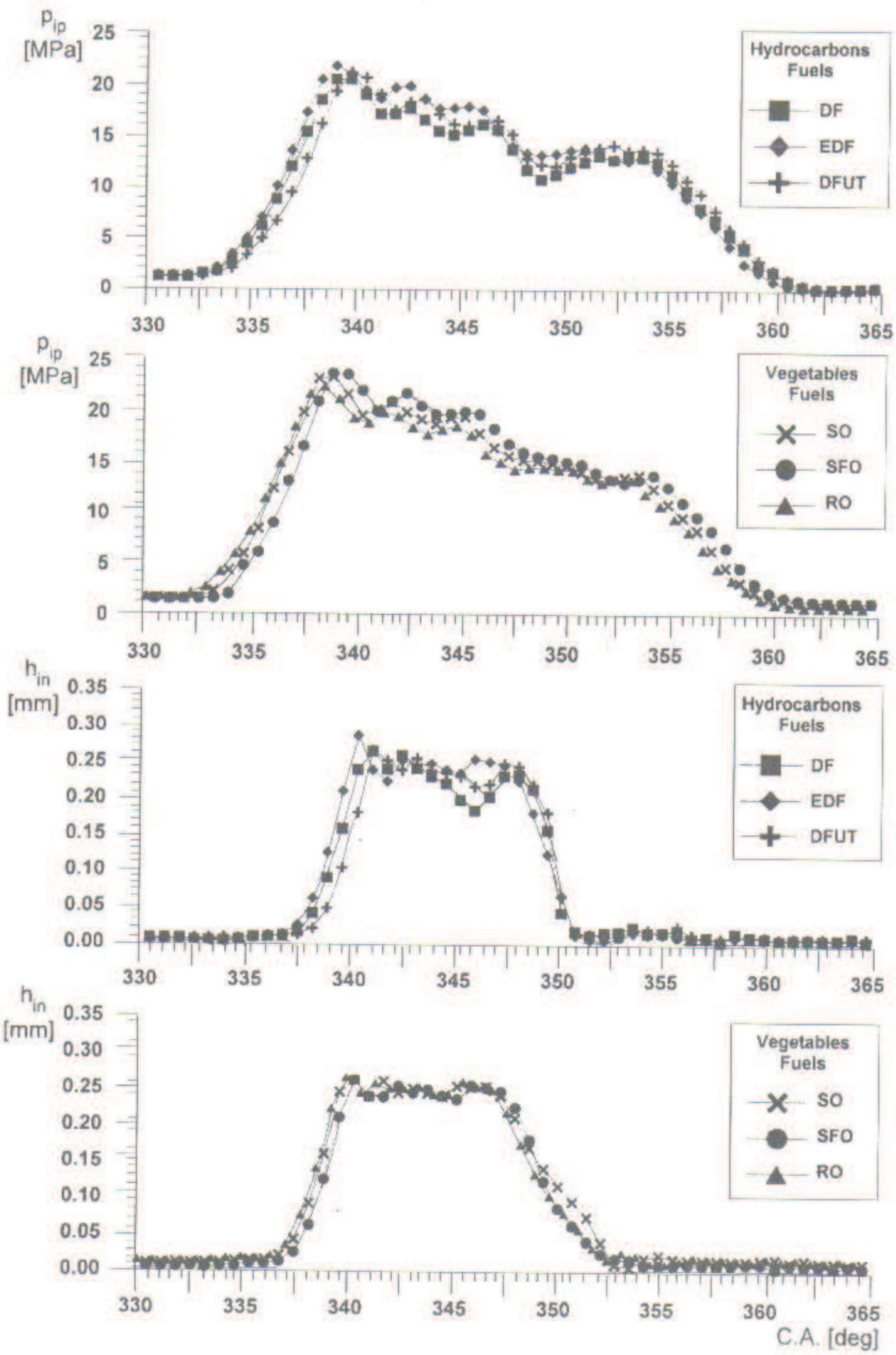

Fig. 3. Fuel pressure course in a delivery pipe $p_{ip} = f(\alpha)$ and injection needle lift $h_{in} = f(\alpha)$ for vegetable and hydrocarbon fuels

a delivery pipe ahead of the injector $p_{ip}=f(\alpha)$ and injection needle lift $h_{in}=f(\alpha)$. The main components of the test stand are given in the caption of Fig. 1.

In the measuring system, the sampling frequency ensuring exact projection of high-speed parameters should be greater than the 2100 harmonic frequency. Such requirements of the measuring system have been put into effect using a computer IBM PC/486 with a measuring card equipped with an analog-to-digital converter having one channel conversion time of 2 μs (500 kHz) and internal dynamic memory of 1 MB. Definition of the rotary-to-pulse converter PF 160 was 1024 graduations per 360 C.A. [4].

4. Investigation results

Investigations have been carried out at the full-load torque at $n=1300$ [rpm]. The obtained values of the fuel pressure in a delivery pipe ahead of the injector $p_{ip}=f(\alpha)$ [MPa] and injection needle lif $h_{in}=f(\alpha)$ [mm] for every applied fuel are presented in Fig. 2a, b. The figure has been divided into two parts to make the results more readable. Fig. 3 presents all diagrams in one.

The analysis of Fig. 2a, b and Fig. 3 shows clear differences in: dynamic delivery crank-angle, values of residual fuel pressure, period and character of the full injection needle opening, maximal pressure values, pressure buildup ratio in the delivery pipe, total dynamic delivery crank-angle, total crank-angle of injection duration and in the character of needle settlement in a spray nozzle seat.

5. Conclusions

Comparison of injection parameters for fuelling the engine AD 3.152 with vegetable fuels and the hydrocarbon ones can be summarised as follows:

- full needle opening occurs earlier for vegetable fuels, having higher viscosity, because of better self-tightening of an injection system,
- residual fuel pressure in a delivery pipe is higher for vegetable fuels,
- fuel pressure and injection needle lift for vegetable fuels are more stable; a needle does not try to close, it is supported by fuel in non-changed "on" position $h_{in} \cong$ const.
  This influence a uniform fuel flow rate between the spray nozzle seat and the needle cone and also the course of an injection characteristic $Q=f(\alpha)$.
- higher fuel injection pressures and consequently – greater fuel spray tip penetration – have been found for vegetable fuels,
- vegetable fuels are characterised by higher rate of pressure rise in a delivery pipe $dp_{ip}/d\alpha$,
- total dynamic delivery angle for vegetable fuels is higher by about $1.5 \div 2.5$ C.A.,
- angle of injection duration of vegetable fuels is higher by about $1.5 \div 2.5$ C.A.

The above-mentioned results show the influence of fuel viscosity on the discussed earlier parameters of the injection process. These parameters, next, directly influence parameters of injection and combustion processes. It appears that the optimization of a combustion process in a standard engine at fuelling it with vegetable fuels can be achieved by changes in standard settings in the injection equipment. Some obtained results correspond with the data published e.g. by J. Judge [5].

Investigation results presented in this paper are more detailed in comparison with the results given in the publication [2]. They enable to carry out a more detailed analysis of the parameters of injection process and injection needle lift for fuels having different physicochemical properties. There is a possibility of quantitative comparison of any distinctive points from the diagrams of $p_{ip}=f(\alpha)$ and $p_{in}=f(\alpha)$.

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Studium porównawcze procesu wtrysku paliw roślinnych i węglowodorowych

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań procesu tłoczenia paliw wyrażonych parametrami: wzniosu iglicy rozpylacza i ciśnienia paliwa w przewodzie wtryskowym przed wtryskiwaczem. Obiektem badań był silnik AD3.152 z rozdzielczową pompą wtryskową. Pokazano zmiany w charakterze wzniosu iglicy rozpylacza w poszczególnych jej fazach otwierania i wzniosu do pełnego jej otwarcia, pełnego otwarcia i osiadania w gnieździe rozpylacza, a także odpowiadających tym okresom wartościom ciśnienia paliwa w przewodzie wtryskowym.

Przedstawiono wpływ właściwości fizykochemicznych badanych paliw roślinnych i węglowodorowych na wspomnianie fazy wzniosu iglicy, a niektóre różnice odniesiono do kąta obrotu wału korbowego badanego silnika.