Injection Spray Comparison of Diesel Fuel and Cold Pressed Rape Seed Oil Fuel

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Abstract

Diesel Engines are a popular propulsion not only for on-highway vehicles but also for working machines like agricultural tractors. In this application it is also common to use other fuels than Diesel. One of this fuels is cold pressed rape seed oil. However, this vegetable oil has different physical properties than diesel fuel. This leads to different spray behaviour in an internal combustion engine and subsequently to other emission levels. In this study the spray-patterns of a Diesel fuel CR-Injector are compared to spray-patterns of cold pressed rape oil with the same injector. The results are linked to engine emissions detected on an engine test bench.

Introduction

As in on-road applications, agricaltural vehicles like tractors and other off-road vehicles are forced to fullfil new emission standards, like the EU STAGE 3 B or STAGE 4 respectively or the US TIER 4 levels, subsequently. To meet this demands it is neccessary to know a lot about the spray behaviour of diesel fuel, and above all the spray behaviour of pressed rape seed oil fuel , which is compared to diesel fuel more restrictive to the injection system. The whole injection system is designed for diesel fuel, but in reality the operators of agricultural vehicles do not dispose only diesel fuel but also rape seed oil, whose spray relelvant parameters are quite different compared to diesel fuel, see table 1. To overcome the problems it is essential to know how rape seed oil fuel spray patterns behave in comparison to diesel fuel oil. This study shall show the properties of such sprays. The results will be linked to the emission measurements of the engine to enhance the knowledge of emission formation due to changed injection parameters and to help to solve the problem of fullfilling new emission standards even with cold pressed rape oil fuel.

Table 1. Important Fuel Properties for Spray behaviour, [1]

physical property	unit	Diesel Fuel	rape seed oil
Density ρ (15°C)	$\frac{kg}{m^3}$	835	920
kin. Viscosity ν (20°C)	$\frac{mm^2}{s}$	3,08	78,7
kin. Viscosity ν (40°C)	$\frac{mm^2}{s}$	3,2	33,1
surface tension σ (40°C)	$\frac{mN}{m}$	27	33

Materials and Methods

The investigations of the spray patterns are performed on the pressure chamber of the institute. This chamber was designed for maximum pressures of 150 bar and maximum temperatures of 700 °C. In this chamber it is possible to set up the gas-phase density of the analyzed engine in each operating point. On this chamber optical measurement technique is applied. For illumination of the injection process a high power xenon flash lamp is used. The visualisation is done with a high-speed CMOS camera, with a repetition rate of 20000 fps at 512x512 pixel, see Figure 1. The quality of the investigated spray patterns pictures is shown on the right hand side in Figure 1. For the investigations of the spray patterns only cold conditions on the chamber are applied. The chamber pressure is varied and the rail pressure according to the operation conditions of the engine.

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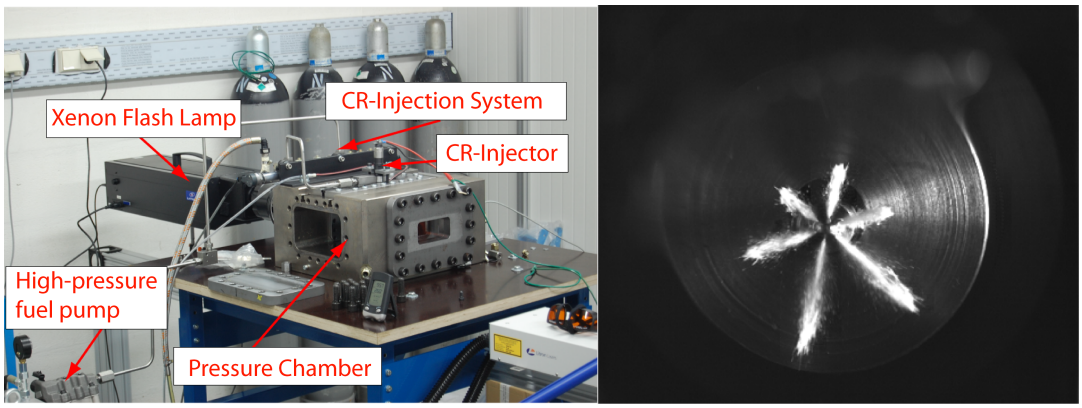

Figure 1. Experimental setup for spray visualization in the pressure chamber (left) Example of Diesel-Spray in pressure chamber (right)

Results and Discussion

On the engine test bench unfavorable operation conditions have been already found. For this operating conditions the properties of rail pressure, gas denisty and the injection duration are assigned to the experiments on the pressure chamber. For each operation condition serveral pictures are taken, an average is build and compared to Diesel Fuel spray pictures. The measured spray properties of the rape seed oil spray (penetration length, spray angle, etc.) are also compared to analytical spray-equations, see below as an example the equation for penetration S of Dent,[2] and Spray angle θ by Hiroyasu and Arai, [4]. With the study it will be possible to explain the different emission behaviour of a Diesel engine fired with rape seed oil fuel. Furthermore the results of this study will indicate problems with deposits which are already observed.

$$S = 3.07 \cdot \left(\frac{\Delta p}{\rho_G}\right)^{\frac{1}{4}} \cdot (t \cdot d_0)^{\frac{1}{2}} \cdot \left(\frac{294}{T_G}\right)^{\frac{1}{4}} \qquad \theta = 83.5 \cdot \left(\frac{l_0}{d_0}\right)^{-0.22} \cdot \left(\frac{d_0}{d_S}\right)^{0.15} \cdot \left(\frac{\rho_G}{\rho_L}\right)^{0.26} \tag{1}$$

Nomenclature

d	spray hole diameter [m]
l	spray hole length [m]
p	pressure [Pa]
S	penetration length [m]
t	time [s]
T	Temperature [K]
ρ	density [kg·s^{-3}]
ν	kinematic viscosity [m^2·s^{-1}]
σ	surface tension [N·m^{-1}]

Subscripts

G	gas
L	liquid
0	initial
S	Sac-hole

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