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Experiments regarding the combustion of camelina oil/kerosene mixtures on a burner

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ABSTRACT

Camelina is well-suited to be a sustainable biofuel crop, as its seeds naturally have high oil content. The process of obtaining bio-kerosene from camelina oil by hydrotreatment is time-consuming and expensive, thus the possibility of using straight camelina oil/kerosene mixtures as fuel in terrestrial applications is considered. For this purpose, combustion tests were conducted on a burner. Three camelina oil/kerosene mixtures were tested. The influence of the variation of the fuel preheating temperature was also studied and presented. During the tests, the composition of the exhaust gas and its temperature were monitored and registered using two gas analysers. The results were compared with those obtained when the burner was fuelled with pure kerosene.

Introduction

Camelina is an oilseed flowering plant that grows optimally in temperate climates, thus it can be cultivated in Romania. Camelina has several beneficial agronomic attributes: short growing season (85–100 days), compatibility with existing farm practises and tolerance of cold weather, drought, semi-arid conditions and low-fertility or saline soils. Camelina has lower water, pesticide and fertilizer requirements than traditional oilseed crops (Shonnard et al., 2010; Moser, 2012; Dobre and Jurcoane, 2011; Johnson, 2006).

Camelina is a second-generation biofuel feedstock (Anon., 2009). The biodiesel obtained from camelina oil meets the requirements of European and American standards for biodiesel, with the exception of two parameters: the iodine number and the oxidation stability (Frohlich and Rice, 2005; Moser and Vaughn, 2010; Ciubota-Rosie et al., 2013). This is due to the high levels of polyunsaturated fatty acids present in the composition of camelina oil.

On the other hand, the bio-kerosene obtained from camelina oil, by hydrotreatment or Fischer–Tropsch synthesis (Bauen et al., 2009), meets all the requirements regarding performance and safety (Frohlich and Rice, 2005) in order to be used in aviation applications. Starting from 2009, the U.S. Air Force successfully tested blends of classic aviation fuel/bio-kerosene obtained from camelina oil on fighting planes (http://en.wikipedia.org/wiki/Aviation_biofuel; Eynck et al., 2013). Passenger air companies such as KLM and Japan Airlines have successfully conducted flights using fuel mixtures of classic jet fuel and bio-kerosene obtained from camelina oil (http://en.wikipedia.org/wiki/Aviation_biofuel; Eynck et al., 2013).

Up to the present day. many researchers have investigated the possibility of using vegetable oils or biofuels obtained from these oils as fuels for internal combustion engines (Altin et al., 2001; Hartmann et al., 2012; Hazar and Aydin, 2010; Chalatlon et al., 2011; Drenth et al., 2014), for micro gas turbines (Cavarzere et al., 2012a; Chiaramonti et al., 2011; Schmellekamp and Dielmann, 2004; Rosa do Nascimento and Cruz dos Santos, 2011) or for furnaces and boilers (Hosseini et al., 2010; Oprea et al., 2008; Thuneke and Widmann, 2001).

The first results regarding the use of straight camelina oil as fuel were reported by Bernardo et al. (2003). They used camelina oil in diesel engines. The results of the study revealed that camelina oil showed an increased maximum power output, from 38.50 kW, in the case of the classic fuel, to 43.25 kW. A decrease of 50% of the carbon monoxide production was observed. Nitric oxide emissions were higher (6%) for camelina oil at high speed, but similar for the two fuels at speeds under 3500 rpm. CO_2 and O_2 levels were similar for both fuels (Bernardo et al., 2003). Paulsen et al. (2011) have also presented results regarding the use of camelina oil as fuel for diesel engines. Burning behaviour and exhaust emission data revealed that straight camelina oil can be used as fuel on diesel engines, but not for long periods of time due to its high Conradson carbon residue (CCR) values and low oxidation resistance (Paulsen et al., 2011). High CCR values may result in the formation of carbonaceous deposits and low oxidation resistance limits storage time (Paulsen et al., 2011). The remedy is relatively simple. Injection nozzles can be cooled to prevent carbon deposition and the oil can be supplemented with antioxidant additives.

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Table 1
Thermo-physical properties of tested fuels.

	Density ρ[kg/m^3] (at 15 °C)	Viscosity υ [mm^2/s]				Specific heat c_p [J/(kg K)]			
		40 °C	60 °C	80 °C	100 °C	20 °C	25 °C	30 °C	35 °C
100% camelina oil	926	31.1	17.5	10.9	8.1	2049	2068	2087	2107
75% camelina oil/25% kerosene	890	11.8	7.5	5.2	3.9	2024	2046	2067	2088
50% camelina oil/50% kerosene	869	5.1	3.6	2.7	2.1	2007	2025	2044	2062
25% camelina oil/75% kerosene	820	2.3	1.7	1.4	1.2	1982	2003	2024	2044
100% kerosene	786	0.79	0.45	0.25	0.14	1959	1978	1997	2015

Tests regarding the combustion of straight camelina oil in a furnace have not yet been reported. Thus, this is an area that needs more research to be conducted.

In this paper, results concerning the combustion process of camelina oil/kerosene mixture on a burner will be presented. The purpose of these tests is to observe flame stability, find the optimum fuel preheating temperature and study the combustion efficiency. Usually, burners function using diesel fuel, or other light fuels, not kerosene. However, camelina oil/kerosene has been taken into consideration because the ultimate objective is to test these unconventional fuels on a micro turbo engine, which, in general, functions on kerosene. Based on the conclusions drawn from the tests presented in this paper, it will be possible to define a suitable functioning regime for the micro turbo engine when fuelled with camelina oil/kerosene mixtures as well as an optimum fuel preheating temperature.

Experimental setup

The laboratory testing rig which was used during the experiments includes a multi-fuel burner, which can function fuelled by classic fuel as well as vegetable oil, waste oil or blends (Anon., 2012), a furnace made of heat-resistant bricks and an air compressor which delivers the air flow necessary for fuel entrainment and atomization to the burner (see Fig. 1).

The burner's fuel tank has an electric resistance inside, thus making the preheating of the fuel possible (Anon., 2012). The pressure of the air used for fuel entrainment and atomization and the air flow necessary for the combustion, delivered by the burner's fan, are adjustable (see Fig. 2).

The air flow delivered by the burner's fan was determined by measuring the air velocity using a Pitot tube connected to a KIMO MP200 anemometer (Anon., 2011). The air flow provided by the burner's fan was varied with the help of a fan position controller; this varied from 0 divisions (closed) to 30 divisions (opened at maximum).

The proportions of the camelina oil/kerosene mixtures used in the experiments are: 25% camelina oil/75% kerosene, 50% camelina oil/50% kerosene and 75% camelina oil/25% kerosene. In Table 1, the experimentally determined thermo-physical properties of the mixtures used in the combustion tests are presented. The measurement principle and the equipment used in the experiments are presented in detail in Petcu et al. (2014).

During the combustion experiments, all the measurements were made after the stabilization of the furnace temperature. The fuel temperature was monitored and maintained.

The concentrations of CO, CO_2, NO_x and O_2 in the exhaust gas and the exhaust gas temperature were monitored and registered for 5 min for each test, using two gas analysers, a MRU Vario Plus gas analyser (Anon., 2007) and a Horiba PG-250 gas analyser (Anon., 2004). The MRU Vario Plus gas analyser can record, with a frequency of 1 reading/second, the concentrations of CO, CO_2 and O_2 in the exhaust gas and their temperature. The Horiba PG-250 gas analyser can record, with a frequency of 1 reading/15 s, the concentrations of CO, CO_2, O_2 and NO_x in the exhaust gas. The measuring principles used by the analysers are the following: in the case of NO_x—the chemiluminescence method (Anon., 2004), in the case of CO and CO_2—the non-dispersive infrared method (Anon., 2007; 2004) and in the case of O_2—the zirconia cell method (Anon., 2007; 2004).

The measurements regarding the composition and temperature of the exhaust gas were performed on a single point of the furnace, as it can be seen from the gas analysers positioning represented in Fig. 3a and b. The point in which the measurements were performed was chosen on the furnace's symmetry axis and at a distance close enough to the flame front in order to ensure, at the same time, a proper characterization of the combustion process and temperature values that would not damage the gas analyser temperature probe.

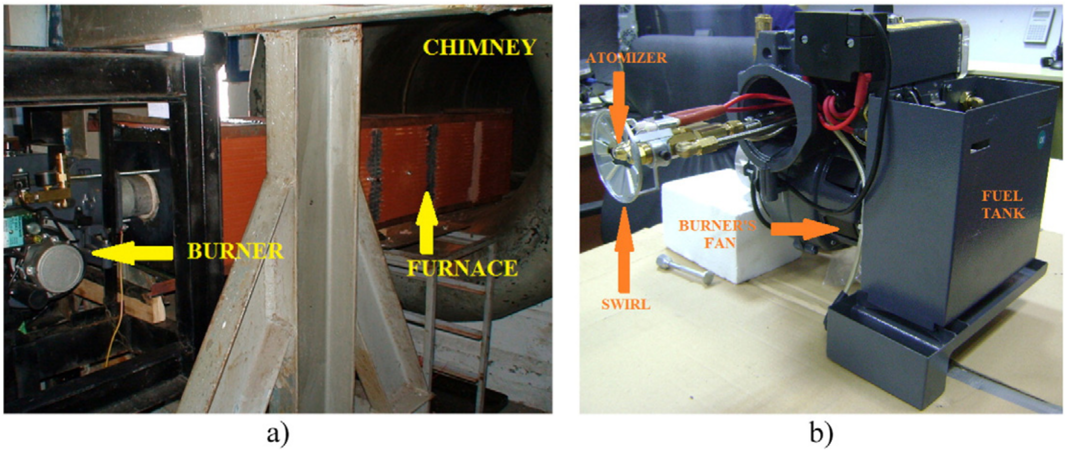

Fig. 1. (a) The testing rig, (b) Kroll KG/UB 100 burner.