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ALCOHOLS AS AN ADDITIVE TO DIESEL FUEL

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Abstract

Strict environmental emission standards, problems in the use of diesel fuel are analyzed in detail, as well as methods to improve the primary injection and combustion processes in the engine chamber application of alternative diesel fuel additives, the tendency to reduce emissions of internal combustion engines. Studies of the thermophysical properties of alternative fuels for the purpose of optimal design of diesel engine combustion and high-pressure fuel injection using fuel blends as a function of pressure, temperature and concentration have been conducted using internationally recognized precision experimental facilities.

Keywords: *alcohol, diesel fuel, alternative fuel, density, speed of sound*

Introduction

The stringent emission standards require advanced internal combustion engines driven with Diesel fuel with improvement of the primary injection and combustion processes within the engine combustion chamber. One important development successfully applied to meet the stringent legal requirements for emissions of Diesel engine is the use of a common rail for fuel injection into the primary combustion chamber. Another current development is the use of alternative fuels instead of fossil diesel or mixtures of alternative fuels and fossil diesel, so-called blends [1]. As alternatives to fossil fuels for the Diesel engine can be rapeseed oil, bio-alcohols, fuel mixtures or even synthetic fuels, biodiesel, liquid petroleum gas, compressed natural gas etc. [2]

Alcohols have been used as alternative fuels or in blends in internal combustion engines for a long time and tends to decrease internal combustion engine emissions [3]. These types of fuels often produce higher evaporative emissions than diesel fuels due to higher vapor pressures, a higher octane number, low heating value, cause a drop in engine performance if the engine management system does no compensation [4], also have less carbon atom content per heating value, less sulphur content, a much lower temperature flash point, a higher vapor formation potential in confined spaces.

Nevertheless, alcohols have a lower cetane number, which limits the usage of neat alcohols in Diesel engine as an alternative fuel. Use of cetane enhancers can improve potential of alcohol fuel blends as a promising fuel for Diesel engine [1]. Using alcohol as addition to diesel fuel changes some thermo-chemical properties of diesel fuel, particularly reductions in cetane number, density, viscosity and heating value. With increase of the amount of alcohol in diesel fuel mixture, there is an increase in both the ignition delay and the rate of initial heat release, premixed combustion, while there is a decrease in diffusion combustion, total combustion duration and combustion temperature [5]. Increase of alcohol percentage in diesel mixtures also improves volatility and viscosity at low temperatures of blend [6].

The best way to use the alcohols as fuel blend in a Diesel engine injection is the injection of them by the injection nozzle. It means, no engine hardware modifications are required, but the engine management system hat to compensate for the changed fuel properties. To ensure an optimal vaporization of the fuel mixture common rail injection systems are preferred [7]. This technology typically employs more than 100 MPa pressure in the common rail and the engineers try to increase this designed injection pressure for still better vaporization of the fuel within the combustion chamber. High pressure injection nozzles to the engine cylinder are used provide complete combustion and thereby reduction of soot emissions and noise levels and thus meet necessary legislative requirements [8]. The most important injection parameters, which depend on the physical properties of the fuel, such as distillation range, cloud point, pour point, sulfur content, fuel stability, etc, are the inlet fuel pressure to the injector and the rate of injection which determine the spray penetration and atomization and finally the vaporization [9].

Upon injection of the fuel in a cylinder, large depressurization of the fuel results in a significant change of the thermophysical properties of the fluid [1]. For optimal design of diesel engine combustion and high pressure fuel injection process with fuel mixtures concerning understanding, modeling and optimizing spray formation, vaporization and combustion and pollutant formation an accurate knowledge of basic fuel thermophysical properties, like density, vapor pressure, viscosity, speed of sound, surface tension, heat capacity, bulk modulus, etc. as a function of pressure, temperature and composition, is required [10].

During the many years, we presented the measurement results for basic thermophysical properties of alcohols (ethanol, 1-propanol and 1-butanol) and diesel fuel blends at high pressures and temperatures and thorough analysis of already existing literature data. From our data we also derived an empirical equation of state (EOS) as a function of pressure, temperature and composition for the every alcohol blends separately.

Experiment

The (p,ρ,T) measurements of alcohols (ethanol, 1-propanol or 1-butanol) and diesel fuel blends are carried out using a high pressure – high temperature Anton Paar DMA HPM vibration tube densimeter [14]. The temperature in the measurement cell, where the U–tube is located, is controlled with a ΔT = ±10 mK uncertainty of the measurement and is measured using the (ITS-90) Pt100 thermometer with a ΔT = ±15 mK experimental uncertainty of the measurement. Pressure is measured by pressure transmitters WIKA, Germany with an average percent deviation in $\Delta p/p$ = ±(0.1 to 0.5) %. According to the specifications of Anton−Paar and calibration procedures the observed repeatability of the (p,ρ,T) measurements at T = (263.15 to 468.65) K and pressures up to p = 140 MPa is $\Delta\rho/\rho$ = (0.01 to 0.03) %. The density values $\rho(p_{0\ \mathrm{or}\ s},T)$/kg·m^{-3} of these fuel blends at ambient or saturated pressures and at T = (263.15 to 468.65) K were investigated using the Anton Paar DSA 5000M and DMA HPM vibration tube densimeters with an uncertainty of $\Delta\rho$ = ± ($5\cdot10^{-3}$ to $3\cdot10^{-1}$) kg·m^{-3}.

Vapor pressure values P/Pa of these fuel blends were measured using the two high-accuracy static experimental set ups [15]. The glass cells are used for vapor pressures lower than ambient pressure and at T = (274.15 to 323.15) K. The glass-cell apparatus consists of a bolted-top cell in a water bath kept at constant temperature ΔT = ±0.01 K. The vapor pressure of blends is measured using a calibrated high-accuracy sensor head 615A with ΔP = ±(10 to 30) Pa uncertainties. The sensor head is placed inside of air reservoirs with an internal temperature T = (333.15 ± 0.01) K. The experiments to determine the vapor pressure of these fuel blends at T = (323.15 to 468.65) K and for vapor pressures higher than ambient pressure are performed in a metal cell by using the static method [15]. The temperature of the measuring cell is stabilized using the thermostat with the accuracy ΔT = ±0.01 K and are measured using two different platinum resistance thermometers PT-100 with an accuracy of ΔT = ±0.001 K. The vapor pressure values higher than ambient pressure depending from the limit of pressure is measured using the four various Omega-Keller pressure transmitters with the uncertainty $\Delta P/P$ = ±0.1%.

The dynamic viscosity $\eta(p_0,T)$/Pa·s of these fuel blends at p=0.101 MPa and temperatures at T= (278.15 to 468.15) K are measured using an Anton Paar SVM 3000 Stabinger Viscometer and Anton Paar Rheometer MCR 302. The accuracy of measured dynamic viscosity η values at p=0.101 MPa according the SVM 3000 Stabinger Viscometer manufacture instructions is $\Delta\eta/\eta = \pm 0.35$ % and of Rheometer MCR 302 - $\Delta\eta/\eta = \pm 1$ %.

The constant pressure specific heat capacity of these fuel blends $c_p(p_0,T)/\mathrm{J\cdot kg^{-1}\cdot K^{-1}}$ at p=0.101 MPa is measured at T = (253.15 to 468.55) K using the differential scanning calorimeter system [16] and the obtained experimental data was used for the calculation of specific heat capacities $c_p(p,T)$ and $c_v(p,T)$ at high pressures and temperatures, in which the density of these blends is experimentally investigated. The accuracy of constant pressure specific heat capacity measurements is $\Delta c_p/c_p = \pm$ 0.5%.

The speed of sound values $u(p_0,T)/\mathrm{m\cdot s^{-1}}$ of investigated alcohol and Diesel fuel blends at p = 0.101 MPa and T = (278.15 to 343.15) K were investigated using the Anton Paar DSA 5000 M vibration tube densimeter and sound velocity meter with ΔT = (5 to 10) K temperature intervals and an uncertainty of $\Delta u = \pm 0.1\ \mathrm{m\cdot s^{-1}}$. These high accuracy values are necessary to check the accuracy of calculated speed of sound values u at p= 0.101 MPa.

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Spirtlər dizel yanacaqlarına əlavələr kimi

Xülasə

Tullantıların sərt ekoloji normaları, dizel yanacağının istifadəsindəki problemlər, eləcə də alternativ dizel yanacağı qarışıqlarının mühərrik kamerasında ilkin vurulma və yanma proseslərinin yaxşılaşdırılması metodları, daxili yanma mühərriklərinin emissiyalarını azaltmaq tendensiyaları ətraflı təhlil olunub. Dizel mühərrikinin yanma prosesinin optimal dizaynı məqsədilə təzyiqin, temperaturun və konsentrasiyanın funksiyasından asılı olaraq alternativ yanacaqların istilik-fiziki xüsusiyyətlərinin tədqiqi beynəlxalq səviyyədə tanınmış həssas təcrübi qurğulardan istifadə edərək aparılıb.

Açar sözlər: *spirt, dizel yanacaq, alternativ yanacaq, sıxlıq, səs sürəti*

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Спирты как добавки к дизельным топливам

Резюме

Подробно проанализированы строгие экологические нормы выбросов, проблемы при использовании дизельного топлива, а также методы улучшением процессов первичного впрыска и сгорания в камере двигателя применение альтернативных присадок к дизельному топливу, тенденция снижению выбросов двигателей внутреннего сгорания. Исследования теплофизических свойств альтернативных топлив с целью оптимального проектирования процесса сгорания дизельного двигателя и впрыска топлива под высоким давлением с использованием топливных смесей в зависимости от функции давления, температуры и концентрации проведены с использованием всемирно признанных точных экспериментальных установок.

Ключевые слова: *спирт, дизельное топливо, альтернативное топливо, плотность, скорость звука*

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