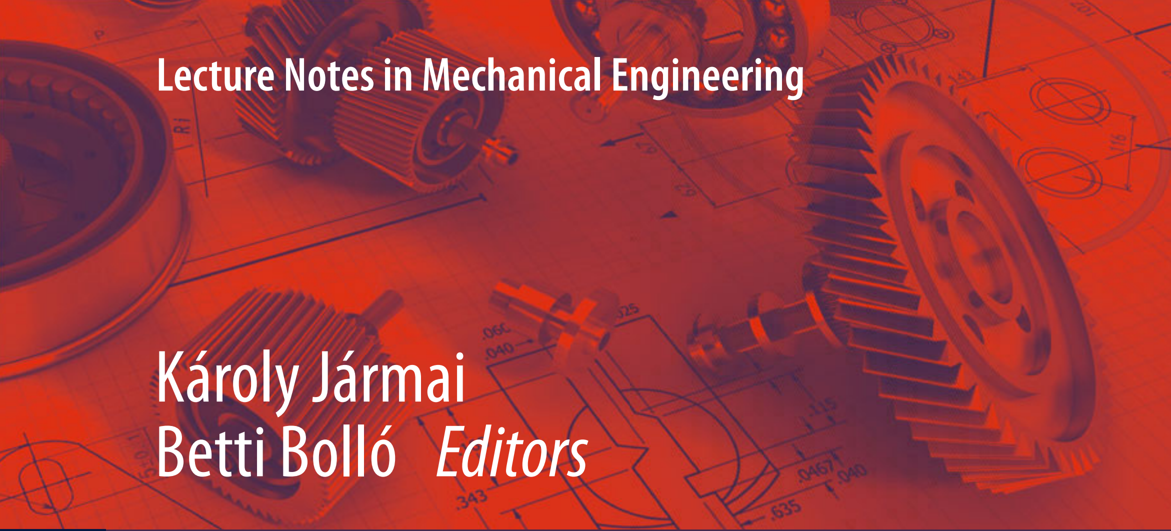

Lecture Notes in Mechanical Engineering

Károly Jármai
Betti Bolló *Editors*

Vehicle and Automotive Engineering 2

Proceedings of the 2nd VAE2018, Miskolc, Hungary

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Editors

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Preface

The production of the automotive and vehicle industry and its component suppliers, manufacturer of machines and equipment, the connected mechanical engineering and process engineering industry have increased greatly in the last decades. The quick transportation of persons and goods is more and more important. People would like to reach the destination as quick as possible. This is the case in Hungary, where the improvement of car and vehicle industry was great in the last decades. Great car producers settled here like Mercedes Benz, Audi, Suzuki, Opel, and small and medium enterprises connected to car element production have developed greatly.

The aim of the 2nd International Conference on Vehicle and Automotive Engineering at the University of Miskolc, Hungary, is to provide a good opportunity for the discussion of professional topics on this field both for academic and industrial experts.

The main requirements for cars and car elements are safety, manufacturability, and economy. Safety against different loads such as permanent and variable actions is guaranteed by design constraints on stresses, deformations, stability, fatigue, eigenfrequency, while manufacturability is considered by fabrication constraints. Economy is achieved by minimization of the cost.

The main topics of the conference are as follows:

- Conventional Powertrain and Emission
  Gasoline engines & emissions, Diesel engines & emissions, Transmissions, simulation, Virtual design and testing, Fuels & lubricants
- Alternative Powertrains
  Hybrid vehicles, Electric vehicles, Fuel cell vehicles
- Vehicle Dynamics
  Suspension, steering & brakes, Tyres, Advanced dynamic vehicle control, Advanced driver assistant systems, Stability
- Materials and Manufacturing

Advanced materials and innovations in manufacturing. Metal parts forming, joining and casting technologies. Coating, Wear, Corrosion Protection and Surface Engineering. Fatigue, Fracture, Failure and Testing of Materials and Structural Parts. Prototype building. Flexible processes. Supply chain and logistics.

- Vehicle Electronics
  Engine control, Voice and motion recognition, Vehicle tracking and monitoring, Suspension control, Brakes management
- Autonomous Vehicles
  Autonomous & connected vehicles, Artificial intelligence, Internet of Things (IoT), Applications in Smart Cities, Future Trends and Emerging Technologies
- Noise and Vibration
  Engine noise, Tyre noise, Other sources of noise, Measurement techniques, Simulation and analysis
- Active and Passive Safety
  Structural crashworthiness, Biomechanics, Test Methods, Safety management, Accident reconstruction, Traffic and human factors, Fire safety
- Sustainability
  Standards and regulations, Design for environment, Virtual design and testing, Inspection and maintenance, Life cycle assessment, Recycling
- Education
  Vehicle and automotive engineering education, Dual training, Industrial practice, Educational aids
- Design of Vehicle Structures and Surfaces
  Geometric modelling, Design and reconstruction of vehicle structures, and surfaces, Evaluation and correction of vehicle surfaces, Computer, graphics and image processing in visualization and design, 3D printing, and prototyping in vehicle development
- Optimization
  Topology optimization, shape optimization, sizing. Optimization methods, cost calculation.
- Welding
  Different welding technologies. Application of ultra-high-strength steel. Application of welding in vehicle industry.

It is a great pleasure to organize this conference and to give participants opportunity to show and discuss the new research results in a friendly atmosphere.

The organizers wish all participants successful days to collect new ideas and get new acquaintances.

February 2018

Károly Jármai
Betti Bolló

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- Hungarian Vehicle Producers Association (MAJOSZ),
- Foundation for the Development of the Education at the University of Miskolc,
- The Mayor and Vice Mayors of town Miskolc,
- Hungarian Trade and Industrial Chamber in Borsod county (BOKIK),
- Hungarian Investment Promotion Agency (HIPA),
- Hungarian Iron and Steel Association (MVAE),
- North Hungarian Automotive Cluster (NOHAC),
- Hungarian Welding Association (MAHEG),
- Hungarian Welding Technology and Material Testing Association (MHtE),
- The EFOP-3.6.1-16-2016-00011 "Younger and Renewing University—Innovative Knowledge City—institutional development of the University of Miskolc aiming at intelligent specialisation" project implemented in the framework of the Széchenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

and last but not least the

- University of Miskolc, Hungary, which hosts the conference.

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- László Kota, Assistant Professor,
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Conventional Powertrain

Investigation of Diesel – n-Butanol Fuel Blend in the Function of Pre-injection Angle

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Abstract. The utilisation of renewable fuels and decreasing emission are important targets of the development and utilisation of compression-ignited and spark-ignited internal combustion engines. One solution can be the utilisation of different alcohols. With compression-ignited internal combustion engines, very often, ethanol and n-butanol are used for this purpose. The benefit of higher alcohols (C3–C4), like n-butanol, can be blended with diesel fuel without any surfactant or emulsifier. The aim of this study is to evaluate the effects of the blend containing 10 V/V% n-butanol, and the pre-injection angle on engine performance, combustion, and emission. It is a three–cylinder, direct-injection diesel engine used for the tests.

While testing, it was observed that the fuel consumption of the blend was high compared to that of the D2 fuel. Butanol containing blend slightly showed peak cylinder pressure and heat release rate comparable to that of D2. Carbon monoxide (CO) unburned hydrocarbons (THC), and smoke emissions of the BU blend was lower in comparison to D2 fuel.

Keywords: Diesel engine · n-butanol · Combustion process

Nomenclature

ABE:	Acetone-Butanol-Ethanol
BTDC:	Before top dead centre
CA:	Crank angle
CO:	Carbon monoxide
HCCI:	Homogeneous charge compression ignition
LHV:	Lower heating value
NOx:	Nitrogen oxides
O:	Oxygen
pi:	Indicated pressure
PPCI:	Partially premixed compression ignition
PRIA:	Pre-injection angle
ROHR:	Rate of heat release
TDC:	Top dead centre
THC:	Total hydrocarbons

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1 Introduction

On the one hand, the utilisation of renewable fuels is a significant effort to reduce dependence on fossil fuels; while, on the other, it is expected that harmful emission occurring due to the general oxygen content of alcohol will also be reduced. However, higher alcohols (C3–C4) have great advantages as follows. They can be blended with vegetable oils and diesel fuel without any surfactant or emulsifier [1, 2] as opposed to ethanol [3–5] or methanol [5–7]. The investigated butanol production can be carried out in the following way: Acetone–butanol–ethanol (ABE) fermentation (Clostridium beijerinckii bacteria) is commercially produced from fossil fuels [8]. However, its production process from renewable raw materials requires further development.

The auto ignition of n-butanol was investigated by Lapuerta et al. [9]. They used a constant-volume combustion chamber at $p_0 = 21$ bar, and $T_0 = 602.5$ °C. It was found that increasing the alcohol content in diesel always led to an increase in both cold-flame and main-ignition delay, and some increase in pressure peaks was observed at 5–10 V/V % of butanol contents, probably due to an increase in the amount of premixed combustion, and in the flame speed derived from the presence of alcohols in the blends.

There are a lot of papers about the test in compression-ignited type of engines [10–24]. Doğan tested B10, B15, B20, and neat diesel fuel in a diesel engine [10]. The experimental test results showed that smoke opacity, nitrogen oxides, and carbon monoxide emission reduced while hydrocarbon emission was increasing with the n-butanol content increase in the fuel blends. Swamy et al. [20], investigated four different blends of butanol on a volume basis (B0, B5, B10, B15, and B20) to study the impact of using butanol-diesel blends. At higher loads, it was found that CO emission reduced, while HC emission was increasing. At the same time, NO_x emission values, both at low and high loads, are slightly higher than those produced with neat diesel application. Also, smoke opacity at high engine loads decreased as opposed to relevant figures of neat diesel application. Nayyar et al. [21], investigated n-butanol diesel blends under varying engine parameters in a VCR diesel engine. It was found that the reduction in smoke, nitrogen oxides (NO_x), and carbon monoxide (CO) was observed, while carbon dioxide (CO2), and hydrocarbons (HC) were found to be higher.

Nabi et al. [22], conducted the experiment by using a 6-cylinder, turbocharged common, rail diesel engine in accordance with the 13-Mode European Stationary Cycle (ESC). The tested fuels were neat diesel fuel, as reference, and B10, B20, and B30 blends. Most of the emission values were found significantly reduced by the butanol blends, compared to those of the reference diesel, and without causing considerable deterioration in engine performance. Lapuerta et al. [23], carried out tests with following the New European Driving Cycle with B20 diesel/n-butanol blend. They found that the increase in oxygen content inhibited soot formation, as well as increase in hydrocarbon emission, especially under cold-engine conditions, and, finally, NO_x emission values remained unchanged.

Another interesting possibility was the direct (neat) utilisation of n-butanol in diesel engines. Han et al. [24], made tests to examine the PPCI, HCCI and split-combustion strategies with 2–3 combustion events. Two types of premixed combustion, PPCI and HCCI, enabled with direct and port injections, respectively, were found to be feasible to run neat n-butanol on the diesel test engine, and were capable of producing low NO_x and near-zero smoke emission achieving efficiency values of a diesel-type engine at the same time. But the strategies proved to be useful only in the low-mid engine load range; higher load operations were prohibited by excessive pressure-rise rates. The split-combustion strategy enabled neat n-butanol application across the engine load range.

2 Experimental

The n-butanol (BU) (CAS number 71-36-3) was purchased from a chemical shop, while the diesel fuel (D2) used to make the blends, and served as base reference fuel for engine tests, was purchased from a local petrol station (Budapest, Hungary). Blends were prepared in the laboratory by mixing the components in 5000 ml beakers at room temperature. On a volumetric basis, diesel fuel (D2) was fixed at 90% for all blends; the remaining 10% consisted of n-butanol. The main fuel parameters are in Table 1.

Experiments were carried out on a generator set, which involves an IVECO AIFO

Table 1. Fuel properties.

Property	D2	n-butanol	B10
Density (kg/m^3)	0.86	0.81	0.855
LHV (MJ/kg)	42.8	33.1	41.8
Stoichiometric A/F ratio	14.7	11.21	14.4
Latent heat (kJ/kg)	270	581.4	299.5

8031 three-cylinder, naturally aspirated direct injection diesel engine, a MARELLI M8b 160 synchronous generator, and the required control systems (see Fig. 1). The synchronous speed was 1500 RPM. The measured power and efficiency values had

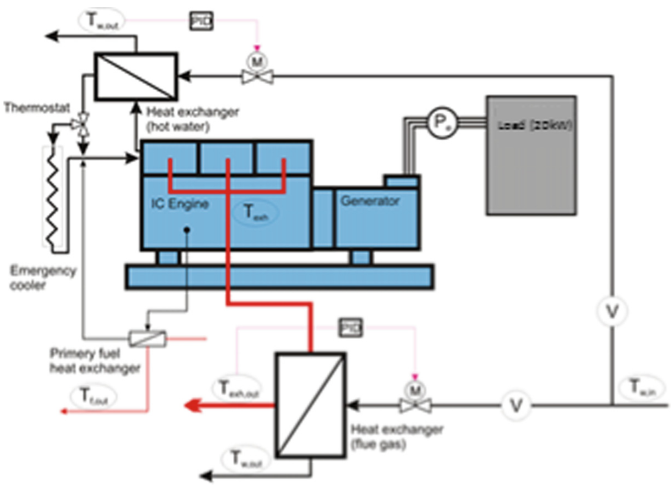

Fig. 1. The test engine system.

to be divided by the efficiency of the generator (which is 0.9 according to its manual) to achieve effective values. The engines were loaded at constant 20 kW power. The pre-injection angle was modified by the mechanical adjustment of the injection pump; the accuracy of the injection set was ±1 deg.

Emission was measured by the Horiba emission gas analyser system (MEXA 8120) and a smoke meter (AVL 415) connected in the engine exhaust pipeline (Table 2).

Table 2. Description of test equipment and equipment accuracy.

Equipment	Description	Accuracy
Fuel consumption measuring system	AVL-7030 fuel balance	±20 g/h
Exhaust gas analyser system	HORIBA MEXA-8120 F	–
CO analyser	AIA-23, NDIR	±0,002 V/V%
CO_2 analyser	AIA-23, NDIR	±0,336 V/V%
THC analyser	FIA-22, H FID	±2,1 ppm
NO/NO_x analyser	CLA-53, H CLD	±42 ppm
Smoke meter	AVL 415	3 mg/m^3
Piezo transducer	Kistler KIAG 6005	Linearity ≤ ±0.8 (% FSO)
Charge amplifier	Kistler KIAG 5001	–
Crank angle speed encoder	HENGSTLER RI 32-0/1024. ER.14KA	0,35 deg

2.1 Simulation Tools

The AVL Boost is AVL's one-dimensional engine gas dynamics and cycle simulation software developed for the modelling of a complete engine [25]. The main program provides optimised simulation algorithms for all available elements. The flow in the pipes is treated as one-dimensional. The elements are the air filters, compressor(s) intake and exhaust manifold, intake and exhaust valves, turbine, exhaust after treatment systems etc.

The used BURN utility of the Boost software system can be used for combustion analysis, which is the inverse process of the combustion calculation performed in the BOOST cylinder. The main input parameters are pressure in the cylinder in the function of the crank angle, main geometry data of the cylinder, including the piston pin offset and the blow-by gap. Additional parameters required like the speed, wall temperatures and the selected heat transfer model, in our case the Woschni 1990 [26] were used.

In order to compensate for noise, errors or inaccuracies in the measured cylinder pressure curve, filtering and for fitting adaptations are available to adjust the measured pressure curve. The resulting adapted pressure curve is then used for the combustion analysis. Important part of the software is the wall heat transfer calibration method.

The output of the software are the results of the fitting (adaptation) process of the measured pressure curve, the calculated mass burned fraction curve, the heat release and the net heat release.

3 Test Results

The combustion process is a complex system in compression ignition engines. Soon after injecting the droplets they begin to evaporate and generate a flammable mixture of fuel and air, that is ready to burn when the temperature is high enough. This process depends on air temperature in the combustion chamber and the evaporative heat of the fuel. During the early phase of injection the temperature will not be high enough, therefore, ignition delay will be identically as high as combustion at 20 deg BTDC pre-injection angle. Therefore, the premixed part of the combustion will be high. With late injection, such as combustion at 0 deg BTDC pre-injection angle, the situation is different; fast evaporation and mixing cause combustion delay and also temperature decreases in the combustion chamber (see Fig. 2).

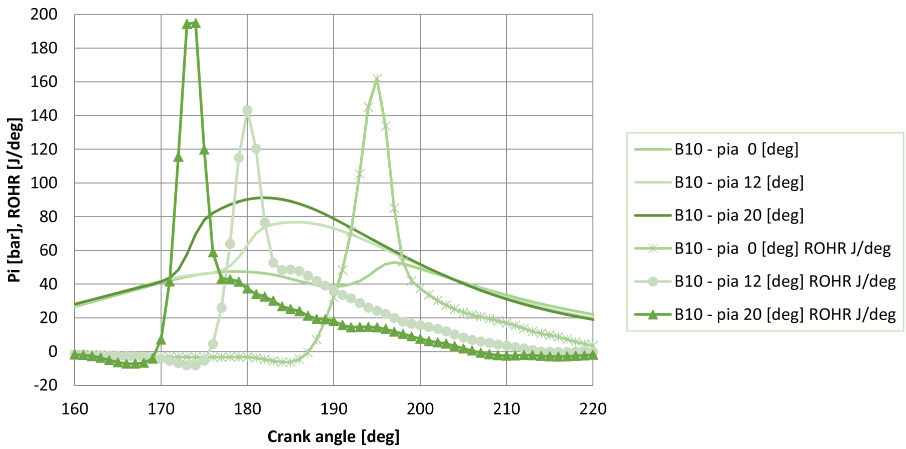

Fig. 2. The Rate of Heat Release (ROHR) and the indicated pressure in the function of the crank angle at different pre-injection timing (0, 12 and 20 deg BTDC) in the case of 10 V/V% n-butanol.

The maximum values of heat release (ROHR) have a minimum value between 8–12 deg BTDC (see Fig. 3) as presented in Fig. 2. In this case the location of the maximum values of heat release rate is close to the top dead centre (TDC). This is the same at D2 and B10 fuel; the ROHR of B10 values are higher. It may be due to higher flame velocity of alcohols and the increase in the amount of premixed combustion.

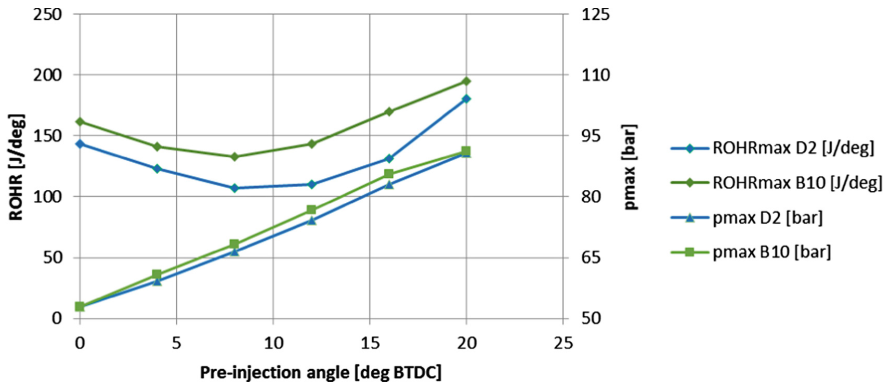

Fig. 3. The maximum values of the indicated pressure and the ROHR in the function of pre-injection timing with D2 and B10 fuels.

The maximum indicated pressure raises with the increase of the pre-injection angle (see Fig. 3). Comparing the two different fuels, it becomes evident that B10 has higher values. However, the differences are almost negligible, as this has been presented by different authors [9].

The maximum values dp/dφ characteristics increase in the function of the pre-injection angle. At high pre-injection angle, the intensive pre-mixed combustion and the compression increase this parameter (see Fig. 4). Comparing the two fuels, it can be seen that similarly to ROHR B10 has higher values; and the reasons can be similar (see Fig. 4).

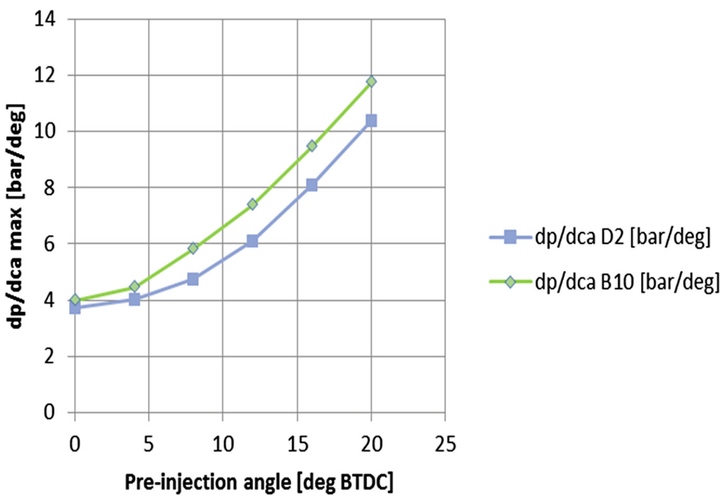

Fig. 4. The dp/dφ_{max} characteristics in the function of pre-injection timing with D2 and B10 fuels.

The fuel consumption of the D2 and B10 fuels has a minimum value at 12 deg BTDC. This is the same pre-injection position as the minimum of the ROHR, for the same reasons. The power of the engine is the same (20 kW), while the B10 fuel consumption proves to be higher because of the lower LHV (see Fig. 5).

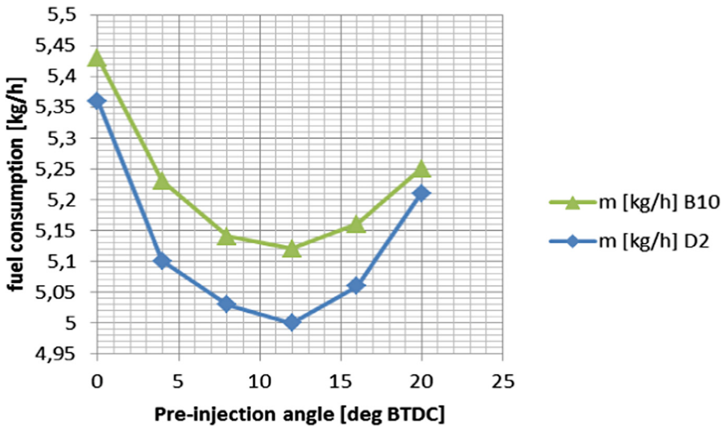

Fig. 5. Fuel consumption in the function of pre-injection timing, with D2 and B10 fuels.

The increase of fuel consumption is nearly the same as LHV decrease. Therefore, BTE can be similar in the case of the two fuels as it is presented in Fig. 6.

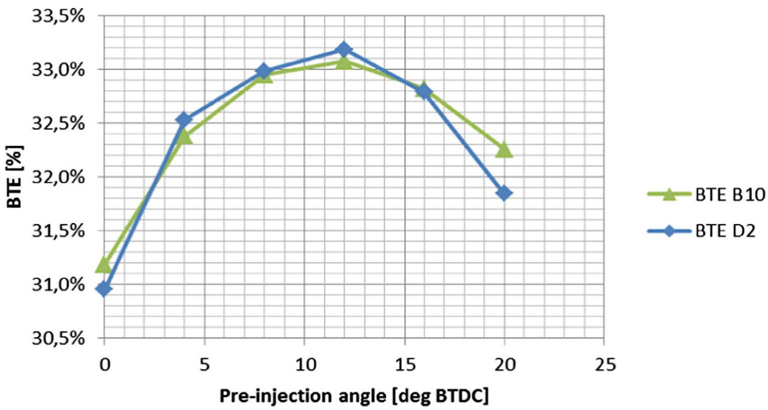

Fig. 6. BTE in the function of pre-injection timing, with D2 and B10 fuels.

The CO and THC emission rates are indicators of complete combustion (see Figs. 7 and 8). THC emission has a minimum value at 12 deg BTDC pre-injection, where there is the most intensive part of combustion (maximum of the ROHR), and is close to

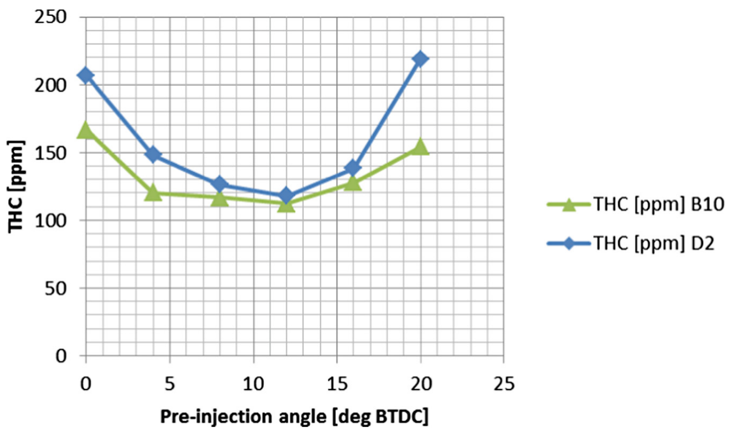

Fig. 7. THC emission in the function of pre-injection timing with D2 and B10 fuels.

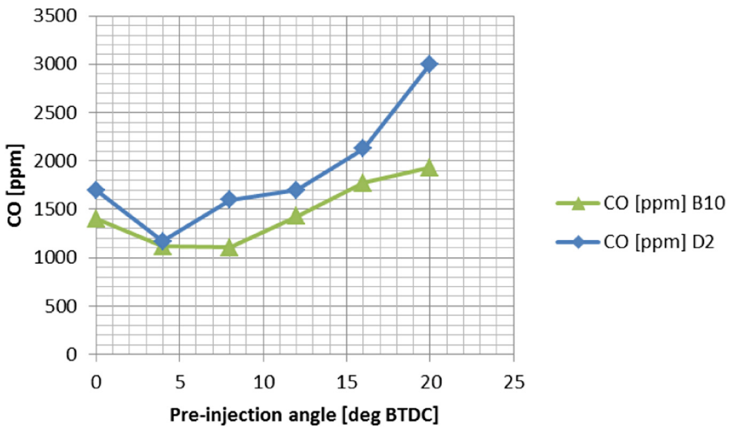

Fig. 8. CO emission in the function of the pre-injection timing with D2 and B10 fuels.

TDC. Therefore, this is where maximum temperature can be measured. The minimum of CO emission is almost the same pre-injection as THC, but the minimum is about 4 deg BTDC pre-injection angle.

For both of the two emissions B10 presents lower values, the alcohol with O content, and the more intensive ROHR, generate higher temperature, thus, improving the combustion process.

The NO_x emission (see Fig. 9) of B10 blend is found to be comparable with that of neat diesel. The main factors effecting NO_x formation are temperature, time of presence in high temperature, and local oxygen concentration [6, 27]. B10 has higher local O

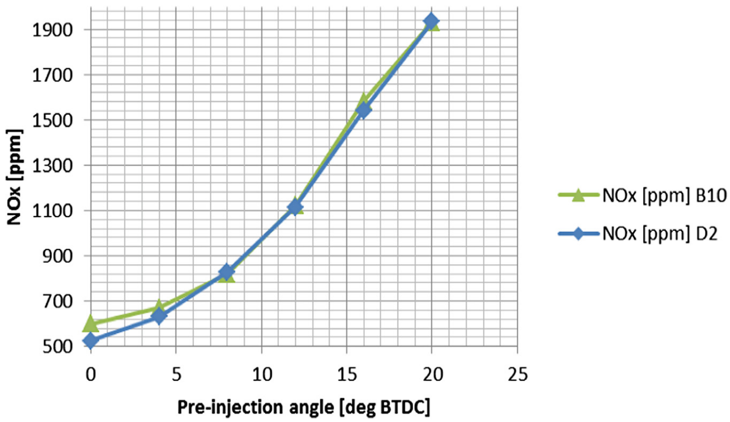

Fig. 9. NOx emission in the function of pre-injection timing with D2 and B10 fuels.

concentration, because alcohol contains O. The more intensive premixed combustion increases local temperature, but it is reduced by the cooling effect of the higher latent heat of B10. The NO_x emission, however, increases with the pre-injection angle, because the high temperature phase is longer [28].

The particulate matter concentration has a maximum value at 12 deg BTDC pre-injection, where there is the minimum premixed combustion (Fig. 10). Therefore, more fuel burns in the diffusion combustion, and the main part of the combustion happens at the minimum volume of the combustion chamber. B10 presents lower values because of higher local O concentration.

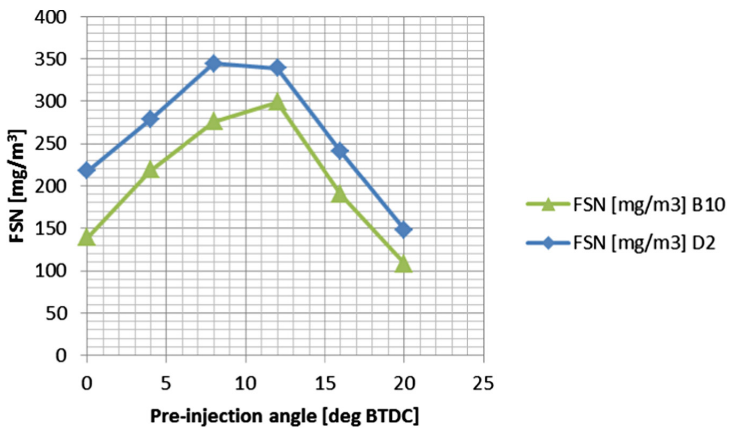

Fig. 10. FSN emission in the function of pre-injection timing with D2 and B10 fuels.

4 Conclusions

Comparing neat Diesel fuel (D2) and 90% D2 and 10% blend of n-butanol in the function of the pre-injection angle, the following can be stated. In the case of:

- NO_x emission increases, in the function of the pre-injection angle, the differences of the fuels are not relevant,
- PM emission, in the function of the pre-injection angle, has about maximum 12 deg BTDC pre-injection, and the B10 fuel emits lower PM,
- THC emission has a minimum value at 12 deg BTDC pre-injection, and the B10 fuel emits lower THC,
- CO emission has a minimum value at 4 deg BTDC pre-injection, and the B10 fuel emits lower concentration,
- BTE has a minimum value at 12 deg BTDC pre-injection, and the differences of the fuels are not relevant,
- The maximum of the heat release rate (ROHR) has a minimum value between 8–12 deg BTDC, and the B10 blends have higher values,
- The maximum of the indicated pressure increases in the function of the pre-injection angle, the B10 blends have slightly higher values.

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Optimal Manufacturing Technology Determination for the Main Parts of a Rotary Internal Combustion Engine

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Abstract. The paper deals with the cutting technology determination and the optimization possibility of finishing process of a new type rotary internal combustion engine. The construction and the working of the engine were introduced in previous publications. These publications presented the innovative idea resulted in the new internal combustion engine that has three rotary parts only. This paper continues the work aiming the realization of the first engine prototype with the investigation of the technological aspects of manufacturing. Among them the most important and interesting ones are the cutting and finishing of the two main parts of the engine: the rotor and the rotary chamber. The outer surface of the rotor is non-equal pitch helicoids, which can be manufactured more easily than the rotary chamber that has similarly changing, but internal helicoids. The paper analyses the possibility of manufacturing of these parts using free form milling with ball end milling cutters, and/or using NC controlled milling with disk-shaped cutters. Then, as an optimal finishing process, the grinding of these very complicated surfaces will be studied. The research work was aided by the Surface Constructor software application. As a conclusion, the selection between the possible milling technologies and the required milling tools and a proper grinding technology will be documented.

Keywords: Internal combustion · Rotary engine · Technology
Milling · Grinding · Simulation

1 Introduction

Though some of the industrial experts bury the gasoline engines, some heavy and exceptional environments will need the special conventional engines. So the development such motors worth considering if they have unique capabilities. The patented invention of the author [1] is such a construction, having only three rotary working parts may reach the extremely high 40 000 rpm speed. The construction is very simple, as can be followed in the lower part of Fig. 1. The two main parts of the engine are the rotor and the rotary chamber. Both have helicoidal working surfaces with changing pitch and there is an e eccentricity between the two axes. The surfaces form closed cavities that move along the axes and perform the four strokes: intake, compression, combustion/expansion and exhaust as can be seen in the figure, which demonstrates these cycles for the well-known Wankel rotary engine and for the discussed new

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