Politehnica University of Timișoara

Summary of the PhD Thesis

STUDY OF ALCOHOL AND WATER DILUTED ALCOHOL INJECTION IN THE INTAKE OF A COMPRESSION IGNITION ENGINE

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Introduction

The thesis aims to determine the impact of secondary fuel injection into the intake of a diesel engine. The secondary fuels studied were alcohol and water, as well as various mixtures of these in different proportions. The purpose of alcohol and water injection is to reduce nitrogen oxides emissions and improve engine efficiency. Injection parameters must be modified in some cases to achieve these objectives.

Chapter 1 The current research in secondary fuel injection for compression ignition engines

The first chapter evaluates the current methods in which a secondary fuel is used in diesel engines, the advantages and disadvantages of using these fuels depending on their type and application method.

The most common types of secondary fuel are gas and alcohol, these can be introduced in various methods, from the simplest to the most complex. The simplest methods of introduction are by fumigation, in which case the amount of secondary fuel per cycle is not very precisely controlled, but rather an overall flow rate. A similar but more precise method is injection into the engine intake, where the dose is controlled per cycle. The most complex method involves direct injection of the secondary fuel into the cylinder, this method requires specialized components and significant modifications to the engine.

The conclusion obtained based on literature analysis, is that the use of gas in the engine intake does not have an easy to predict behavior, some studies obtaining positive results while others have not observed such good results. The use of methanol and ethanol presents the best results when it comes to alcohols, this type of fuel presents in most studies positive results in terms of nitrogen oxides emissions and helps to improve efficiency.

Water injection was another topic investigated, to evaluate the potential of this strategy, as water injection is often associated with the reduction of nitrogen oxides, cases also observed in studies conducted on diesel engines.

Chapter 2 Experimental Test Bench

This chapter presents the construction and configuration of the experimental test bench. This bench was built specifically for the study in this thesis but also allows further studies to be performed. The stand consists of a diesel engine with a common rail injection system, connected to a hydraulic water brake responsible for producing the loads necessary for the measurements. In addition to the mechanical components, the stand was equipped with a series of sensors and measurement systems that allow the for precise monitoring of the interest parameters.

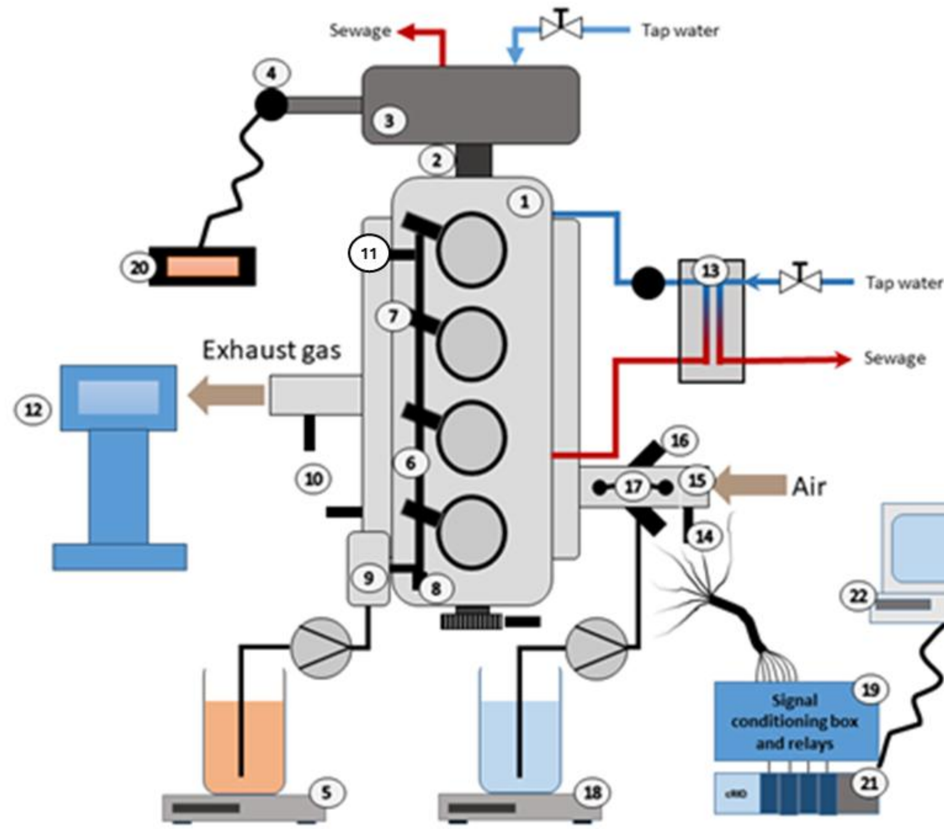

Figure 1Block diagram of experimental test bench

To maintain the desired steady state operating conditions, a control system was developed in the laboratory, based on a Compact RIO control unit from National Instruments, which together with software developed specifically for the experimental stand and a series of relays and signal conditioning circuits, allows the stand to be controlled and monitored.

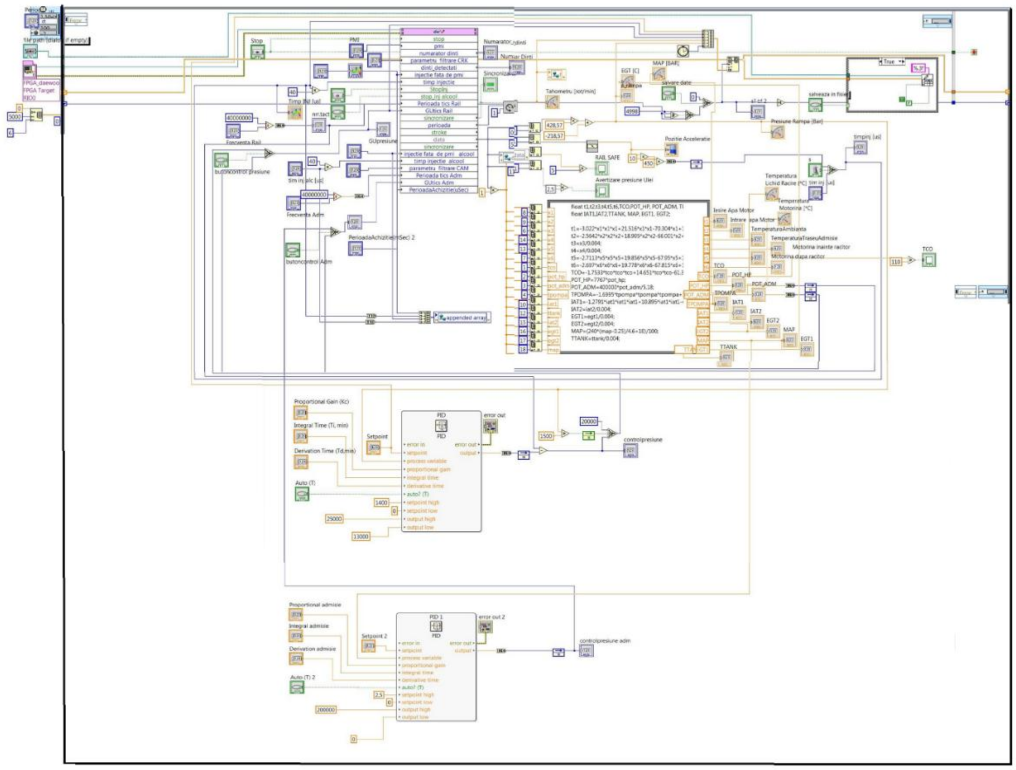

Figure 1 Overall view of the software solution

For the engine control, the injection signals produced by the control unit were amplified using injection relays with a peak and hold system, that allow the use of a high current for the rapid opening of the injectors, followed by a low holding current. These relays were specially built and use an integrated circuit LM1949 type. The input signals were also processed to obtain voltage signals that can be monitored by the control unit. The sensors used in the stand were characterized to ensure a correct reading of the measured physical values.

A calibration and characterization process that received increased attention was the calibration of the fuel consumption measurement system, a system developed specifically for the experimental stand. This consumption measurement system monitors the mass of fuel at fixed time intervals and reports the consumption between these intervals. The system uses an Arduino microcontroller for this monitoring. The calibration was performed by using standard weights and measuring the value reported by the microcontroller, subsequently generating a calculation formula for the real weight inside the microcontroller.

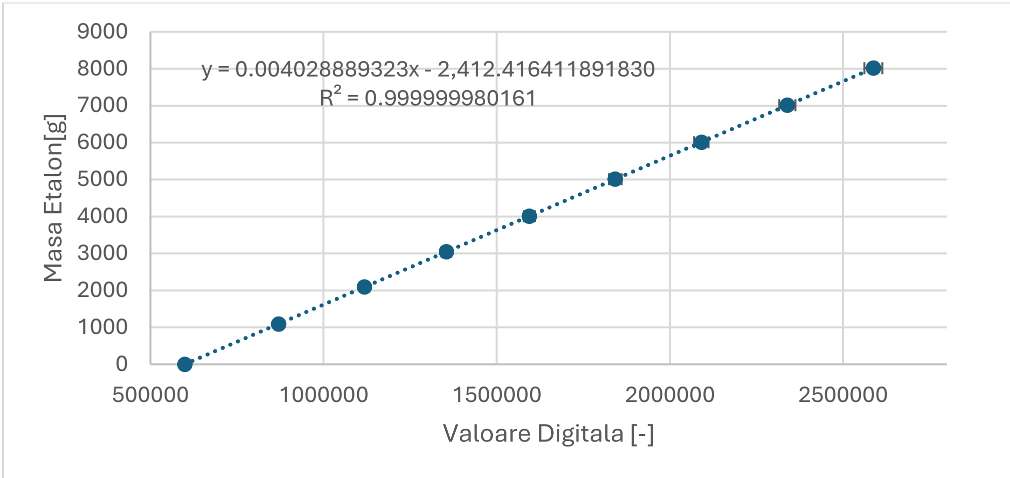

Figure 2 Characteristic curve of scales for determining fuel consumption

Chapter 3 Experimental results, analysis and discussions

Chapter three is structured in a series of subchapters, chapter begins by presenting the operating modes and how they were chosen based on certain preliminary measurements, decisions based on the operation of the vehicle equipped with the chosen engine but also limitations of the experimental stand. For this thesis 3 load values were chosen: 17, 19 and 22 kW. For each of these loads, the diesel injection timing was adjusted from 12.5 to -2.5 ^{0}BTDC in 7 steps. Once dual injections were activated, 5 settings for the injection time of the secondary injectors were also used for each of these measurement points.

Also in this chapter, the accuracy of the measurements obtained with diesel is evaluated, the results being evaluated in comparison with the specialized literature in the field. The source of information used also allowed for a better evaluation of the results obtained with dual fuel. The results obtained with diesel are comparable with the ones observations in the specialized literature, an example of this can be seen in Figure 4, where nitrogen oxides emissions decrease with load and with the reduction of the advance, just as the specialized literature specifies.

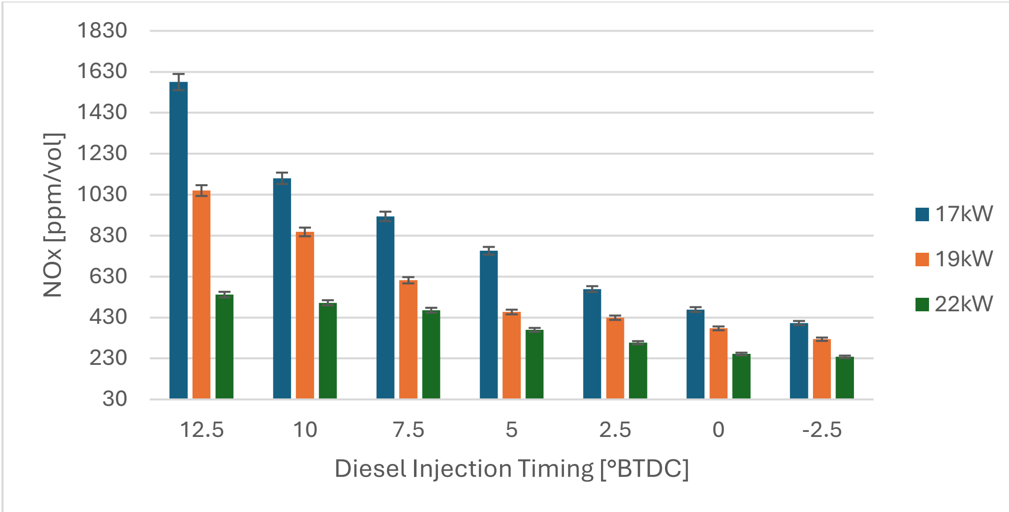

Figure 3 NOx emissions as a function of diesel injection advance, and as a function of load, for diesel operation, at a engine speed of 1819±13 rpm and loads of 17.2±0.34kW; 19.8±0.17kW; 22.4±0.14kW

Once the results of dual fuel operation were evaluated for each secondary fuel separately, it was concluded that the best advance for these regimes is in the region of 5-10 ^{0}BTDC, the comparative analysis of the secondary fuels being focused on this range. After the collective comparison of all secondary fuels, it was concluded that each secondary fuel has advantages and disadvantages, and engine operating parameters must be adjusted to obtain the best results.

The chapter concludes by presenting the main benefits that can be obtained from the use of secondary fuels, how we can optimize their use to achieve the improvement of a certain parameter as well as the impact it has on other factors of interest. The main benefits are presented in the following figures: Figure 5 shows the maximum substitution ratio of diesel with alcohol depending on its concentration; Figure 6 shows the maximum efficiency that we can obtain when operating the engine with secondary fuel, in which case we observe that we can exceed the efficiency obtained with diesel in multiple cases; Figure 7 shows the minimum level of NOx that we can obtain using dual fuel, in which case we observe that we can easily reach a threshold much lower that the one observed with diesel.

The conclusion of this chapter shows that the use of dual fuel allows both increasing efficiency and reducing polluting emissions, without affecting other important engine parameters as long as operating parameters are well chosen.

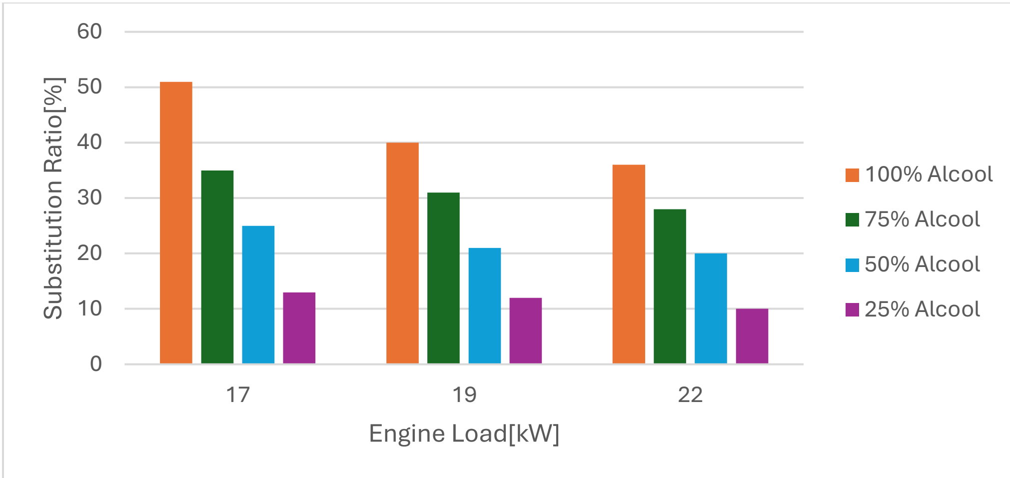

Figure 4 Maximum substitution ratio depending on load and type of secondary fuel used

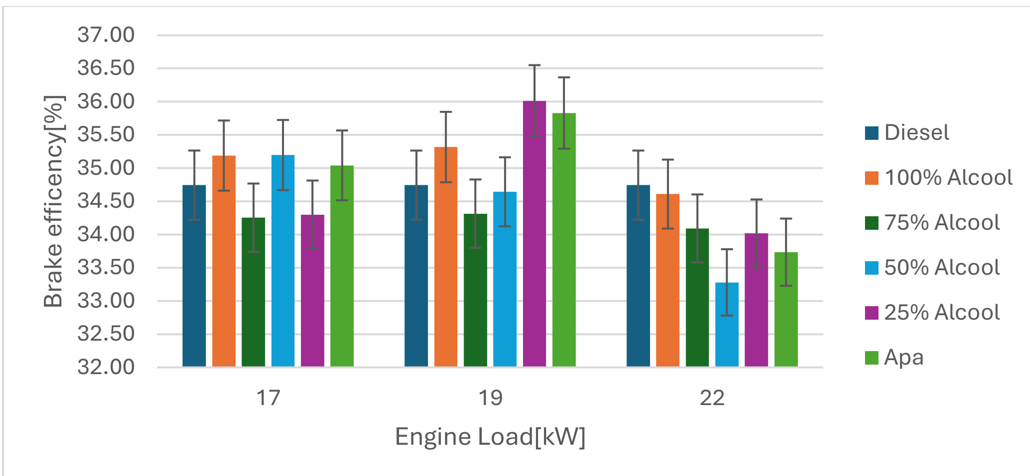

Figure 5 Variation of brake efficiency, depending on the load and the secondary fuel used, to obtain the maximum efficiency of each secondary fuel-load combination

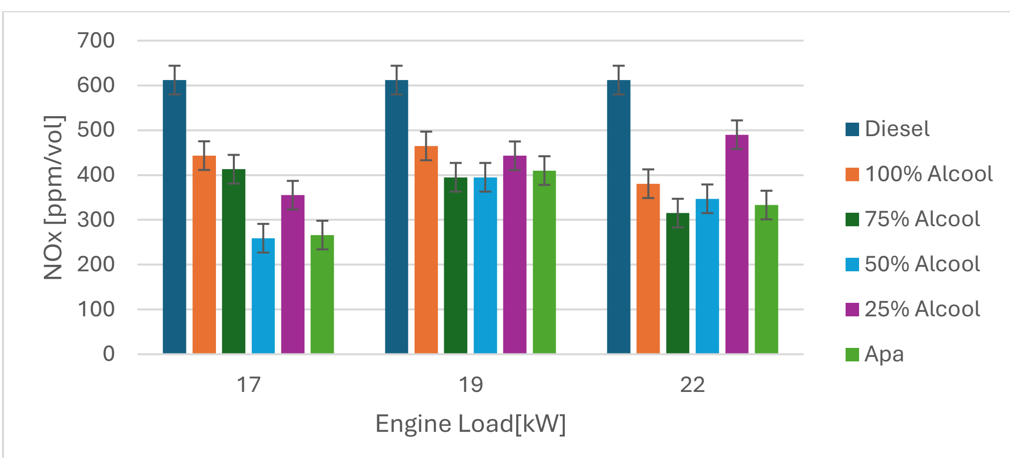

Figure 6 Variation of NOx emissions, depending on the load and the secondary fuel used, to obtain the minimum NOx level of each secondary fuel load combination

Chapter 4 Conclusions and personal contributions

The last chapter summarizes the information from the first chapters, and concisely summarizes the results obtained, but also presents the author's contributions.

Personal contributions:

- **- Development and construction of the diesel engine experimental stand,** the author built the test bench and the auxiliary systems used for its operation and for measurements.
- **- Establishing operating regimes, establishing the research plan and carrying out experimental measurements,** the author established the operating regimes, carried out the experimental measurements according to the established test plan and processed the data obtained after the measurements.
- **- Analysis of experimental results,** the author analyzed the results, drew the relevant graphs and presented the results obtained in the text.

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