Politehnica University of Timișoara

Summary of the PhD Thesis

The water injection analysis inside the cylinder of the spark ignition internal combustion engine

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Introduction

The thesis analyses the impact of water injection on the performance and emissions of a spark-ignition internal combustion engine. The use of water injection is proposed as a method for reducing NOx emissions and improving thermal efficiency, thus addressing the increasingly stringent international regulations regarding pollutant emissions and fuel efficiency.

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Chapter 1: Current State of Research

1.1 Introduction

This chapter provides a detailed review of the literature on water injection techniques and their effects on internal combustion engines. The current context of emission regulations and modern engine design trends are discussed.

1.2 Emissions and Knock Combustion

The impact of knocking on engine performance and traditional methods of preventing it, as well as the effects of NOx emissions and strategies for reducing them, including the use of biofuels and exhaust gas recirculation (EGR) techniques, are analysed.

1.3 Water Injection Techniques

Various methods of implementing water injection, such as single-point injection in the intake manifold, multi-point injection at the valve port, and direct cylinder injection, are presented. Each method is evaluated based on the efficiency of water evaporation and its impact on the air-fuel mixture distribution.

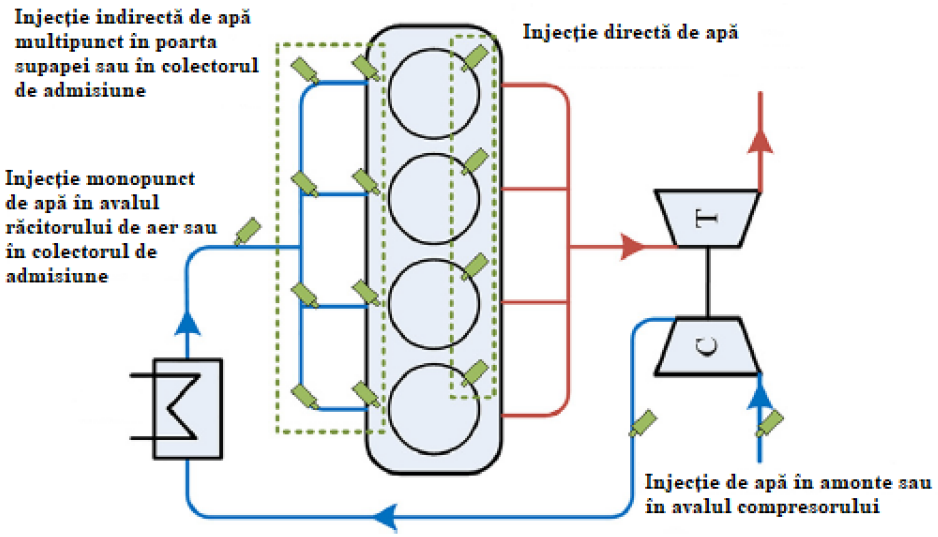

Figure 1.1 Possible Locations for Water Injectors

1.4 Conclusions of the Current State Research

The analysis of published works in the field of water injection indicates several advantages for spark-ignition internal combustion engines with in-cylinder water injection:

- Increased compression ratio.
- Increased boost pressure.
- Increased spark advance.
- Suppression of knocking.
- Reduction of NOx emissions.

For compression ignition internal combustion engines, the findings are slightly different:

- Reduction in NOx formation.
- The timing and location of water injection are crucial for combustion quality.

Most studies report the ratio of water injected to fuel injected to reduce NOx emissions. The best results are obtained around 30-40% water to fuel ratio.

Chapter 2: Construction of the Experimental Test Bench

2.1 Introduction

This chapter details the construction of the experimental stand used for testing water injection. The stand includes various essential components for measuring and controlling engine parameters.

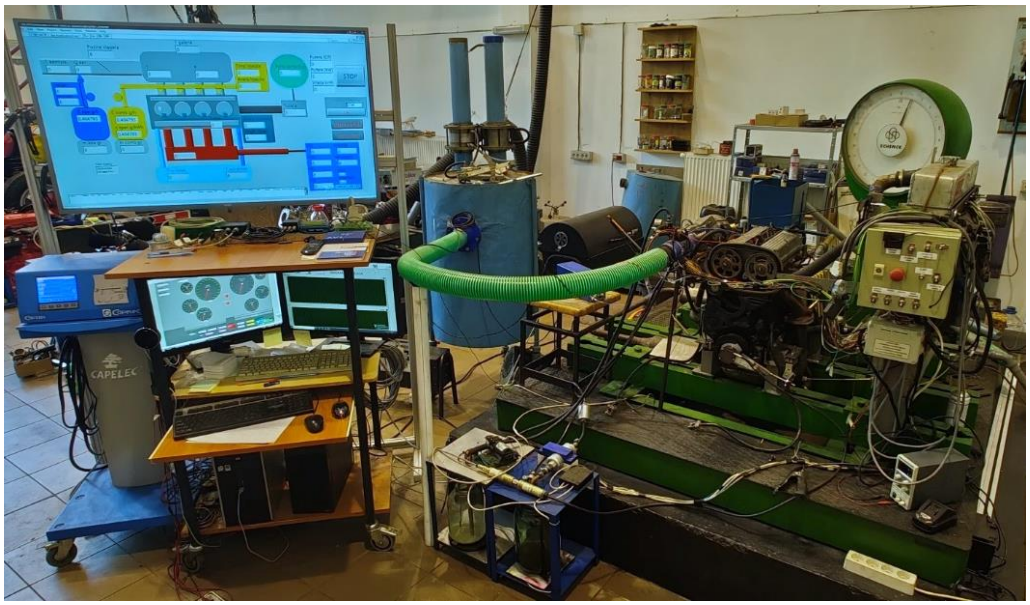

Figure 2.1 Internal combustion engine test bench

2.2 Experimental Test Bench

The main components of the experimental test bench, including the Daewoo A16DMS engine, test brake, and National Instruments CompactRIO data acquisition system, are described. Measurement equipment such as the CAPELEC CAP3201 gas analyser and pressure sensors are also presented.

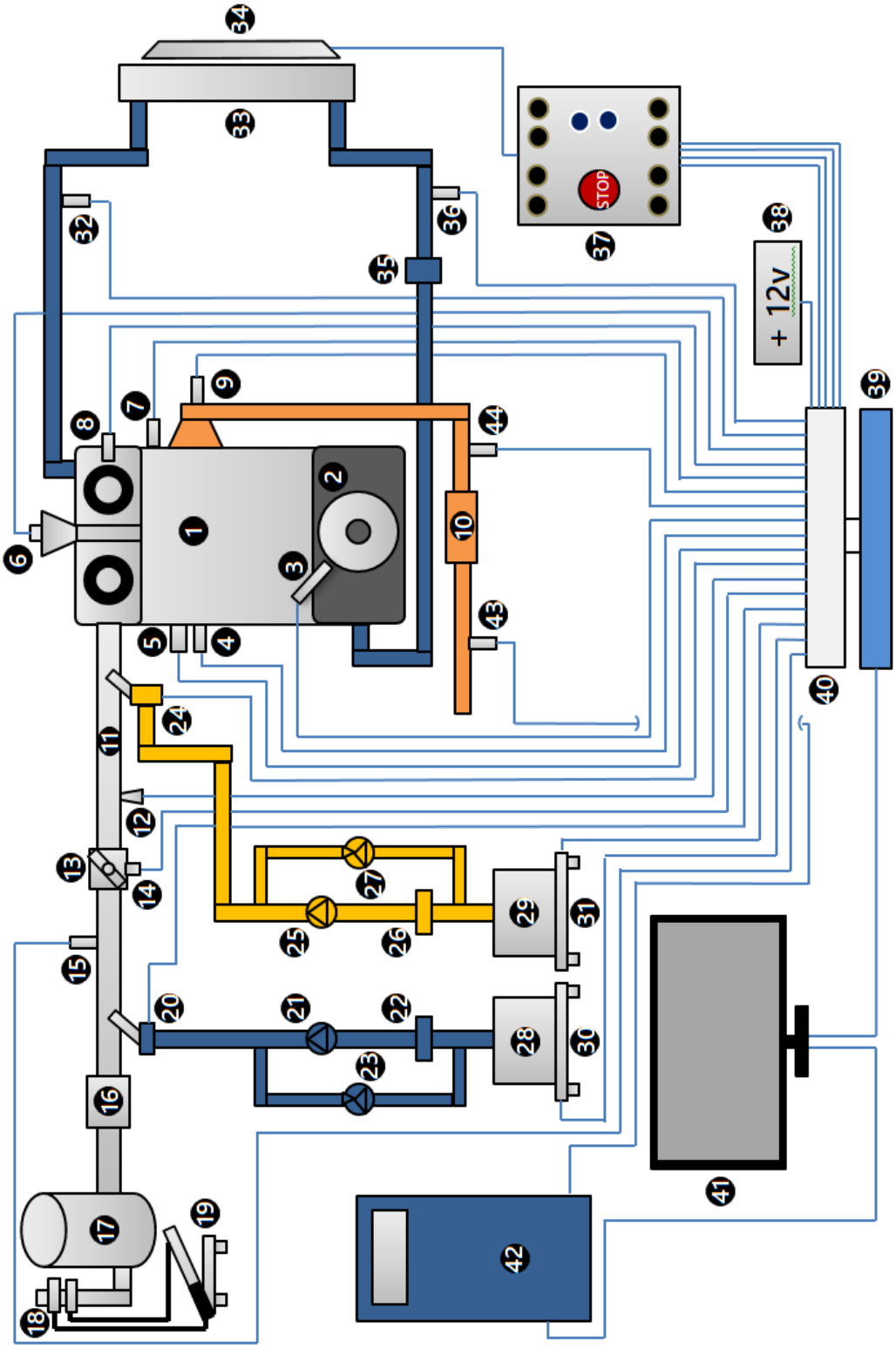

Figure 2.2 Diagram block view of the test bench – front view

Chapter 3: Characterizing Normal Engine Operation

3.1 Ignition and Fuel Supply System

This chapter focuses on the engine's operation without water injection, analysing essential operating parameters such as spark advance and optimal injector opening times.

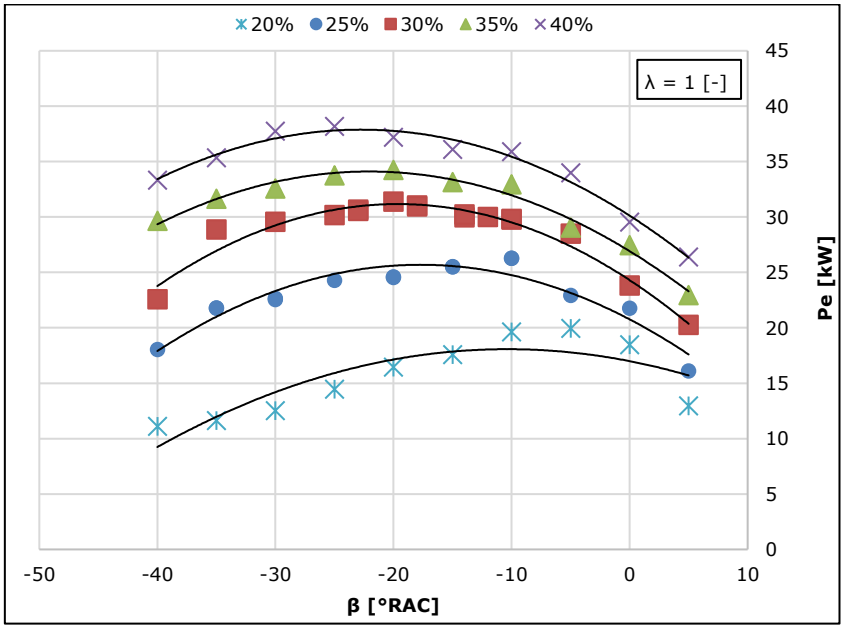

Figure 3.1 Advance Curves for Different Loads at 2400 RPM

3.2 Experimental Investigation of Normal Combustion

The experimental results regarding normal combustion, including pressure diagrams and performance parameters, are presented. Pollutant emissions resulting from normal combustion, such as hydrocarbons (HC) and NOx, are also analysed.

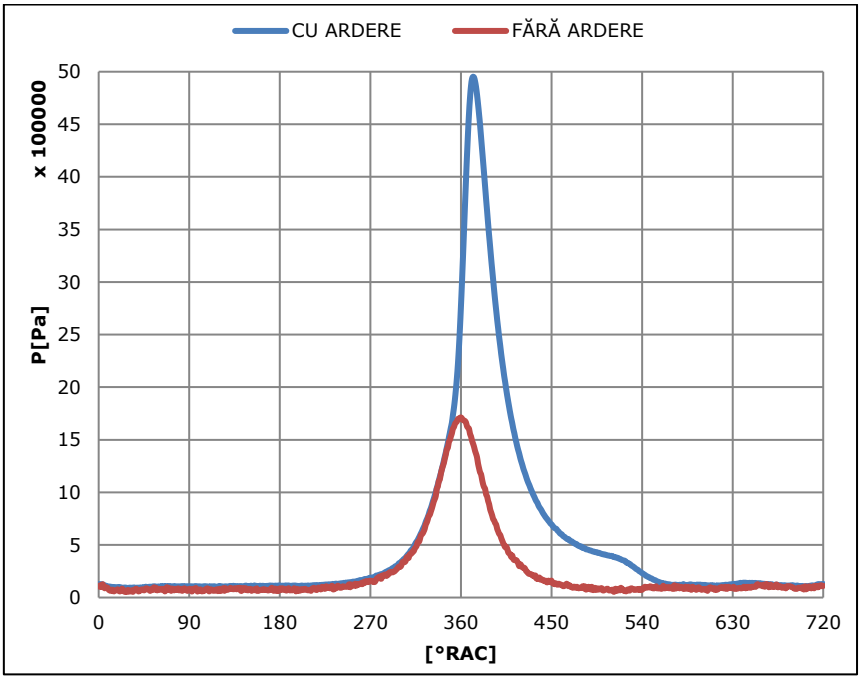

Figure 3.2 Indicated Diagram at 25% Load at 2400 RPM

Chapter 4: Characterizing Engine Operation with Water Injection

4.1 Water Injection System Operation

The implementation of the water injection system and its dosing, as well as the effects of water injection on cylinder pressure and temperature, are discussed.

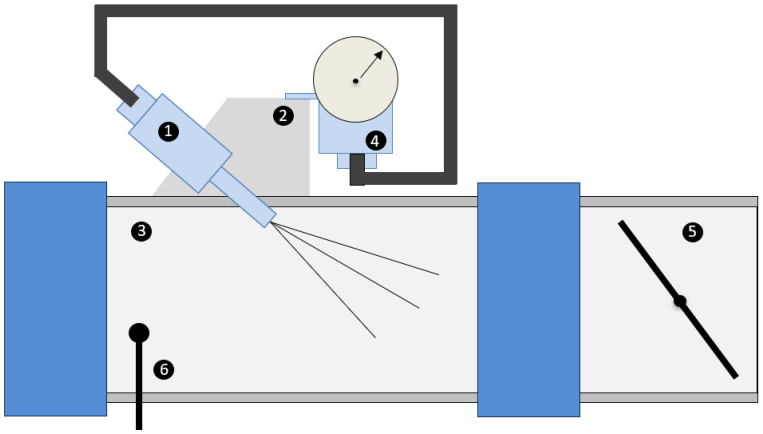

Figure 4.1 Schematic principle of the water injection system

4.2 Experimental Investigation of Combustion with Water Injection

Experimental results show that water injection significantly reduces NOx emissions and improves combustion efficiency. Indicated diagrams for various loads and speeds are presented, highlighting the impact of different water-fuel ratios on the combustion process.

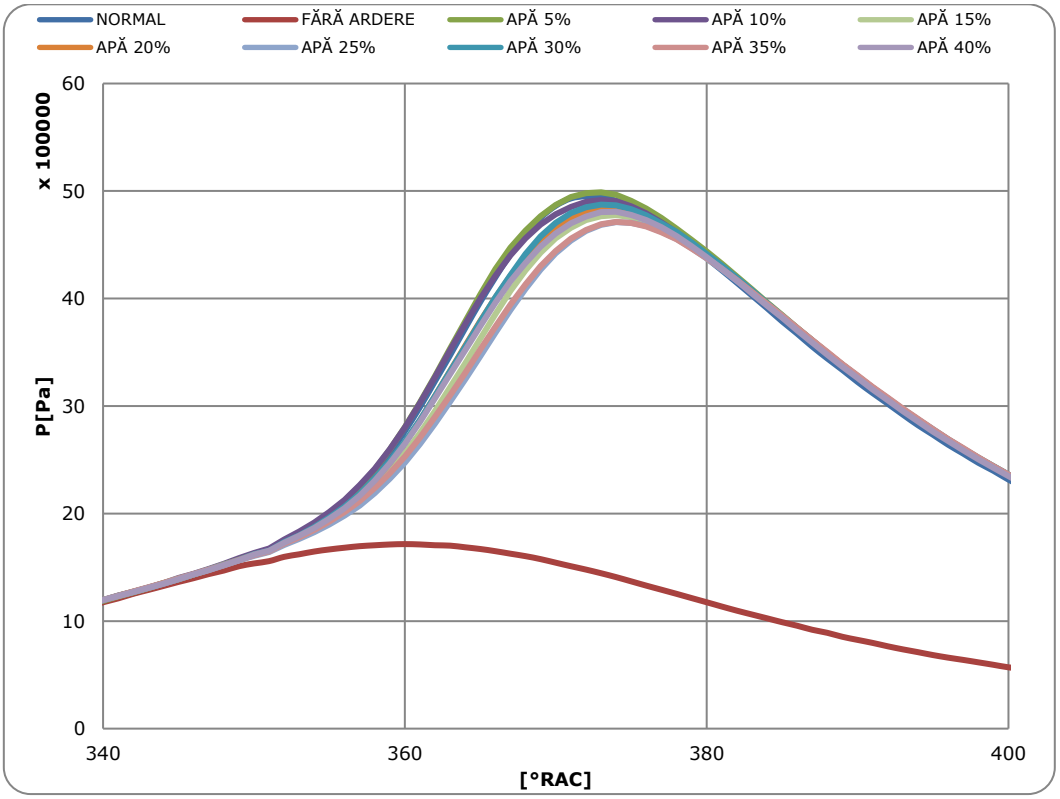

Figure 4.2 Indicated Diagrams at 25% Load at 2400 RPM with Water Injection

4.3 Experimental Investigation of Emissions with Water Injection

The impact of water injection on pollutant emissions, including NOx, HC, and CO, is analysed. Results indicate that water injection can reduce NOx emissions by up to 40% under certain operating conditions.

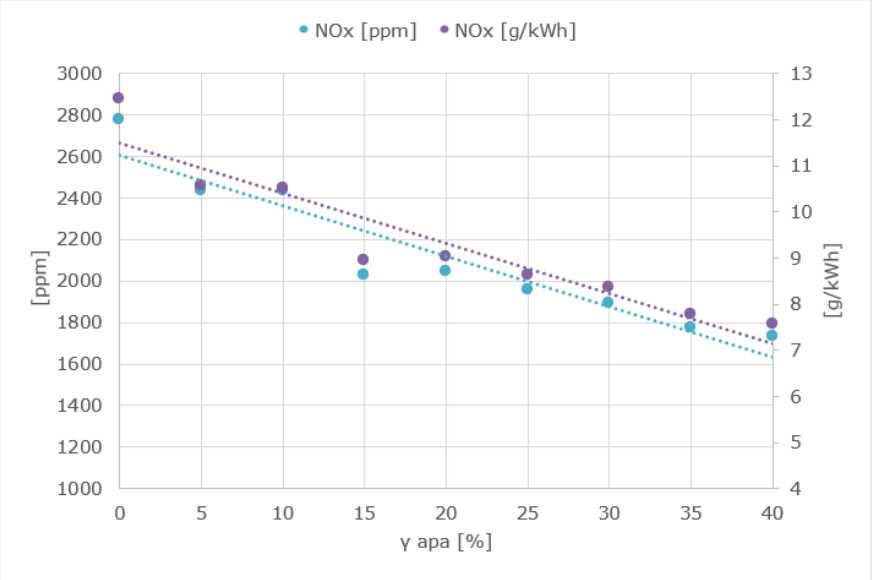

Figure 4.3 NO_x Emission Variation at 25% Load at 2400 RPM with Water Injection

Chapter 5: Conclusions and Personal Contributions

5.1 Conclusions

The thesis concludes that water injection in spark-ignition internal combustion engines is an effective method for reducing emissions and improving thermal efficiency. The need for further research to optimize water injection and evaporation processes is emphasized.

5.2 Personal Contributions

Development of the Experimental Stand: The author created an innovative testing stand that allows detailed testing of water injection under various operating conditions.

Testing Methodology: A rigorous testing methodology was implemented, including optimal parameters for water injection quantity and timing.

Detailed Combustion Analysis: The author conducted a detailed experimental analysis of combustion processes in the presence of injected water, contributing to a deeper understanding of this technique's impact on engine performance.

Injection System Optimization: A precise control strategy for water injection was developed, contributing to improved performance and reduced emissions.

Impact Evaluation: Qualitative and quantitative evaluations of the impact of water injection on emissions and engine performance were published and presented in specialized journals and conferences.

General Conclusion

The thesis makes a significant contribution to the field of mechanical engineering by investigating water injection in spark-ignition internal combustion engines in detail. The results provide a solid foundation for future research and the development of innovative solutions for emission reduction and efficiency improvement in modern engines.

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