Title:

Experimental study of neat Hydrotreated Vegetable Oil (HVO) as an alternative fuel in light duty internal combustion engines

Abstract

The current PhD dissertation is a report of a comprehensive investigation on the use of Neat Hydrotreated Vegetable Oil (HVO) as an alternative fuel in light-duty internal combustion engines (ICEs). HVO, a second-generation biofuel, offers promising properties such as lower carbon footprints to address the growing need for sustainable and environmentally friendly fuels in the transportation sector.

The thesis begins with an extensive review of the existing literature on HVO and its application in internal combustion engines. This review highlights the current state of research, identifying gaps and opportunities for further investigation.

In the second chapter, the aim of this research activity as well as the methodology is described in detail, providing a clear roadmap for the experimental campaign. The case study focuses on a specific light-duty diesel engine, chosen for its relevance to current automotive standards. The methodology encompasses the sequence of the steps planned for conducting the experiments, and the procedures for data collection and analysis.

Chapter three delves into the experimental setup, describing the equipment and instrumentation used in the study. This includes the engine test bench, fuel injection system, and various instruments for measuring spray characteristics, combustion parameters, and emissions. The setup is designed to simulate real-world operating conditions, ensuring the relevance and applicability of the results.

The fourth chapter, Results and Discussion, presents a thorough analysis of the experimental findings, structured on several key topics. First, the hydraulic behavior of HVO injection is examined, highlighting differences in injection flow rates and injected energy content compared to conventional diesel fuel. Next, the microscopic and macroscopic characteristics of HVO spray are investigated using advanced imaging techniques. The results demonstrate that the main spray characteristics (penetration, cone angle, spray structure, SMD) of HVO closely match diesel ones. The latter was continued with a fundamental investigation of HVO combustion within a LD engine with a methodology whose key feature is the adoption of a single injection strategy in all the injection and combustion tests so to fully understand the impact of HVO characteristics on injection and combustion processes, as well as on the interactions between the two, eliminating the effects of pilot and post injections as well as the impact of engine calibration.

The thesis then explores the steady-state part-load and full-load performance of the engine fuelled with HVO, in a drop-in scenario (adopting the engine base calibration). Various engine operating parameters, as well as ECU parameters and emissions are compared to those of diesel. The results accentuate the capability of HVO to be used as a drop-in fuel, indicating comparable or in terms of emissions, even superior performance to market diesel.

In addition, the engine's transient operation as well as its cold performance with HVO are evaluated, showing the potentials of HVO in maintain its achieved advantages of steady-state points in transient operation, and its capability to provide high-quality ignition and reliable operation at cold conditions.

In the subsequent step, the potential for recalibrating a Euro 6 light-duty diesel engine to optimize its performance with HVO under various conditions and combustion modes was evaluated using multiple data sets obtained through a DOE approach. The study reveals that HVO can be effectively integrated into current engine management systems, offering only marginal room for further recalibration to enhance engine performance and emission outcomes.

Finally, this research activity addresses the characterization of particulate matter (PM) emissions from HVO combustion. Advanced analytical techniques are used to assess the size, number and mass properties of particles emitted. The findings suggest that HVO produces lower PM emissions compared to diesel, contributing to improved air quality, and reduced environmental impact, however with higher rates of Ultra-fine particles.

This research activity demonstrates that Neat Hydrotreated Vegetable Oil is one of the most viable alternative to conventional diesel fuel in light-duty internal combustion engines for the current fleet. It further elucidates the HVO benefits in drastically reducing GHG emissions on a WTW basis. The comprehensive experimental investigations provide valuable insights into the fuel's hydraulic behavior, spray characteristics, combustion dynamics, cold/hot and steady-state/transient operation, and overall engine performance, underscoring the potential of HVO to support the transition to more sustainable solutions in the transportation sector.