Study of Hydrogen Fumigation in Compression Ignition Engine

A THESIS

submitted by

Priybrat Sharma (Roll No. S13012)

for the award of the degree

of

MASTER OF SCIENCE

(by Research)

School of Engineering

INDIAN INSTITUTE OF TECHNOLOGY MANDI

JULY 2017

INDIAN INSTITUTE OF TECHNOLOGY MANDI
MANDI- 175 005 (H.P.), INDIA
www.iitmandi.ac.in

DECLARATION BY THE RESEARCH SCHOLAR

This is to certify that the Thesis entitled **"Study of Hydrogen Fumigation in a Compression Ignition Engine",** submitted by me to the Indian Institute of Technology Mandi for the award of the Degree of **Master of Science (by research),** is a bonafide record of research work carried out by me at the School of Engineering, Indian Institute of Technology Mandi, under the supervision of ***Dr Atul Dhar***. The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

I.I.T. Mandi (H.P.)

Date:

Signature:

Priybrat Sharma

DECLARATION BY THE RESEARCH ADVISOR

This is to certify that the Thesis entitled **"Study of Hydrogen Fumigation in a Compression Ignition Engine",** submitted by ***Priybrat Sharma*** to the Indian Institute of Technology Mandi for the award of the Degree of **Master of Science (by research)**, is a bonafide record of research work carried out by him under my supervision at the School of Engineering, Indian Institute of Technology Mandi. The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

Signature:

Dr Atul Dhar
Assistant Professor
School of Engineering
IIT Mandi

Date: 26 July 2017

ACKNOWLEDGMENTS

Foremost, my deepest gratitude is extended to my advisor Dr Atul Dhar for the continuous support of my M.S. study and related research, for his patience, motivation, enthusiasm, and immense knowledge. Without this aid and enlightenment, it would not have been possible for me to complete this study, especially when I was baffled by the complexity and diversity of the field.

Besides my advisor, I would like to thank the rest of my thesis committee: Dr C.S. Yadav, Dr Rahul Vaish, Dr P. Anil Kishan and Dr Sunny Zafar, for their insightful comments and encouragement, but also for the hard question which incented me to widen my research from various perspectives.

I would like to express my appreciation to the machinists and technicians in the Mechanical Workshop especially Mr R.S. Raghav and Mr Ankush Kapil, for their assistance in the fabrication of equipment, for dual fuel conversion and for instrumentation of the test setup.

Special thanks to my fellow lab mates at Renewable Fuels and Internal Combustion Engines Lab: Punit Bansal and Sarthak Nag, for the stimulating discussions, for invaluable support in the assembly of the setup and experimentation, and for all the fun we have had during the course of my M.S. program. Also, I thank Ajay Bhardwaj, Sumeet Sharma, Vishrut Shah, Abhishek Banagunde, Tushar Kant Swain, and Gaurav Tripathi, with whom I shared a large part of my stay here at IIT Mandi, for sharing their valuable time and enlivening moments.

Finally, my inexpressible debt is to my parents, who provided me with unfailing love, support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Priybrat Sharma

ABSTRACT

Transportation sector consumes 63 % of the oil extracted worldwide and produces 22 % of the total global greenhouse gas (GHG) emissions. The rapacious growth of transport sector in last few decades has made it a front line source of air pollution. Dual fuel and advanced combustion technologies are being extensively researched for meeting the emission norms. Additionally, such technologies coupled with an alternative fuel not only reduce the emissions but also deflate the energy dependency on fossil fuels. Among such alternative fuels, hydrogen is particularly attractive due to its extremely clean combustion properties, yet remains relatively unexplored.

The thesis focuses on

- Experimental study of combustion, performance, regulated and unregulated emissions from hydrogen diesel dual fuel internal combustion engine.
- Numerical study of effects of compression ratio and injection timing variation on combustion performance and emissions of a hydrogen-diesel dual fuel compression ignition engine.
- Assessment of combustion performance of neat hydrogen operated CI engine under HCCI mode using stochastic zero-dimensional numerical model.

Experiments have been conducted at Renewable Fuels and Internal Combustion Engine Laboratory, IIT Mandi on an in-house designed and constructed dual fuel CI engine test setup. The experiments were performed at 25, 50 and 75 % engine load with a timed manifold injection of hydrogen. Hydrogen energy substitution is varied as 5, 10 and 20 %. LabView codes have been developed to acquire and analyse the data of combustion and engine performance. Cycle to cycle variability of dual fuel engine is studied. Other than regulated emissions, unregulated hazardous air pollutants (HAPs) such as formaldehyde, acetaldehyde, ethylene, propylene and aromatic hydrocarbons along with NO_x components are the focus of study.

Using convergeCFD software integrated with the LLNL combustion chemistry solver, full load combustion performance and emissions of hydrogen diesel dual fuel engine under full load are evaluated. Engine performance at compression ratio of 14.5, 16.5 and 19.5 along with pilot diesel fuel injection timings variation are assessed. The study accesses the possibility of stable engine combustion at high levels of hydrogen substitution. For exploration of possibility towards operating a CI engine on neat

hydrogen, the 0-D model is developed using Cantera (Open-Source combustion chemistry Solver) to predict combustion behaviour in an H_2HCCI engine.

KEYWORDS

Compression Ignition, HCCI, Dual Fuel, Hydrogen Fuel, Low-Temperature Combustion, Regulated Emissions, Unregulated Emissions, Particulate Matter, Particle Number, Engine CFD Simulation, Engine Zero-Dimensional Simulations, Chemical Kinetics.

TABLE OF CONTENTS