UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Investigating eco-driving technology to reduce fuel consumption and emissions by using an on-board safety device in diesel commercial vehicles in Hong Kong

by Ng Cheuk Yin, Elvin

Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

under the supervision of Dr Nic Surawski, Professor Guang Hong and Professor John Zhou.

University of Technology Sydney
Faculty of Engineering and Information Technology

Oct 2022

Certificate of Original Authorship

I, Ng Cheuk Yin, Elvin, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Civil and Environmental Engineering of Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Signature: Production Note:
Signature removed prior to publication.

Date: 24 October 2022

Acknowledgements

To pursue a doctoral degree could be a long and challenging journey. This journey becomes a reality with the kind support and help of many individuals. I would like to extend my sincere thanks to the following wonderful people who made this journey fruitful and enjoyable.

First of all, I would like to express my deep gratitude to my principal supervisor, Dr. Nic Surawski. I have learned many things since I became Dr Surawski's student. He invested numerous efforts in supervising me and spends vary much time instructing me how to prepare a paper, search literature and perform data analysis. Without his guidance and persistent help this dissertation would not have been possible. I am also grateful to my co-supervisors Professor Guang Hong and Professor John Zhou who giving me opportunity to do research and providing invaluable guidance throughout this research. Their vision, sincerity and motivation have deeply inspired me. They have taught me the methodology to carry out the research. It was a great honor to work and study under their guidance.

I really appreciate Dr. Yuhan Huang for your time and assistance in the experiments. I would like to thank him for helping and supporting me and specially for being always available when I needed something.

This study was sponsored by the industry doctorate degree program between UTS and VTC. The funding provided by the Vocational Training Council of Hong Kong is gratefully appreciated.

Contents

List of Publications

Journal articles

[1] **Elvin C.Y. Ng**, Y. Huang, G. Hong, et al. Reducing vehicle fuel consumption and exhaust emissions from the application of a green-safety device under real driving. Science of the Total Environment 2021; 793: 148602. (IF=7.963, SJR Q1)

[2] Y. Huang, **Elvin C.Y. Ng**, Nic C. Surawski, et al. Effect of diesel particulate filter regeneration on fuel consumption and emissions performance under real-driving conditions. Fuel 2022; 320: 123937. (IF=6.609, SJR Q1)

[3] Y. Huang, **Elvin C.Y. Ng**, J. Zhou, et al. Impact of drivers on real-driving fuel consumption and emissions performance. Science of the Total Environment 2021; 798: 149297. (IF=7.963, SJR Q1)

[4] Y. Huang, **Elvin C.Y. Ng**, J. Zhou, et al. Eco-driving technology for sustainable road transport: A review. Renewable & Sustainable Energy Reviews 2018; 93: 596-609. (IF=14.982, SJR Q1)

Conference proceedings

[5] **Elvin C.Y. Ng**, Y. Huang, G. Hong, et al. Effects of an on-board safety device on the emissions and fuel consumption of a light duty vehicle. SAE conference paper - International Powertrains, Fuels & Lubricants Meeting 2018; 2018-01-1821. (SIR Q2)

[6] **Elvin C.Y. Ng**, Eco-driving - Fuel Saving Techniques, Eco-driving Seminar (Hong Kong SAR Environmental Protection Department), Invited talk, 19th of Jan 2018.

Other publications arising from this thesis

[7] Y. Huang, **Elvin C.Y. Ng**, Nic C. Surawski, et al. Large eddy simulation of vehicle emissions dispersion: Implications for on-road remote sensing measurements. Environmental Pollution 2020; 259: 113974. (IF=8.071, SJR Q1)

[8] Y. Huang, **Elvin C.Y. Ng**, Y.S. Yam, et al. Impact of potential engine malfunctions on fuel consumption and gaseous emissions of a Euro VI diesel truck. Energy Conversion and Management 2019; 184: 521-529. (IF=9.709, SJR Q1)

Successful grants

[9] **Elvin C.Y. Ng (Principal Investigator)**, Y. Huang and Eddy F.C. Chan. Evaluation of eco-driving technology for reducing fuel consumption and emissions. Environment and Conservation Fund (Project No.: ECF Project 56/2018), HK$496,193, (Completed in 2021).

List of Tables

List of Figures

Definitions and Abbreviations

Acronyms

CAN	Control Area Network
CMOS	Complementary Metal-Oxide-Semiconductor
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DCV	Diesel Commercial Vehicle
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECU	Engine Control Unit
EEA	European Environment Agency
EGR	Exhaust Gas Recirculation
FID	Flame Ionization Detector
GHG	Greenhouse Gas
GPS	Global Positioning System
HC	Hydrocarbons
HGV	Heavy Goods Vehicle

HKEPD	Hong Kong Environmental Protection Department
HKSAR	Hong Kong Special Administrative Region
ICE	Internal Combustion Engine
JCEC	Jockey Club Heavy Vehicle Emissions Testing and Research Centre
LGV	Light Goods Vehicle
LPG	Liquefied Petroleum Gas
MGV	Medium Goods Vehicle
MPA	Mean Positive Acceleration
MANOVA	Multivariate Analysis of Variance
NDIR	Non-dispersive Infra-red
NDUV	Non-dispersive Ultra-violet
NEDC	New European Driving Cycle
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
O_2	Oxygen
OBD	On-Board Diagnostics

PEMS	Portable Emissions Measurement System
PM	Particulate Matter
UNFCCC	United Nations Framework Convention on Climate Change
USDoE	United States Department of Energy
RDE	Real-Driving Emissions
RPA	Relative Positive Acceleration
RSP	Respirable Suspended Particulates
SCR	Selective Catalytic Reduction
THC	Total Hydrocarbons
VSP	Vehicle Specific Power
WLTC	Worldwide Harmonized Light Vehicles Test Cycle

Symbols

VSP_{LGV}	Vehicle specific power of LGVs
VSP_{MGV}	Vehicle specific power of MGVs
v	Vehicle velocity
a	Instantaneous vehicle acceleration
g	Gravity
$\emptyset$	Road grade
φ_{LGV}	Coefficient of rolling resistance term for LGV
φ_{MGV}	Coefficient of rolling resistance term for MGV

Abstract

Vehicle emissions have negative impacts on climate change, air quality and human health. The driver is the last major and often overlooked factor that determines vehicle performance. Eco-driving is a relatively low cost and driving-behavior-based method aimed to reduce vehicle fuel consumption and emissions. In this thesis, a safety device was installed on a suite of diesel commercial vehicles to assess its eco-driving capabilities. Because the on-board safety device provided real-time feedback to the driver on their driving performance, actioning of the warnings provided from the safety device could enable not only safety benefits to be achieved but potentially reductions in fuel consumption and emissions as well. Exploring the hypothesis that a safety device can simultaneously facilitate the reduction of fuel consumption and emissions is the principal contribution of this thesis.

To investigate the effects of driving behavior on fuel consumption and gaseous emissions of diesel goods vehicles, a portable emissions measurement system was installed on three target vehicles to measure real-driving emissions. In addition, driving and environmental parameters were recorded in the experiments. The on-board safety device installed on the test vehicle was used to record the number of warnings in two separate stages of testing. In the first stage, the number of warnings were recorded while the driver implemented their natural driving style. In the second stage, the number of warnings were recorded but real-time warnings were issued to the driver to improve their driving behavior. The experimental results were evaluated using the Vehicle Specific Power methodology to understand the effects of driving behavior on