

LIST OF CONTENT

| Chapter | Page |
|--|------|
| I INTRODUCTION | 1 |
| Background | 1 |
| Purposes of the study | 4 |
| Scopes of the study | 4 |
| Limitation of the study | 5 |
| Key words | 5 |
| Benefits of the study | 5 |
| II THEORIES AND RELATED LITERATURE | 6 |
| Introduction to internal combustion engine | 6 |
| Diesel engine technology | 8 |
| Dual Fuel Engine | 11 |
| Worldwide Automobile Emission Standards | 12 |
| Fuel economy in automobiles | 18 |
| Performance Calculation | 22 |
| Emission Calculation | 27 |
| Related Literatures | 28 |
| III RESEARCH METHODOLOGY | 38 |
| Materials for the experiment | 38 |
| Testing equipment | 46 |
| Testing Procedures | 49 |
| Data Collection | 51 |
| Data Analysis | 53 |

LIST OF CONTENT (CONT.)

| Chapter | Page |
|--------------------------------|------|
| IV RESULTS | 54 |
| Performances Results | 54 |
| Emission Characteristics | 57 |
| Fuel Economy..... | 61 |
| V CONCLUSION | 62 |
| Conclusion..... | 62 |
| Recommendation..... | 63 |
| REFERENCES | 64 |
| APPENDIX | 72 |
| BIOGRAPHY | 99 |

LIST OF TABLES

| Table | | Page |
|-------|---|------|
| 1 | EURO emission standards for passenger cars (M) | 14 |
| 2 | EURO emission standards for light commercial vehicles (N1) | 14 |
| 3 | EURO emission standards for light commercial vehicles (N1-II) | 15 |
| 4 | EURO emission standards for light commercial vehicles (N1-III)..... | 15 |
| 5 | Specification of “Commonrail D4D vehicle” for this experiment..... | 39 |
| 6 | Specification of “CNG automotive cylinder” for this experiment..... | 39 |
| 7 | Specification of “CNG filling valve” for this experiment | 40 |
| 8 | Specification of “CNG reducer” for this experiment..... | 41 |
| 9 | Specification of “CNG pressure sensor” for this experiment | 42 |
| 10 | Specification of “CNG LED indicator” for this experiment..... | 43 |
| 11 | Specification of “CNG high pressure tube” for this experiment..... | 43 |
| 12 | Specification of “CNG stepping motor” for this experiment..... | 44 |
| 13 | Specification of “The electronic controlled unit” for this experiment..... | 45 |
| 14 | Specification of “Electrolyzer and its accessories” for this experiment | 46 |
| 15 | Specification of “Chassis dynamometer” for this experiment | 47 |
| 16 | Specification of “Smoke meter unit” for this experiment..... | 48 |
| 17 | Specification of “Automotive gas analyzer” for this experiment | 48 |
| 18 | Results of the first performance test on chassis dynamometer | 73 |
| 19 | Results of the second performance test on chassis dynamometer..... | 74 |
| 20 | Results of the third performance test on chassis dynamometer | 75 |
| 21 | Results of an average performance test on chassis dynamometer | 76 |
| 22 | Average sensor measurements in diesel mode..... | 77 |
| 23 | Average sensor measurements in HCNG dual fuel mode..... | 78 |
| 24 | Results of the first CO emission test..... | 79 |
| 25 | Results of the second CO emission test | 79 |
| 26 | Results of the third CO emission test..... | 80 |

LIST OF TABLES (CONT.)

| Table | | Page |
|-------|--|------|
| 27 | Average results of CO emission test | 80 |
| 28 | Results of the first HC emission test..... | 81 |
| 29 | Results of the second HC emission test | 82 |
| 30 | Results of the third HC emission test..... | 83 |
| 31 | Average results of HC emission test | 84 |
| 32 | Results of the first PM emission test..... | 85 |
| 33 | Results of the second PM emission test | 86 |
| 34 | Results of the third PM emission test..... | 87 |
| 35 | Average results of PM emission test..... | 88 |
| 36 | Results of the first NO _x emission test | 89 |
| 37 | Results of the second NO _x emission test..... | 90 |
| 38 | Results of the third NO _x emission test | 91 |
| 39 | Average results of NO _x emission test..... | 92 |
| 40 | Fuel saving measurement..... | 93 |
| 41 | Brake thermal efficiency of normal diesel and HCNG DDF | 98 |

LIST OF FIGURES

| Figures | | Page |
|---------|--|------|
| 1 | Basic four stroke processes in gasoline engine | 7 |
| 2 | Basic four stroke processes in diesel engine | 7 |
| 3 | Vehicle with Commonrail D4D engine for this experiment | 38 |
| 4 | CNG cylinder ISO11439 standard for CNG storage..... | 39 |
| 5 | CNG filling valve with NGV1 profile | 40 |
| 6 | Three stages CNG reducer for this project..... | 41 |
| 7 | CNG pressure sensor..... | 42 |
| 8 | CNG LED level indicator..... | 42 |
| 9 | CNG high pressure tube for this experiment..... | 43 |
| 10 | CNG stepping motor | 44 |
| 11 | Electronic controlled unit for the project | 44 |
| 12 | Various parts and sensor for the hydrogen generator for this project..... | 45 |
| 13 | Chassis dynamometer..... | 46 |
| 14 | Smoke detector and the measuring equipment..... | 47 |
| 15 | Gas analyzer stationary unit for this experiment..... | 48 |
| 16 | BHP comparison of Diesel Operation and Diesel with HCNG Operation..... | 55 |
| 17 | RPM versus Torques | 55 |
| 18 | CO emission in comparison between diesel and diesel with HCNG..... | 57 |
| 19 | HC emission in comparison between diesel and diesel with HCNG..... | 58 |
| 20 | NO _x emission in comparison between diesel and diesel with HCNG ... | 59 |
| 21 | PM emission in comparison between diesel and diesel with HCNG..... | 59 |
| 22 | Smoke density | 60 |
| 23 | Smoke turbidity..... | 60 |
| 24 | Fuel economy of pilot diesel in 1 liter per a kilometer | 61 |
| 25 | An overview of the connection diagram | 94 |
| 26 | An overview of the complete designed HCNG DDF system | 95 |
| 27 | Wiring diagram for the controlled unit | 96 |

LIST OF FIGURES (CONT.)

| Figures | Page |
|---|-------------|
| 28 Diesel dual fuel (DDF) ECU connection diagram..... | 97 |

ABBREVIATIONS

| | | |
|-----------------|---|--|
| HCNG | = | A mixture of hydrogen and compressed natural gas |
| DDF | = | Diesel dual fuel |
| CO | = | Carbon Monoxide |
| CO ₂ | = | Carbon Dioxide |
| HC | = | Hydro Carbon |
| PM | = | Particulate Matter |
| NO _x | = | Nitrogen Oxide |
| LHV | = | Lower heating value |
| ECU | = | Electronic controlled unit |
| LPG | = | Liquefied petroleum gas |
| CNG | = | Compressed natural gas |
| H ₂ | = | Hydrogen |
| GHG | = | Greenhouse gas |
| BSFC | = | Brake specific fuel consumption |
| HP | = | Horsepower |
| TPS | = | Throttle Body Position Sensor |
| RPM | = | Round per minute |
| IC | = | Internal combustion engine |
| SI | = | Spark ignition engine |
| BTDC | = | Bottom top dead center |
| TDC | = | Top dead center |
| C° | = | Degree Celsius |
| F° | = | Degree Fahrenheit |
| ECM | = | Electronic Controlled Management |
| CH ₄ | = | Methane |
| EPA | = | Environmental protection agency |
| CARB | = | The California Air Resources Board |
| EU | = | European Union |
| SUV | = | Sport Utility Vehicle |

ABBREVIATIONS (CONT.)

| | | |
|--------------|---|---|
| NAAQS | = | National ambient air quality standards |
| PPM | = | Part per million |
| g | = | Gram |
| km | = | Kilometer |
| mi | = | Mile |
| kW | = | Kilowatt |
| Mpg | = | Mile per gallon |
| L | = | Liter |
| h | = | Hour |
| EC | = | European Commission |
| \dot{m}_f | = | Mass flow rate in kg per hour |
| W_f | = | Actual mass of fuel in kg |
| t | = | Time consumed to burn the actual mass in second |
| Bsec | = | Brake specific energy consumption in kJ per kW per hour |
| Q_{HV} | = | Lower heating value in kJ per kg |
| FP | = | Fuel power in kW |
| η_{BTH} | = | Brake specific thermal efficiency in percentage (%) |
| BP | = | Brake power in kW |
| FP | = | Fuel power in kW |
| A/F | = | Air fuel ratio per unit of mass fuel |
| \dot{m}_a | = | Volume of air intake into the cylinder in kg/s |
| \dot{m}_f | = | Mass flow rate in kg per hour |
| SDC | = | Specific diesel consumption in gram per kilowatt per hour |
| V_d | = | Volume of diesel consumed in cubic meter, cm^3 |
| P_d | = | Specific weight of diesel in kg/l |
| p | = | Engine power in kW |
| P_f | = | Power input from fuel in kW |
| CV_d | = | Calorific value of diesel |
| f_c | = | Fuel consumed in cm^3 per hour |

ABBREVIATIONS (CONT.)

| | | |
|-----------|---|--|
| P_g | = | Power from gas in kW |
| CV_g | = | Calorific value of gas in kJ/Nm ³ |
| g_c | = | Gas consumption in Nm ³ per hour |
| ds | = | Diesel substitution |
| W_i | = | Work output |
| β | = | Density of CO ₂ in gram per ft ³ |
| \forall | = | Volume flow rate in ft ³ per minute |
| F | = | Water condensation in the sample line factor |
| dt | = | delta time in 1 second |
| Bsfc | = | Brake specific fuel consumption |