CHAPTER -1  INTRODUCTION  01

1.1 Motivation for IC Engine Research  01

1.2 Definition of HCCI Combustion  03

1.3 Parameters Influencing HCCI Combustion  05

1.3.1 Fuel Used  05

1.3.2 Homogeneous Air-Fuel Mixture Formation  05

1.3.3 Thermodynamic State and Composition of the Cylinder Charge  06

1.3.4 In-Cylinder Charge Motion  06

1.4 Comparison of HCCI Engine with Conventional CIDI and SIDI Engines  06

1.5 Benefits of HCCI Engine  09

1.6 Challenges of HCCI Engine  11

1.6.1 Controlling Initiation of Combustion  12
1.6.2 Extending the Loading Range to High Loads 12
1.6.3 Cold-Start Capability 13
1.6.4 Hydrocarbon and Carbon Monoxide Emissions 14

1.7 Structure of Thesis 14

CHAPTER-2 REVIEW OF LITERATURE 16

2.1 Introduction 16
2.2 HCCI Operation 17
   2.2.1 HCCI Engine with In-Cylinder Injection 17
   2.2.2 HCCI Engine with Inlet Manifold Injection 37
2.3 PCCI Operation 44
2.4 Diesel Engine Emissions 48
2.5 Modeling of HCCI Engine 49
   2.5.1 Single-Zone Models 50
   2.5.2 Multi-Zone Models 50
   2.5.3 PDF Models 51
   2.5.4 Cycle Simulation Codes 51
   2.5.5 Multi Dimensional CFD Models 51
2.6 Summary 52
2.7 Scope of Present Work 53
CHAPTER-3 PRODUCTION OF ETHANOL, PREPARATION OF BLENDS AND EVALUATION OF PROPERTIES 55

3.1 Introduction 55

3.2 Ethanol Production 56

3.2.1 Ethanol from Cane Molasses and other Directly Fermentable Feed Stocks 57

3.2.2 Ethanol from Starchy Material 57

3.2.3 Ethanol from Lignocellulosic Biomass 57

3.2.4 Ethanol from Industry and Urban Wastes 57

3.3 Preparation of Blends of Diesel and Ethanol 58

3.4 Blending Procedure 61

3.5 Measurement of Fuel Properties 63

3.5.1 Measurement of Density 63

3.5.2 Measurement of Kinematic Viscosity 63

3.5.3 Measurement of Cetane Number 64

3.5.4 Measurement of Calorific Value 65

3.6 Properties of Diesel and Ethanol Blends 67

3.7 Properties of Diesel and Ethanol Blends with Di-Tertiary Butyl Peroxide 69

3.8 Properties of Diesel and Ethanol Blends with Diethyl Ether 70
CHAPTER-4  EXPERIMENTAL SETUP  71

4.1 Introduction  71
4.2 Engine Test Rig  71
4.3 Modifications Required for HCCI Engine  72
4.4 Instrumentation  75
  4.4.1 Load Cell for Torque Measurement  75
  4.4.2 In-Cylinder Pressure Sensor  75
  4.4.3 Fuel Supply and Measurement  76
  4.4.4 Air Consumption Measuring System  76
  4.4.5 Speed Measurement  76
    4.4.6 Crank Angle Encoder  77
    4.4.7 Temperature Measurement  77
    4.4.8 Exhaust Gas Calorimeter  78
    4.4.9 Fuel Injection Pressure Sensor  78
    4.4.10 Exhaust Gas Analyzer  78
    4.4.11 Smokemeter  79
4.5 Data Acquisition System  80
  4.5.1 Generation of Signal  81
    4.5.2 Signal Conditioning  81
    4.5.3 Data Conversion  81
    4.5.4 Data Storage and Display  82
    4.5.5 Data Processing  82
CHAPTER-5 RESULTS AND DISCUSSION

5.1 Introduction

5.2 Investigation on HCCI Engine at Injection Timing 60° bTDC Using Diesel for Different Compression Ratios

5.2.1 Brake Thermal Efficiency
5.2.2 Exhaust Gas Temperature
5.2.3 Carbon Monoxide Emissions
5.2.4 Carbon Dioxide Emissions
5.2.5 Hydrocarbon Emissions
5.2.6 Oxides of Nitrogen
5.2.7 Smoke Density
5.2.8 In-Cylinder Pressure
5.2.9 Heat Release Rate
5.2.10 Conclusions

5.3 Investigation on HCCI Engine at Injection Timing 70° bTDC Using Diesel for Different Compression Ratios

5.3.1 Brake Thermal Efficiency
5.3.2 Exhaust Gas Temperature
5.3.3 Carbon Monoxide Emissions 100
5.3.4 Carbon Dioxide Emissions 100
5.3.5 Hydrocarbon Emissions 100
5.3.6 Oxides of Nitrogen 101
5.3.7 Smoke Density 101
5.3.8 In-Cylinder Pressure 101
5.3.9 Heat Release Rate 102
5.3.10 Conclusions 102

5.4 Investigation on HCCI Engine at Injection Timing 80° bTDC

Using Diesel for Different Compression Ratios 109
5.4.1 Brake Thermal Efficiency 109
5.4.2 Exhaust Gas Temperature 109
5.4.3 Carbon Monoxide Emissions 110
5.4.4 Carbon Dioxide Emissions 110
5.4.5 Hydrocarbon Emissions 110
5.4.6 Oxides of Nitrogen 111
5.4.7 Smoke Density 111
5.4.8 In-Cylinder Pressure 111
5.4.9 Heat Release Rate 112
5.4.10 Conclusions 112

5.5 Optimization of Injection Timing for HCCI Engine

Using Diesel 118
5.5.1 Brake Thermal Efficiency 118
5.5.2 Exhaust Gas Temperature 118
5.5.3 Carbon Monoxide Emissions 118
5.5.4 Carbon Dioxide Emissions 119
5.5.5 Hydrocarbon Emissions 119
5.5.6 Oxides of Nitrogen 119
5.5.7 Smoke Density 119
5.5.8 In-Cylinder Pressure 119
5.5.9 Heat Release Rate 120
5.5.10 Conclusions 120

5.6 Investigation on HCCI Engine Using Diesel for Different Fuel Injection Pressures 126
5.6.1 Brake Thermal Efficiency 126
5.6.2 Exhaust Gas Temperature 127
5.6.3 Carbon Monoxide Emissions 127
5.6.4 Carbon Dioxide Emissions 127
5.6.5 Hydrocarbon Emissions 127
5.6.6 Oxides of Nitrogen 128
5.6.7 Smoke Density 128
5.6.8 In-Cylinder Pressure 128
5.6.9 Heat Release Rate 129
5.6.10 Conclusions 129
5.7 Investigation on HCCI Engine Using Blends of Diesel and Ethanol

5.7.1 Brake Thermal Efficiency
5.7.2 Exhaust Gas Temperature
5.7.3 Carbon Monoxide Emissions
5.7.4 Carbon Dioxide Emissions
5.7.5 Hydrocarbon Emissions
5.7.6 Oxides of Nitrogen
5.7.7 Smoke Density
5.7.8 In-Cylinder Pressure
5.7.9 Heat Release Rate
5.7.10 Conclusions

5.8 Investigation on HCCI Engine Using Optimum Blend E30 and Di-Tertiary Butyl Peroxide (DTBP)

5.8.1 Brake Thermal Efficiency
5.8.2 Exhaust Gas Temperature
5.8.3 Carbon Monoxide Emissions
5.8.4 Carbon Dioxide Emissions
5.8.5 Hydrocarbon Emissions
5.8.6 Oxides of Nitrogen
5.8.7 Smoke Density
5.8.8 In-Cylinder Pressure
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.8.9</td>
<td>Heat Release Rate</td>
<td>150</td>
</tr>
<tr>
<td>5.8.10</td>
<td>Conclusions</td>
<td>150</td>
</tr>
<tr>
<td>5.9</td>
<td>Investigation on HCCI Engine Using Optimum Blend E30 and Diethyl Ether (DEE)</td>
<td>157</td>
</tr>
<tr>
<td>5.9.1</td>
<td>Brake Thermal Efficiency</td>
<td>158</td>
</tr>
<tr>
<td>5.9.2</td>
<td>Exhaust Gas Temperature</td>
<td>158</td>
</tr>
<tr>
<td>5.9.3</td>
<td>Carbon Monoxide Emissions</td>
<td>158</td>
</tr>
<tr>
<td>5.9.4</td>
<td>Carbon Dioxide Emissions</td>
<td>159</td>
</tr>
<tr>
<td>5.9.5</td>
<td>Hydrocarbon Emissions</td>
<td>159</td>
</tr>
<tr>
<td>5.9.6</td>
<td>Oxides of Nitrogen</td>
<td>159</td>
</tr>
<tr>
<td>5.9.7</td>
<td>Smoke Density</td>
<td>159</td>
</tr>
<tr>
<td>5.9.8</td>
<td>In-Cylinder Pressure</td>
<td>160</td>
</tr>
<tr>
<td>5.9.9</td>
<td>Heat Release Rate</td>
<td>160</td>
</tr>
<tr>
<td>5.9.10</td>
<td>Conclusions</td>
<td>160</td>
</tr>
<tr>
<td>5.10</td>
<td>Comparison between Base Engine Diesel and HCCI Engine</td>
<td>167</td>
</tr>
<tr>
<td>5.10.1</td>
<td>Brake Thermal Efficiency</td>
<td>167</td>
</tr>
<tr>
<td>5.10.2</td>
<td>Exhaust Gas Temperature</td>
<td>168</td>
</tr>
<tr>
<td>5.10.3</td>
<td>Carbon Monoxide Emissions</td>
<td>168</td>
</tr>
<tr>
<td>5.10.4</td>
<td>Carbon Dioxide Emissions</td>
<td>168</td>
</tr>
<tr>
<td>5.10.5</td>
<td>Hydrocarbon Emissions</td>
<td>168</td>
</tr>
<tr>
<td>5.10.6</td>
<td>Oxides of Nitrogen</td>
<td>169</td>
</tr>
</tbody>
</table>
CHAPTER-6 CONCLUSIONS 177

6.1 HCCI Engine Using Diesel Fuel 177

6.2 HCCI Engine Using Diesel at Optimum Conditions 178

6.3 HCCI Engine Using Blends of Diesel and Ethanol as Fuel 179

6.4 Comparison of HCCI Engine Using Blend E30 and Base Engine Diesel 180

6.5 Comparison of HCCI Engine Using Blend E30D3 and Base Engine Diesel 181

6.6 Comparison of HCCI Engine Using Blend E30DEE6 and Base Engine Diesel 182

6.7 Summary 182

6.8 Scope of Future Work 184

REFERENCES 185

APPENDICES 204

LIST OF PUBLICATIONS 213