Numerical simulation and Investigation of Producer gas based dual fuel mode SI engine performance: Parametric and Optimization study

Thesis Submitted in Partial Fulfilment

For the Award of Degree

Doctor of Philosophy

By

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I, **Priyaranjan Jena,** certify that the work embodied in this thesis is my own bona fide work carried out by me under the supervision of **Dr. J.V. Tirkey** for a period of 3 years from June 2021 to June 2024 at IIT (BHU) Varanasi. The material contained in this thesis has not been submitted for the award of any other degree. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not wilfully copied any others' work, paragraphs, text, data, results, etc. reported in journals, books, magazines, reports, dissertations, theses, etc, or available at websites and have not included them in this thesis and have not cited as my own work.

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Abbreviations

ANOVA	Analysis of Variance
BTDC	Before Top Dead-center
ABDC	After Bottom Dead-center
BDC	Bottom dead-centre
BMEP	Brake-mean effective pressure
BF	Volumetric Propane Blend fraction
BP	Brake Power
BTE	*(%)* Brake Thermal Efficiency
BSEC	*(MJ/kWh)* Brake-Specific Energy Consumption
BSFC	*(kg/kWh)* Brake-Specific Fuel Consumption
CD	Combustion duration (10V%-90V%)
CA	(^{o}) Crank angle
CR	Compression ratio
CO	*(V%)* Carbon mono-oxide: *response*
CV	*(MJ/kg)* Calorific value
COV	Coefficient of variance
ER	Equivalence ratio
FS	Flame Speed
EVO	Exhause-valve open
HHV	Higher Heating Value *(MJ/kg)*
IMEP	Indicated Mean Effective Pressure *(bars)*
ITE	Indicated Thermal Efficiency *(%)*
LIVC	*(^{o}ABDC)* Late Inlet-valve Closure

Symbol and units

a_c	Crank length *(metre)*
^{o}	Angular degree
α,θ	Crank angle
C_p	const. pres. Specific heat (*kJ/kgK*)
β	regression coefficient
C_v	const. vol. Specific heat (*kJ/kgK*)
bars	IMEP and BMEP units
MJ	Mega joules
f	Fractions (0 ~ 1)
g	Specific-Gibbs function *(kJ/kg)*
kW	Kilo watt
ρ_u	Density-unburned charge *(kg/m^3)*
L	Connecting rod length *(m)*
S_p	Mean piston speed
Φ	Fuel-air equivalence ratio
K_{1b}	Backward rate constant
T	Cylinder-Temperature *(K)*
V	Chamber volume *(m^3)*
m	Mass *(kg)*
K_{1f}	Forward rate constant
p	Product
R_j	Rate constant
R	Gas constant *(kJ/kgK)*

NO	*(V%)* Nitrogen Oxide: *response*
PP	Peak pressure *(bars)*
PG	Producer Gas
RPM	Revolutions per minute
SOI	*(º BTDC)* Start of Ignition
TDC	Top dead-centre
MBT	*(Nm)* Max. Brake-torque
TM	Thermodynamic Modelling
QDTM	Quasi-Dimensional TM
One-D	one-Dimensional modelling
Three-D	Three-Dimensional modelling
SSPG	Sewage Sludge Producer Gas
CI	Compression Ignition
SI	Spark Ignition

u'	Turbulent flame intensity
u_T	Turbulent flame speed *(m/sec)*
S_p	Mean piston speed
V	Volume *(m^3)*
V%	Percentage by volume

Suffixes

ch	Charge property
m	Unburned mixture
T	Turbulent nature
e	Equilibrium condition
p	Burned product