Optimum experimental performance analysis of Downdraft air gasifier-IC engine and simulation of some waste material gasification using Aspen Plus

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By

Deepak Kumar Singh

DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI – 221005, INDIA

Roll No-19131004 **2022**

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Dr. J.V. Tirkey

Supervisor

Department of Mechanical Engineering

IIT(BHU) Varanasi

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Date: **....................**

Place: IIT (BHU) Varanasi **(Deepak Kumar Singh)**

Table of Contents

Section	Content	Page No.
1.	**Introduction**	1-25
1.1.	Conventional waste biomass feedstock	11
1.2	Fixed bed type gasifier	14
1.2.1	Updraft Gasifier	15
1.2.2	Downdraft Gasifier	16
1.2.3	Cross draft Gasifier	18
1.3.1	Bubbling Bed Gasifier	20
1.3.2	Circulating Bed Gasifier	20
1.4	Research gap	23
1.5	Research objective	24
2.	**Literature Review**	26
3.	**Materials and Methodology**	35
3.1	Backhand Principle of Aspen plus	35
3.2	Aspen plus Modelling Approach	37
3.2.1	Property package	37
3.2.2	Assumptions	38
3.2.3	Development of ASPEN Plus model	39
3.3	Experimental Methodology	41

3.3.1	Test fuels	41
3.3.2	Experimental setup and procedure	45
3.4	Optimization Methodology	46
4	**Result and Discussions**	49
4.1.	**Numerical Simulation: Gasification of Syzygium cumini biomass**	50
4.1.1	Model Validation	53
4.1.2	Sensitivity analysis	55
4.1.3	Effect of temperature	56
4.1.4	Effect of equivalence ratio	59
4.1.5	Regression analysis	61
4.1.6	Normal probability plots	61
4.1.7	ANOVA results	62
4.1.8	Multi-objective optimization using contour and 3-D	65
4.1.9	Interaction effect of the decision variables	66
4.1.10	Interaction effect of the decision variables on the cold gas efficiency	67
4.1.11	Interaction effect of the decision variables on the higher heating value	67
4.1.12	Optimal state of decision variables	68
4.1.13	Summary of the present work	70
4.2	Numerical Simulation–Gasification of Poultry litter	72
4.2.1	Model validation	73
4.2.2	Sensitivity Analysis	74

4.2.3.	Temperature effects on syngas compositions and gasification efficiency	75
4.2.4.	Equivalence ratio (ER) effect on syngas composition and its gasification efficiency	78
4.2.5.	Moisture content (MC) effect on syngas composition and gasification efficiency.	80
4.2.6	Regression analysis	83
4.2.7	Normal probability plots	84
4.2.8	ANOVA results	85
4.2.9	Parametric impact using contour and 3-D surface plot	88
4.2.10	Simultaneous influence on the Hydrogen concentration	88
4.2.11	Simultaneous effect on efficiency	90
4.2.12	Simultaneous influence on the higher heating value	91
4.2.13	Optimal state of decision variables	93
4.2.14.	Summary of the present work	94
4.3	**Numerical simulation- Gasification of low-density polyethylene waste**	95
4.3.1	Model description	97
4.3.2	Model validation	98
4.3.3	Sensitivity Analysis	99
4.3.4.	Influence of temperature on Producer gas composition	100
4.3.5.	Influence of equivalence ratio (ER) on syngas composition	101
4.3.6.	Influence of steam/plastic on syngas composition	102
4.3.7	Influence of reactor temperature on Tar and Char production	103
4.3.8	Regression analysis	105
4.3.9	Pareto Chart	107

4.3.10	ANOVA results	108
4.3.11	Parametric impact of multiple independent parameters using 3-D surface plot	110
4.3.12	CO concentration	110
4.3.13	H_2 concentration	110
4.3.14	Cold gas efficiency	111
4.3.15	Higher heating value	111
4.3.16	Multi-objective optimization	113
4.3.17.	Summary of the present work	114
4.4	**Modelling of Steam injected Plasma Gasifier**	115
4.4.1	Model description	115
4.4.2	Model validation	117
4.4.3	Sensitivity Analysis	118
4.4.4.	Influence of temperature	118
4.4.5	Influence of equivalence ratio (ER)	122
4.4.6.	Influence of steam/biomass	124
4.4.7	Regression analysis	126
4.4.8	Normal probability plots	127
4.4.9	ANOVA results	129
4.4.10	Parametric impact using contour and 3-D surface plot	129
4.4.11	Common impact of the independent parameters on the H_2 concentration	130
4.4.12	Common impact of the independent parameters on the cold gas efficiency	130
4.4.13	Common impact of the independent parameters on the higher heating value	131

4.4.14.	Optimal state of decision variables	135
4.4.15	Summary of the present work	137
4.5	**Experimental analysis-Gasification of coconut shell**	139
4.5.1	Experimental arrangement	140
4.5.2	Experimental uncertainty	143
4.5.3	RSM Normal Probability Plots	144
4.5.4	RSM regression analysis	146
4.5.5	ANOVA analysis	147
4.5.6	Parametric impact using contour plot and 3-D surface plot	150
4.5.7	Common impact of the independent parameters on Brake Power	150
4.5.8	Common impact of the independent parameters on Brake thermal efficiency	151
4.5.9	Common impact of the independent parameters on Brake specific fuel consumption.	152
4.5.10	Common impact of the independent parameters on engine exhaust emission	153
4.5.11	Response optimizer	157
4.5.12	Summary of the present work	158
4.6	**Triple fuelled gasification utilizing Biodiesel, Diesel and Producer gas**	159
4.6.1	Experimental setup	160
4.6.2	Experimental procedure	163
4.6.3	Experimental uncertainty	165
4.6.4	Normal Probability Plots	166
4.6.5	RSM regression analysis	169
4.6.6	ANOVA assessment	172

4.6.7	Parametric impact using 3-D surface plot	175
4.6.8	Brake Power	175
4.6.9	Brake thermal efficiency	176
4.6.10	Brake specific fuel consumption.	178
4.6.11	Engine exhaust emissions	179
4.6.12	Response optimizer	183
4.6.13	Summary of the present work	184
4.7	**Experimental Investigation on the coal gasification**	186
4.7.1	Test fuels	186
4.7.2	RSM Normal Probability Plots	188
4.7.3	RSM regression analysis	188
4.7.4	Gasifier performance and diesel saving	189
4.7.5	ANOVA analysis	193
4.7.6	Parametric impact using 3D Surface plot	196
4.7.7	Common impact of the independent parameters on Brake thermal efficiency	196
4.7.8	Common impact of the independent parameters on Brake specific fuel consumption.	197
4.7.9	Common impact of the independent parameters on engine exhaust emission	198
4.7.10	Response optimizer	199
4.7.11	Summary of the present work	202
4.8	**Experimental investigation- Gasification of Syzygium cumini biomass**	203
4.8.1	Biomass characteristics	203
4.8.2	Effect of Gasifier equivalence ratio (ER) on gasification	205

	temperature	
4.8.3	Effect of Gasifier ER on fuel consumption with and without PG at different BP.	206
4.8.4	Diesel saving at different Gasifier ER and Engine load	208
4.8.5	Effect of CR on fuel consumption with and without PG at different Engine load	209
4.8.6	Diesel saving at different CR.	210
4.8.7	Effect of CR on Brake specific fuel consumption (BSFC) with and without PG.	212
4.8.8	Mass balance	213
4.8.9	Summary of the present work	214
5	**Conclusion and Future work**	216
5.1	Numerical simulation work conclusion	217
5.2	Experimental work conclusion	220
5.3	Scope for Future work	223
List of Publications		224
References		226
Appendix		235

List of Figures

Fig. No.	Title	Page No.
Fig. 1.1.	Global energy consumption (Left) and Indian energy demand in different sector (Right)	2
Fig. 1.2.	Conversion route of biomass to fuel	4
Fig. 1.3.	Schematic of the gasification process from harvesting feedstock to possible products	7
Fig. 1.4.	Line diagram of (a) Updraft (b) Downdraft and (c) Crossdraft gasifier	19
Fig. 1.5.	Schematic of Bubbling fluidized bed (Left) and circulating fluidized bed. (Right)	21
Fig. 3.1.	Schematic layout of the biomass gasification process in ASPEN PLUS	39
Fig. 3.2.	Block Diagram of ASPEN Plus simulation for the different zone of a gasifier	41
Fig. 3.3.	Schematic of the downdraft gasifier-CI engine experimental setup unit	42
Fig. 3.4.	Photograph of Downdraft gasifier experimental setup	43
Fig.3.5	Photograph of the VCR IC engine testbed in lab	44
Fig. 3.6.	Flow diagram of RSM solving methodology and CCD design	48
Fig. 4.1	Comparison of experimental and theoretical result on the syngas composition	55
Fig. 4.2.	Effect of temperature on gas compositions with ER 0.2 and biomass MC 5 wt%.	57
Fig. 4.3.	Effect of temperature on CGE and HHV	58

Fig. 4.4.	Effect of ER on gas compositions with temperature 800^0C and biomass moisture content of 5 wt%.	59
Fig. 4.5.	Effect of equivalence ratio on CGE and HHV	60
Fig. 4.6.	Normal probability plot for output responses against residuals	62
Fig. 4.7.	Response surface plots (contour (Left) and 3D (Right)) for H_2 showing the effect of Temp and ER	66
Fig. 4.8.	Response surface plots (contour and 3D) for H_2 showing the effect of Temp and ER	67
Fig. 4.9.	Response surface plots (contour and 3D) for HHV showing the effect of Temp and ER	68
Fig. 4.10.	RSM optimizer plot	69
Fig. 4.11.	Aspen plus modelling	73
Fig. 4.12.	Model validation a. Hardwood chip, b. Poultry litter pellet, c. Softwood pellet d. Rapestraw Pellet	74
Fig. 4.13	Influence of temperatures on syngas compositions for poultry litter pellets	75
Fig. 4.14.	Variation of H2/CO and GY with temperature	77
Fig. 4.15	Variation of CGE and HHV with temperature	77
Fig. 4.16.	Influence of ER on syngas compositions for poultry litter pellets	78
Fig. 4.17.	Variation of H_2/CO and GY with equivalence ratio	79
Fig. 4.18.	Variation of CGE and HHV with equivalence ratio.	80
Fig. 4.19.	Effect of Moisture Content (%) on syngas composition	80
Fig. 4.20.	Variation of H_2/CO and GY with moisture content	82
Fig. 4.21.	Variation of CGE and HHV with moisture content	82
Fig. 4.22.	Normal probability plot for output responses	85
Fig. 4.23.	Contour and surface plot of Hydrogen concentration under variable parameters	89
Fig. 4.24.	Contour and surface plot of CGE under variable parameters	90

Fig. 4.25.	Contour and surface plot of HHV under variable parameters	92
Fig. 4.26.	RSM optimizer plot	94
Fig. 4.27.	Aspen plus flowsheet for steam gasification of plastic waste	98
Fig. 4.28.	Model validation using food waste	99
Fig. 4.29	Influence of temperatures on syngas compositions for Plastic waste	100
Fig. 4.30	Influence of ER on syngas compositions for Plastic waste	102
Fig. 4.31	Influence of S/B on syngas compositions for plastic waste	103
Fig. 4.32	Variation of tar and char with varying temperature	105
Fig. 4.33.	Pareto chart for responses	107
Fig. 4.34.	Surface plot of A. CO B. H_2 C. CGE D. HHV under variable parameters	112
Fig. 4.35.	RSM optimizer plot	113
Fig. 4.36.	Aspen plus flowsheet	116
Fig. 4.37	Comparison of experimental and theoretical result on the syngas composition	117
Fig. 4.38.	Influence of temperatures on syngas compositions for Medical waste	118
Fig. 4.39	Variation of H_2/CO and GY with temperature	121
Fig. 4.40.	Variation of CGE and HHV with temperature.	121
Fig. 4.41.	Influence of ER on syngas compositions for Medical waste	122
Fig. 4.42.	Variation of H_2/CO and GY with equivalence ratio.	123
Fig. 4.43.	Variation of CGE and HHV with equivalence ratio	124
Fig. 4.44.	Influence of S/B on syngas compositions for Medical waste	125
Fig. 4.45.	Variation of H_2/CO and GY with S/B.	125
Fig. 4.46.	Variation of CGE and HHV with SBR.	126
Fig. 4.47.	Normal probability plot for output responses	128

Fig. 4.48.	Contour and surface plot of Hydrogen concentration under variable parameters	132
Fig. 4.49.	Contour and surface plot of CGE under variable parameters	133
Fig. 4.50.	Contour and surface plot of HHV under variable parameters.	134
Fig. 4.51.	RSM optimizer plot	136
Fig. 4.52.	Coconut Shell: A-supply feedstock (before gasification), B-Coconut char (after gasification)	141
Fig. 4.53.	Normal probability plots for emission characteristics	145
Fig. 4.54.	Normal probability plots for performance characteristics	145
Fig. 4.55.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on Brake power	150
Fig. 4.56.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on BTE	152
Fig. 4.57.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on BSFC	153
Fig. 4.58.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on NO_x emission.	154
Fig. 4.59.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on CO_2 emission	155
Fig. 4.60.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on UHC emission.	156
Fig. 4.61.	Simultaneous impact of Equivalence ratio, Compression ratio, and Engine load on CO emission.	156
Fig. 4.62.	RSM optimizer plot	158
Fig. 4.63	Conversion step for extracting lab-scale biodiesel from safflower seed	164
Fig. 4.64	Normal probability plots for emission parameter	168
Fig. 4.65.	Normal probability plots for performance parameter	169
Fig. 4.66.	Surface plot of BP	176

Fig. 4.67.	Surface plot of BTE	178
Fig. 4.68.	Surface plot of BSFC	179
Fig. 4.69.	Surface plots of NO_x emission.	180
Fig. 4.70.	Surface plots of CO_2 emission	181
Fig. 4.71.	Surface plots of UHC emission.	182
Fig. 4.72.	Surface plots of CO emission.	182
Fig. 4.73.	RSM optimizer plot	184
Fig. 4.74.	Sankey diagram for energy balance in gasifier.	190
Fig. 4.76.	Simulataneous impact of independent operating parameters on (a) BP, (b) BTE, (c) BSFC	197
Fig. 4.77.	Simulataneous impact of independent operating parameters on (a) NO_X (b) CO_2 (C) HC and (d) CO	199
Fig. 4.78.	RSM optimization setup	200
Fig. 4.79.	RSM optimizer plot	201
Fig. 4.80.	Temperature profile inside the reactor at different ER.	206
Fig. 4.81.	Effect of variable ER on fuel consumption with and without PG at different BP	208
Fig. 4.82.	Variation of Diesel saving at variable ER and BP	209
Fig. 4.83	Variation of fuel consumption at load with a variable CR (15, 16, 17, and 18)	211
Fig. 4.84.	Variation of diesel saving with load at a different compression ratio	211
Fig. 4.85	Brake specific fuel consumption of the engine with PG without PG at a different compression ratio	213
Fig. 4.86	Photographs of (a) Feedstock (b) Charcoal (c) Unburnt wood (d) Ash collected after the experiment	213

List of Tables

Table No.	Title	Page No.
Table. 1.1.	Comparative assessment of advanced and conventional gasification technology	9
Table 1.2.	Comprehensive Summary of raw feedstock used for gasifier	12
Table. 1.3.	Summary of installed decentralized biomass-based gasifier in India	16
Table. 1.4.	Summary of the basic differences between a bubbling and a circulating fluidized bed gasifier	21
Table.2.1	Comprehensive Summary of research progress in Downdraft Gasifier	26
Table. 3.1.	Explanation of Aspen plus operating block used for modeling	38
Table. 3.2.	The detailed specification of Gasifier	43
Table.3.3.	Technical Specifications of Engine	44
Table 4.1.	Proximate and Ultimate analysis of Syzygium cumini	52
Table 4.2.	Previous investigation vs. Present study	52
Table. 4.3.	Chemical properties of different biomass	53
Table. 4.4.	Experimental result versus Model Prediction	54
Table. 4.5	Input and response variables along with the residuals (Appendix)	242
Table. 4.6.	ANOVA result for the Cold gas efficiency	63
Table. 4.7.	RSM model assessment	64
Table 4.8.	ANOVA result for the Hydrogen concentration	64
Table 4.9.	ANOVA result for the Higher heating value	65
Table.4.10.	Chemical properties of waste Poultry litter pellets	72
Table. 4.11	Parameter settings plan along with the responses	83
Table 4.12.	ANOVA analysis for the H_2	86
Table 4.13.	ANOVA analysis for the CGE	87
Table 4.14.	ANOVA analysis for the HHV	87
Table. 4.15.	RSM model assessment	88
Table. 4.16.	Optimization setup	93
Table. 4.17.	Proximate and ultimate analysis results of LDPE	97

Table. 4.18.	Design matrix plan along with the responses	106
Table 4.19.	ANOVA analysis of CO and H_2 concentration	108
Table 4.20.	ANOVA analysis of CO and H_2 concentration	109
Table.4.21.	Chemical properties of Medical waste	116
Table. 4.22	Design matrix plan along with the responses	127
Table. 4.23	ANOVA for H_2 (Appendix)	243
Table. 4.24	ANOVA for CGE (Appendix)	243
Table. 4.25	ANOVA for HHV (Appendix)	243
Table. 4.26.	RSM model assessment	129
Table. 4.27	Comparative analysis of optimized result between Aspen plus and RSM	137
Table. 4.28	Chemical property of fuel- coconut shell	142
Table. 4.29.	Instrument details and the associated uncertainties	143
Table. 4.30.	ANOVA for engine performance parameters	148
Table. 4.31.	ANOVA for engine emission characteristics	149
Table 4.32a:	Particular Mahua tree (Madhuca longifolia)	161
Table 4.32b:	Proximate and ultimate analysis of Madhuca longifolia Biomass	161
Table. 4.33	Comparative property analysis of safflower oil and its methyl ester	162
Table. 4.34.	Apparatus details & Associated uncertainties	166
Table 4.35.	Experimental design matrix of 48 trials	171
Table. 4.36.	ANOVA regarding the performance of the engine.	173
Table. 4.37.	ANOVA regarding emissions from the engine	174
Table. 4.38.	Basic property of hard coke-low grade coal	187
Table. 4.39.	Comparative analysis of diesel and producer gas diesel saving	190
Table. 4.40.	Experimental design matrix for 48 trials	191
Table. 4.41.	ANOVA for engine performance parameters.	194
Table. 4.42.	ANOVA for engine emission	195
Table. 4.43.	Proximate and Ultimate analysis of Syzygium cumini	204

List of Symbols

Nomenclatures

BTE	Brake thermal efficiency
BP	Brake power
BSFC	Brake specific fuel consumption
ANOVA	Analysis of Variance
RSM	Response Surface Methodology
EL	Engine Load
ER	Equivalence Ratio
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydrocarbon
LHV	Lower heating value (MJ/Kg)
$\dot{m}$	Mass flow rate (kg/s)
N	Engine speed
NO_x	Oxide of nitrogen
$\dot{n}$	Number of moles
P	Pressure (bar)
R	Gas constant
T	Temperature (°C)
Y	Mole fraction

Subscript

a	Air
c	Coolant
des	Destruction
f	Fuel
l	Loss
g	Exhaust gas
gen	Generation
ref	Dead state
w	Shaft power

Superscript

Ph	Physical
Ch	Chemical

Abstract

Increasing energy requirements worldwide have significantly prompted energy generation migration through alternate resources. Humankind dependency on fossil fuels cannot be continued due to its non-sustainability issues in energy, environment, and economic practice. It is proclaimed that the global energy demand will increase around 25% in 2040, where the electric power consumption will double by 2060. As per the present scenario, due to the fast depletion of energy sources and reserves-to-production (R/P) ratio, there will be atrocious growth in energy demand. So, to the large extent, optimum and efficient use of the present resource will be a significant support to sustain the energy, economic and environmental demands.

Regarding these issues and daunting challenges, it is mandatory to opt replacement of fossil fuel carriers with sustainable alternate fuel resources. As far as a renewable energy source is concerned, biomass-derived energy carriers could be one of the promising solutions. Biomass is primarily derived from the forest, and worldwide forests cover around 30% of the land base, which possesses approximately 384 billion m^3 as total forestry inventory. To convert biomass to higher-value products, the primary routes followed to convert biomass into energy-rich are combustion, thermochemical processes, and biochemical processes.

Among this, researchers posit that thermochemical conversion-based gasification technology is more suitable for biomass conversion due to their self-sufficient auto thermic process and more energy recovery and heat capacity in compared to combustion and pyrolysis. Furthermore, the gasification process is appealing since it offers many benefits, such as biomass adaptability and waste type, use of entire feedstock, high-temperature range, and high conversion rate. Gasification comprises the thermochemical transformation of solid feedstock (coal, biomass, etc.) into gaseous fuel through partial oxidation with the gasifying agents like air, steam, oxygen,

or their mixtures. However, the gasification significantly depends on the type of gasification and feedstock, air or steam/feedstock, gasification temperature, particle size, and feed rate.

In regard to the previous work, mostly the research work has been done in the area of biomass gasification with limited operating conditions. In addition to this, there is very little work has been attempted in the literature that specially studied the Waste Biomass and low-grade coal gasified producer gas (PG) and integration with diesel-fuelled CI engine, and to analyze engine performance and emission characteristics experimental as well as numerically. Also, there is no author that has concluded the cumulative effect of engine input variable for an optimum response of performance and emission together.

Hence, there is essential to study low-grade coal and biomass gasified PG coupled with an internal combustion engine and provide the optimum engine input parameters for improved engine performance and operation. Because, if the blended form of chemical energy is available for power generation in an engine and its operating variables are not optimized, there will be a reduction in power and increment in fuel consumption and emission. Concerning these aspects, in the present study, we have attempted to resolve this obvious gap.

In light of the above discussions, the present work by the author presents an experimental and numerical study to optimize the operating parameters of diesel engines fuelled by biomass or coal based producer gas blended with diesel fuel in terms of optimal performance and exhaust emissions by integrating advanced multi-objective optimization technique Response surface Methodology. A comprehensive thermochemical equilibrium based model of downdraft gasifier was developed by minimizing Gibbs free energy using Aspen Plus software. In the experiment, a total of 48 number of the experimental matrix wherein downdraft gasifier integrated with dual fuel diesel engine fuelled with multiple biomass and coal were executed to perform RSM optimization and ANOVA sensitivity test.

The results of these stimulated model and experimental analysis shall not only be helpful in designing a optimized biomass fixed bed gasifier, but shall also be useful to obtain the optimum performance and emission analysis of dual fuel diesel engine fuelled with Producer gas and diesel. The complete work has been segregated into five chapters.

The present work, comprising five chapters, has been made with this motivation to emphasize on various issues related to the possibilities, problems, and prospects of utilizing gasification technique in better way so that the infrastructural problems of fuel oil scarcity and environment degradation could be squarely met.