Development of Carburetor for Optimum Performance of Producer Gas Fueled Dual Fuel Compression Ignition Engine

N.R.Banapurmath[1], V.S. Yaliwal[2], K. J. Noolageri[3], P.G.Tewari[4]

Professor[1, 4], Assistant Professor[2], Student[3]

[1, 4] B.V.B. College of Engineering and Technology, Hubli 580031, Karnataka, India

[2,3] S.D.M. College of Engineering and Technology, Dharwad 580 002, Karnataka, India

INTRODUCTION

- Alternative fuels have numerous advantages compared to fossil fuels as they are renewable, biodegradable; provide energy security and foreign exchange savings besides addressing environmental concerns, and socio-economic issues.
- With regard to stringent emission legislation in the automotive sector and need to save fossil fuel for other developmental and research activities over the coming decades this research work is directed at developing diesel engine-gasifier integrated systems to operate on renewable fuels such as Honge oil methyl ester [HOME] and Producer gas with specially designed carburetor.
- Branches of the Honge tree were used as the biomass feed stock in the downdraft gasifier for the producer gas generation.
- This work mainly aims at total substitution for fossil fuel by respective renewable fuels and is a step towards energy security and sustainability.
- In this proposed research work different carburetor shapes were identified and developed to maximize the gasifier-engine performance. The developed producer gas carburetor was further analyzed for its mixing performance with a subsequent CFD modeling.

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- The model is a mixing chamber having essential orifices for air and producer gas inlets to generate stoichiometric mixture at near to ambient conditions with required driving pressure differential for the flow.

- The carburetors were drawn from Y – shape, and parallel gas entry.

- **Preprocessing has been done in GAMBIT and solver FLUENT has been used for analysis**.

- The main objectives of the present work;

  (a) Determine the good carburetor for producer gas – air mixing to get stoichiometric ratio.

  (b) Performance of carburetor is validated experimentally.

  (c) Experiments were conducted on a producer gas fueled dual fuel engine and evaluated Performance of dual fuel engine with different carburetor types and determined best carburetor, which will give stoichiometric air – fuel ratio

PRODUCER GAS SUPPLY SYSTEM WITH CARBURETOR

- The carburetor used must be developed in such a way that, it should give air and producer gas mixture at stoichiometric and at an ambient conditions for a particular engine depending on engine operating conditions (load and speed conditions).
- Experiments with use of different gas carburetors for dual fuel engine applications were reported [1, 2, 3, 5, 19].
- The required air-to-fuel ratio for natural gas is 17:1, whereas for producer gas is 1.3:1. The carburetors available for gaseous fuels such as natural gas, Biogas and landfill gas is unsuitable due to widely different stoichiometric air to fuel requirement [3]. Therefore different carburetor is required for producer gas operated engines.
- The carburetor designed for producer gas must have an ability to maintain the required air-to-fuel ratio (1.2 to 1.5:1) with varying load conditions, smooth operation with minimal pressure loss and on-line provision for air/fuel tuning during the operation [3].
- The out let of carburetor is attached to the intake manifold of an engine and the producer gas line with Y –shaped carburetor, venturimeter and digital gas flow meter as shown in Figure 1.

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The equivalence ratio at 80% load were found to be 0.69, 0.71, 0.74 and 0.82 for Y – shaped, 60, 90 deg and parallel flow gas entry carburetors respectively.

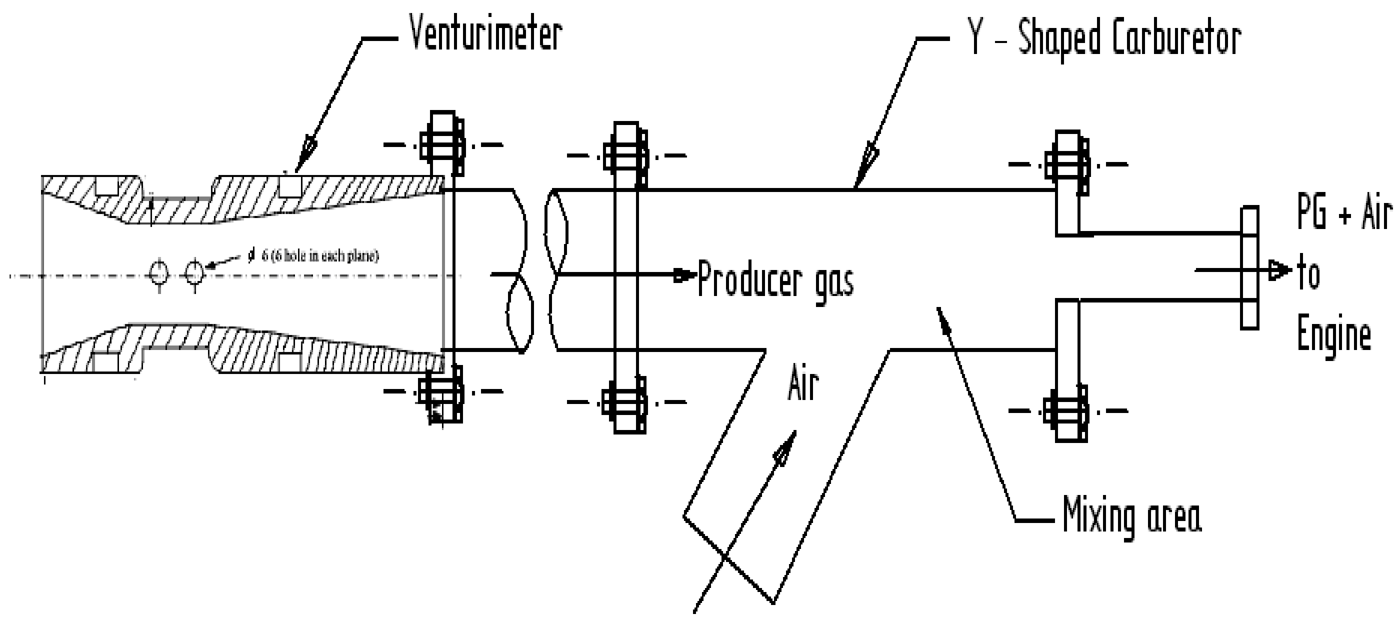

Fig. 1 Schematic of Producer Gas Y – shaped carburetor with venturimeter connection

CHARACTERIZATION OF FUELS TESTED

Table 1 Properties of liquid fuels and Proximate and ultimate analysis of biomass feed stocks

Sl.No	Properties	Diesel	HOME	Description	Babul wood
1	Viscosity @ 40 ^{0}C (cst)	4.59 (Low)	5.6	Moisture Content, % wlw	10.3
2	Flash point ^{0}C	56	163	Ash Content, % wlw	0.79
3	Calorific Value in kJ / kg	45000	36,010	Volatile Matter, % wlw	85.8
4	Specific gravity	0.830	0.870	Fixed Carbon % wlw	13.4
5	Density Kg / m3	830	890	Sulphur, % wlw	0.05
6	Type of oil	Fossil	Non edible	Nitrogen, as N % wlw	0.30
7	------	----	------	Gross Calorific value, Cal/g	5631.O
	------	-----	------	Gross Calorific value, kJ/ kg	23575.8
8	------	----	------	Density, kg/ m^3	380
9	------	-----	------	Phosphorus % w/w	---
10	------	----	------	Potassium	---

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Table 2 Composition of producer gas

Type of wood	CO %	H_2 %	Methane %	HC %	N_2 %	Water Vapour %	CO_2 %	Calorific value MJ/Nm^3	Density kg/m^3
Babul wood	18-22%	15-19%	1-5 %	0.2-0.4%	4.5-5.5%	4	8 -10%	5.6	360

EXPERIMENTAL SETUP

Fig. 2 Overall view of Experimental Setup

Fig. 4 Parallel gas entry carburetor for producer gas induction fitted to the engine

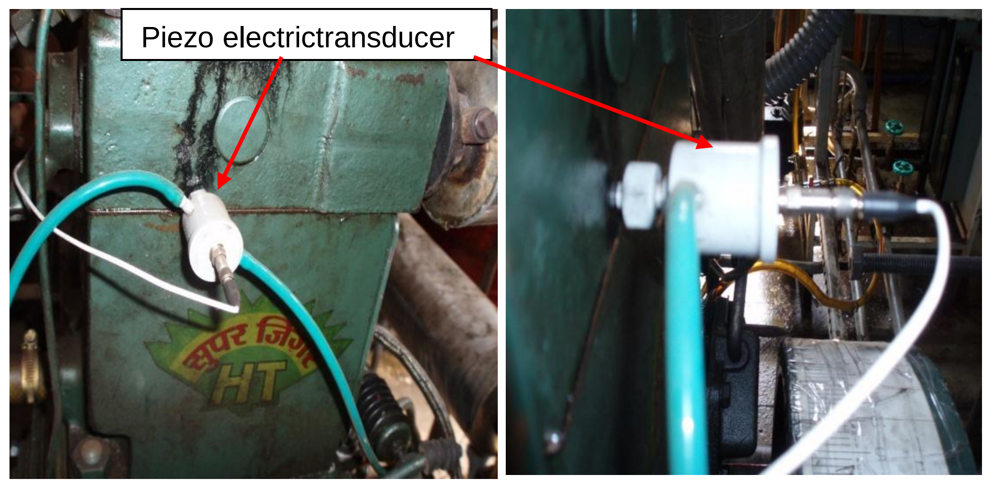

Fig. 3 Views of Pressure Sensor fitted to engine cylinder

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Fig. 5 Y- shaped carburetor

Fig. 6 Parallel flow gas entry carburetor

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Table 3 shows specification of experimental test rig

Sl No	Parameters	Specification
1	Machine Supplier	Apex Innovations Pvt Ltd, Sangli. Maharastra State.
2	Engine Type	Single cylinder four stroke water cooled direct injection TV1 compression ignition engine with a displacement volume of 662 cc, compression ratio of 17:1, developing 5.2 kW at 1500 rev/min TV1 (Kirolsker make)
3	Software used	Engine Soft
4	Nozzle opening pressure	200 – 225 bar
5	Governor type	Mechanical centrifugal type
6	Cylinder diameter (Bore)	0.0875 mtr
7	Stroke length	0.11 mtr
8	Combustion camber	Open Chamber (Direct Injection) with hemispherical cavity
9	Eddy current dynamometer:	Model :AG – 10, 7.5 KW at 1500 to 3000 RPM and Water flows through dynamometer during the use

DOWNDRAFT GASIFIER

Fig. 7 Photographic view of a Downdraft Gasifier.

Fig. 8 Flaring for checking quality of producer gas

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Table 7 Specification of the downdraft gasifier

Type	**Down draft gasifier**
Rated capacity	15000kcal/hr
Rated gas flow	$15Nm^3/hr$
Average gas calorific value	$1000kcal/m^3$
Rated woody biomass consumption	5-6kg/hr
Hopper storage capacity	40kg
Biomass size	10mm (Minimum) 50mm (Maximum)
Moisture content (DB)	5 to 20%
Typical conversion efficiency	70-75%

OPTIMIZATION OF CARBURETOR FOR DUAL FUEL OPERATION: COMPUTATIONAL APPROACH

For the modeling and analysis, five different carburetors shapes were developed and tested for air fuel mixing through CFD software package. The detailed explanation is discussed below.

Boundary conditions

- The inlet boundary conditions for air and Producer gas are mass flow rate and pressure were applied and no buoyancy steady state condition.
- The initial condition of flow rate through the air inlet with ideal mass fraction as 0 is considered and mass fraction of Producer gas is 1.
- The results obtained for different carburetor shapes were given in the Table 8. The CFD analysis was carried out on a different carburetor shapes are given below.
- Three - dimensional model has been used to simulate the air and producer gas analysis.
- Producer gas mass fraction across a selected plane, velocity streamlines and velocity vectors were explained in the subsequent paragraphs.

(A) Y-SHAPE CARBURETOR

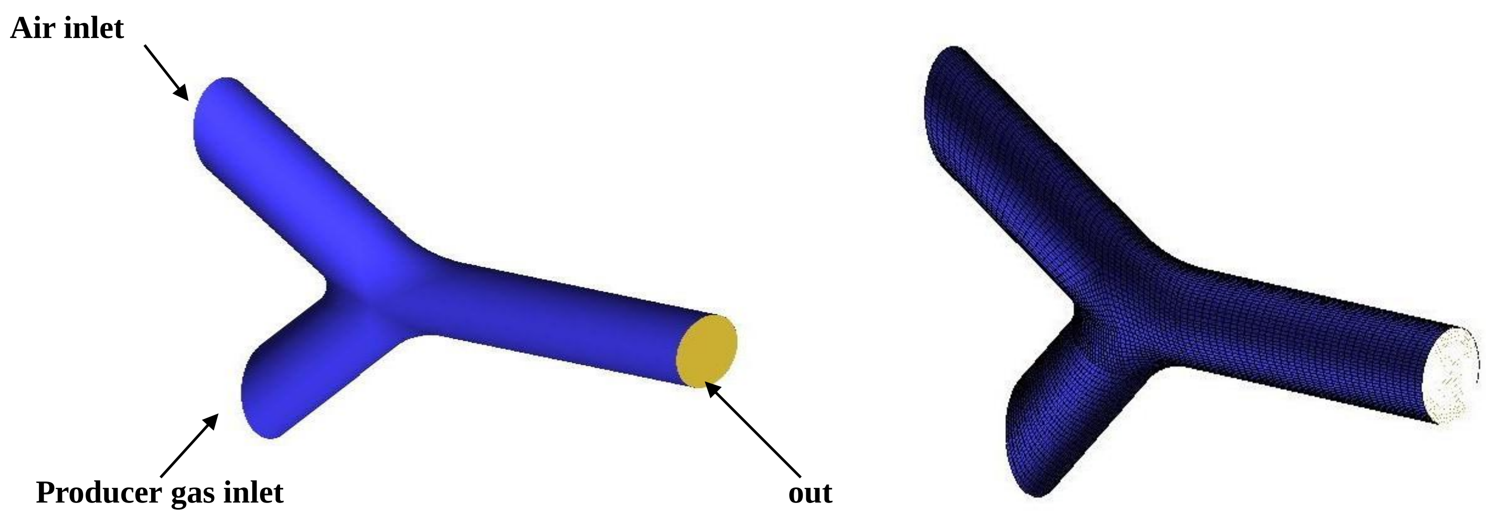

Fig. 9 Three -D-model of carburetor (b) Structured mesh

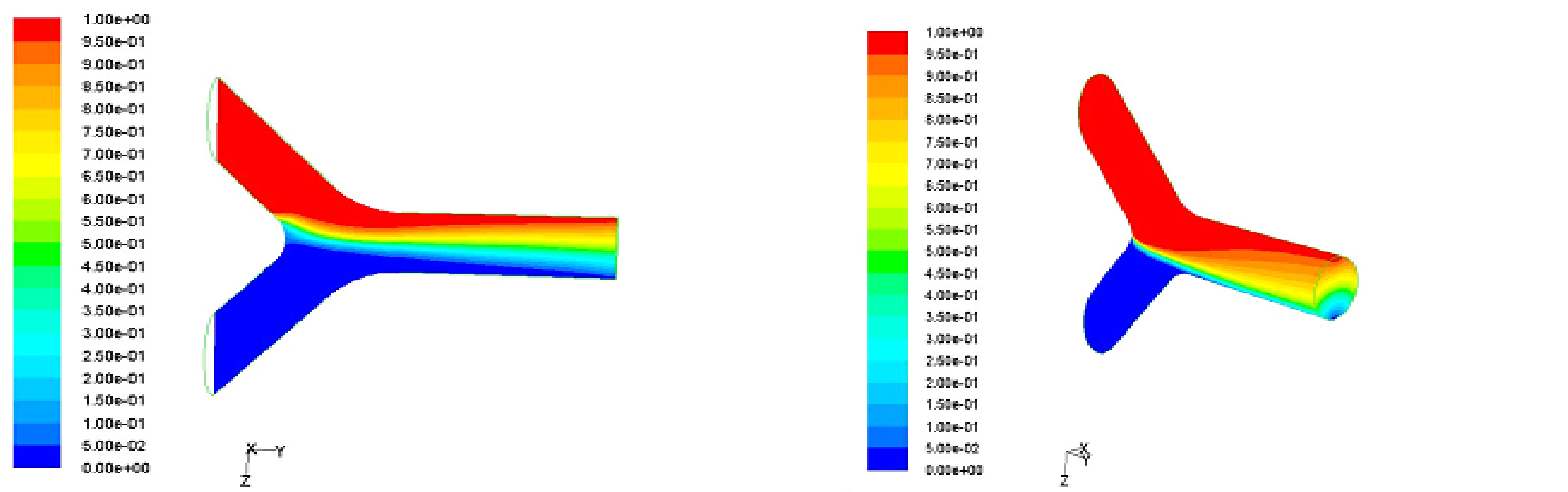

Fig. 10 Contours of producer gas (a) cut- sectional view (b) Isometric view

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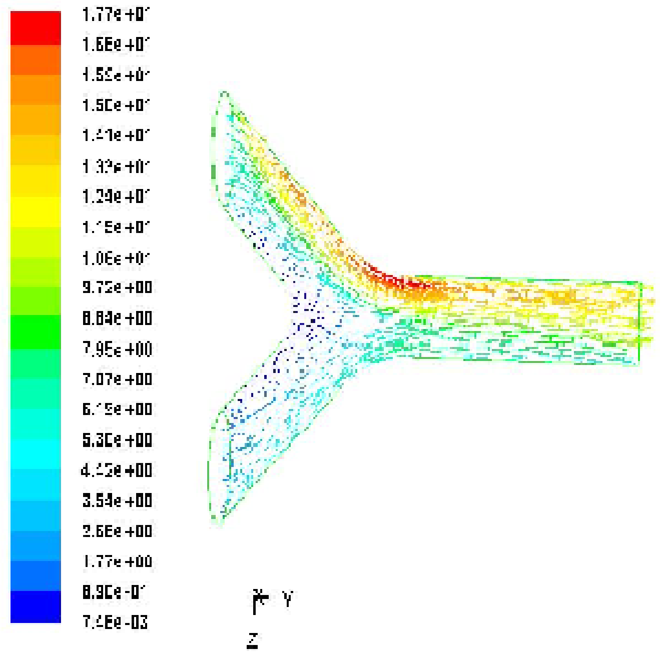

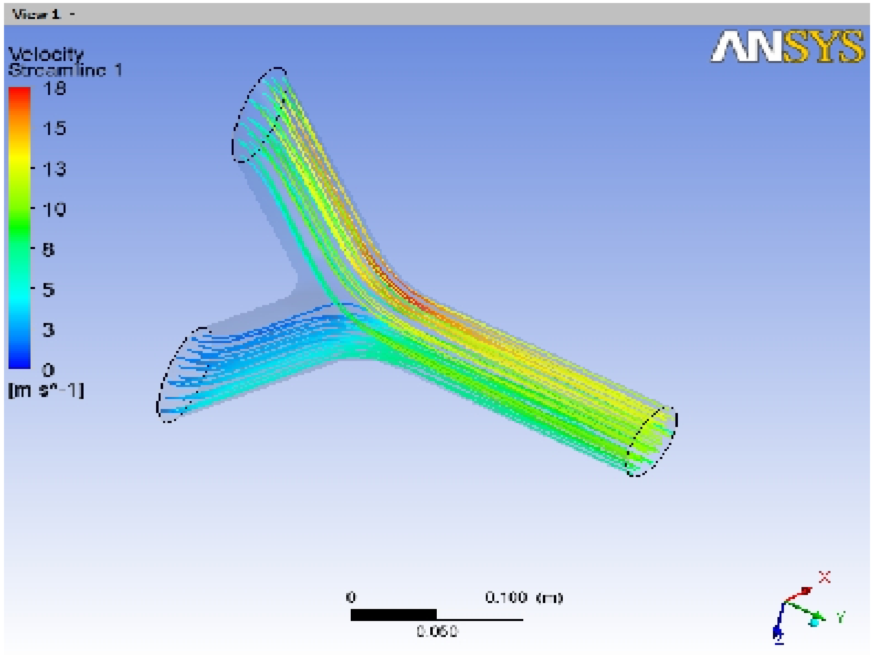

Fig. 11 (a) Velocity streamlines (b) Velocity vectors

(b) PARALLEL FLOW CARBURETOR

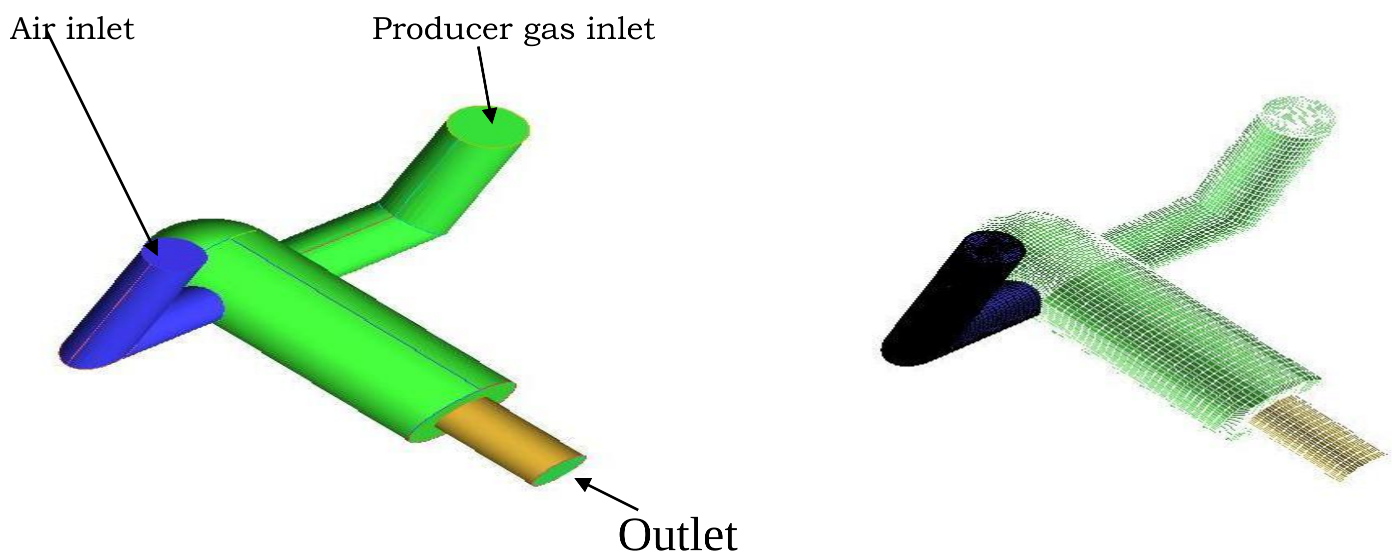

Fig. 12 Three -D-model of carburetor (a) Front view (b) Hex mesh

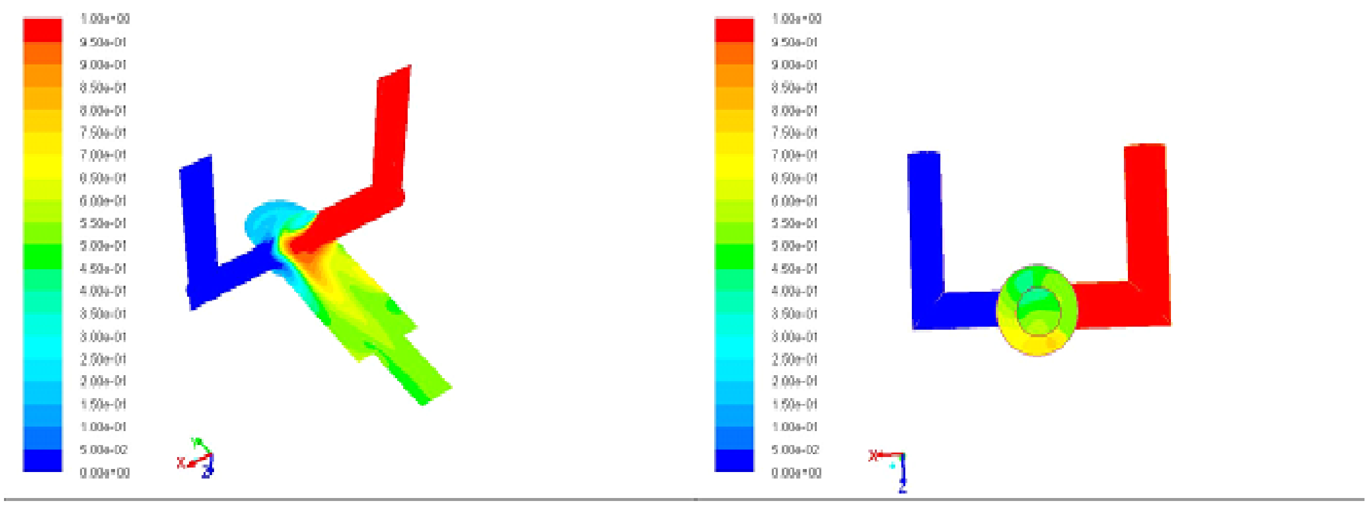

Fig. 13 Contours of producer gas (a) Cut-section view (b) Front view

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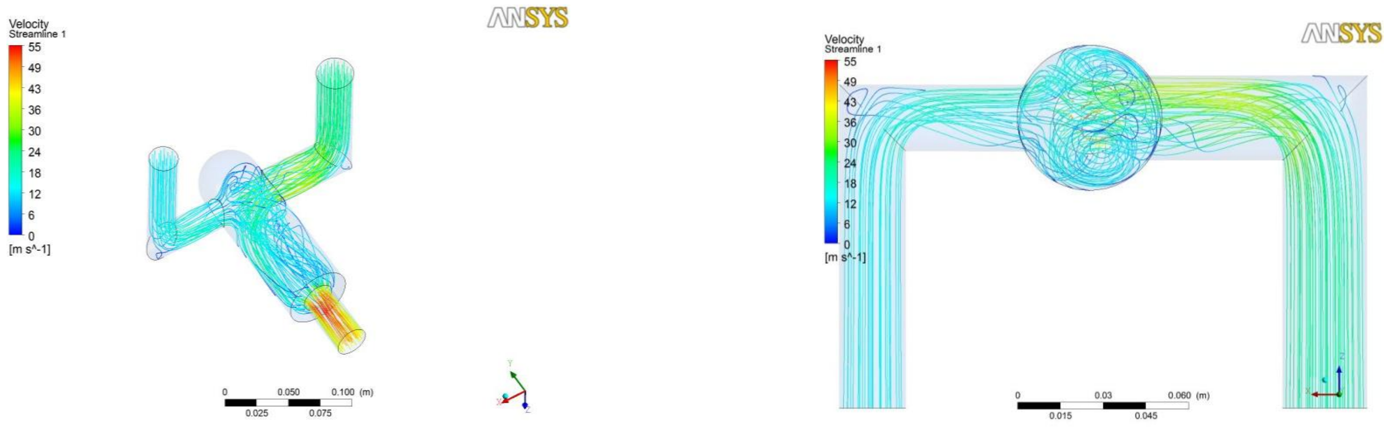

Fig. 14: Velocity streamlines (a) Isometric view (b) Side view

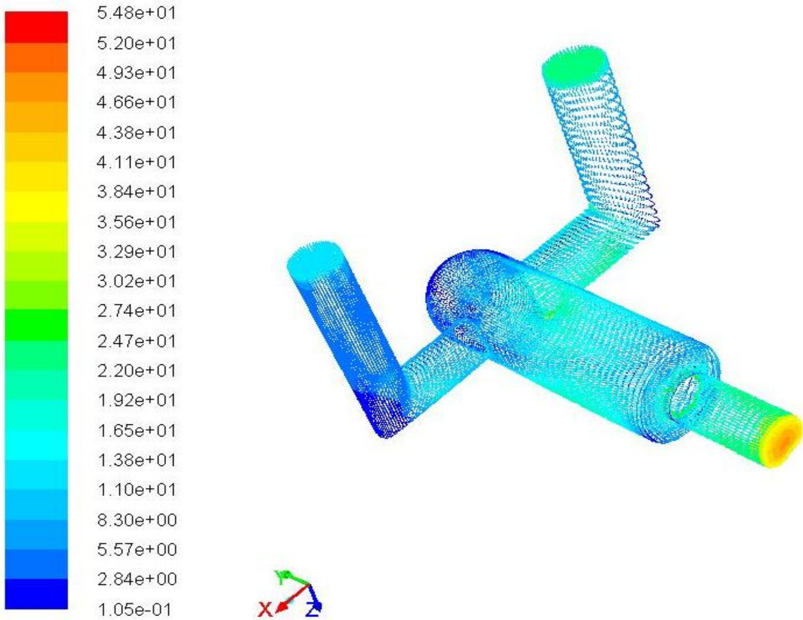

Fig. 15 Velocity vectors

Table 8 Results of CFD analysis for different carburetors

Carburetor type	Inlet dia, mm	Outlet dia. mm	Description	Producer gas mass fraction	Air mass fraction	Velocity at outlet m/s	Equiva - lence ratio
Y-shape carburetor	50.8	50.8	135000 with nodes structured mesh	0.56	0.44	12	0.62
30 Deg. Gas Entry	31.75	25.4	Structured mesh, 145734 nodes	0.55	0.45	41.84	0.65
60 Deg. Producer Gas Entry	31.75	25.4	Structured mesh, 156431 nodes.	0.54	0.46	41.86	0.68
90 Deg. Producer Gas Entry	31.75	25.4	Structured, 154643 nodes	0.55	0.45	42	0.65
Parallel flow gas enrty	31.75	25.4	Structured hex with mesh156677	0.50	0.50	39	0.8

RESULTS AND DISCUSSIONS

Experimental Investigations of dual fuel operation

(a) PERFORMANCE CHARACTERISTICS

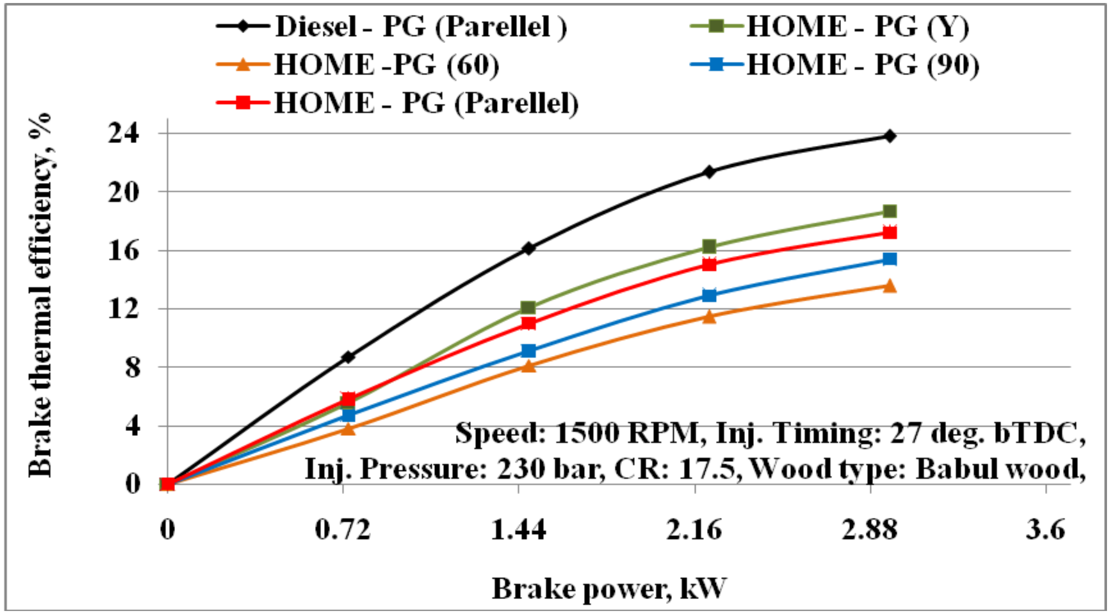

Fig. 16 Brake thermal efficiency

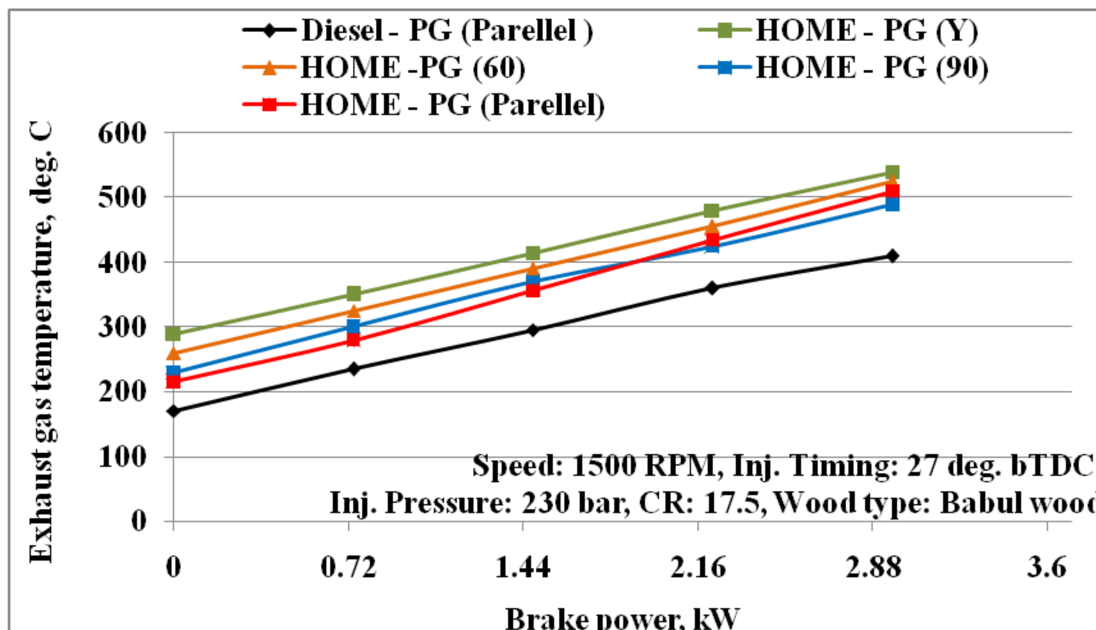

Fig. 17 Exhaust gas temperature

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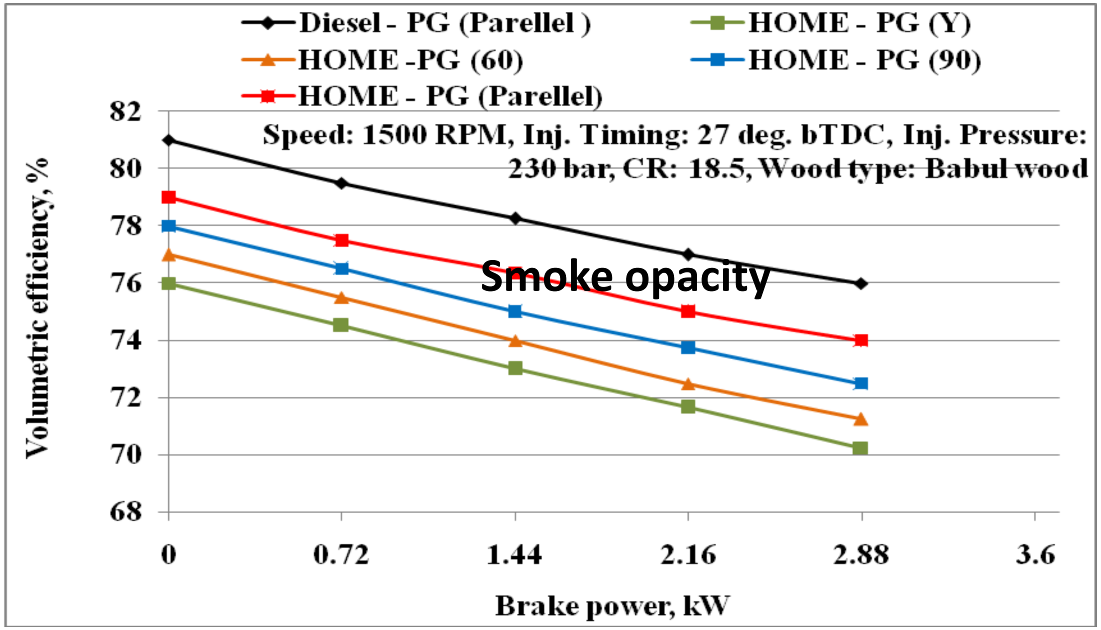
Fig. 18 Volumetric Efficiency



(b) EMISSION CHARACTERISTICS

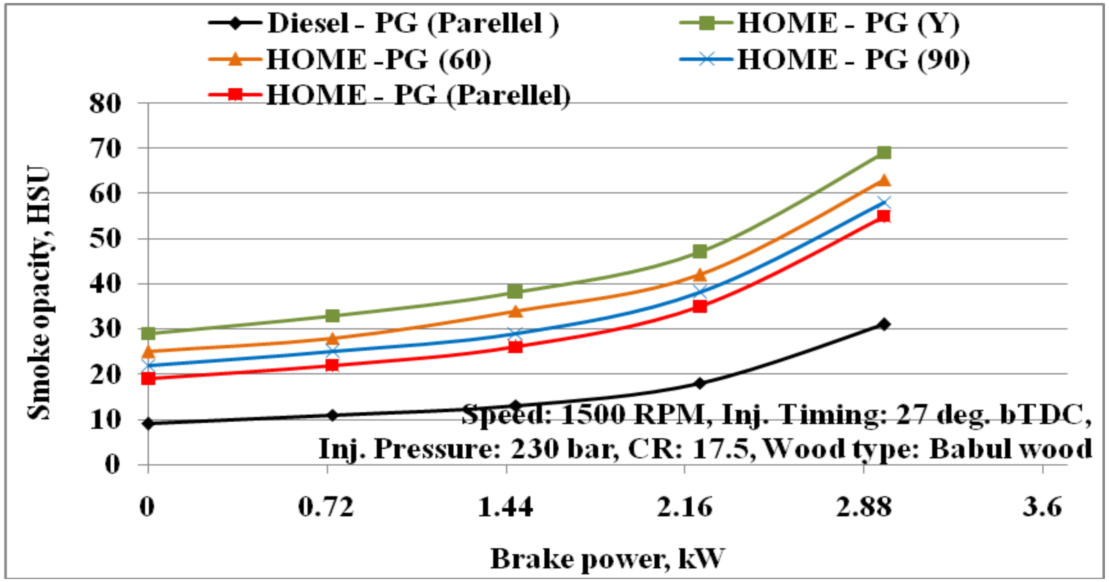


Fig. 19 Smoke opacity

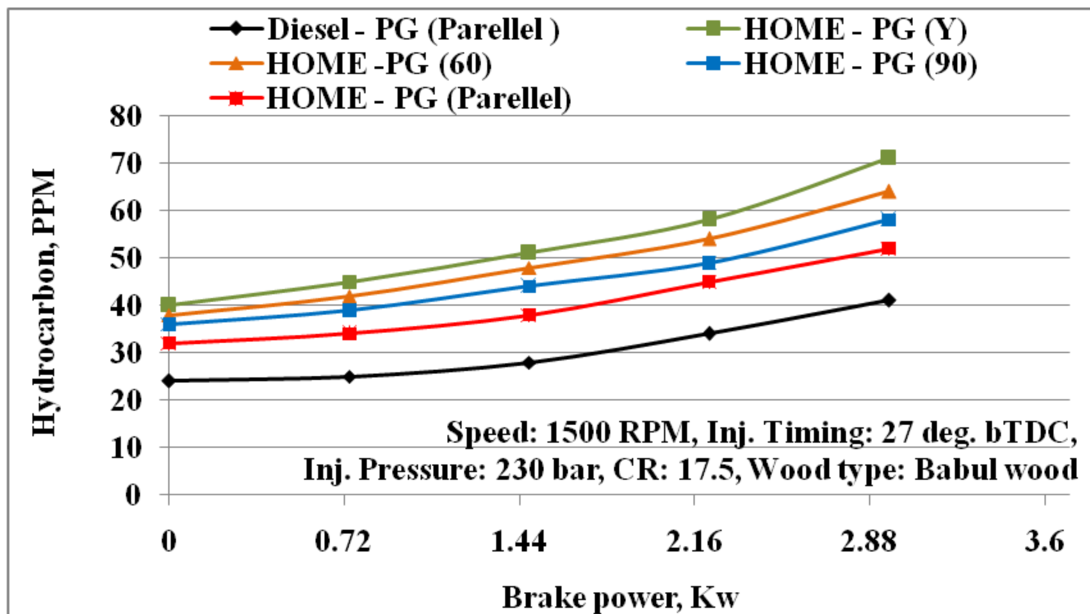


Fig. 20 HC emissions

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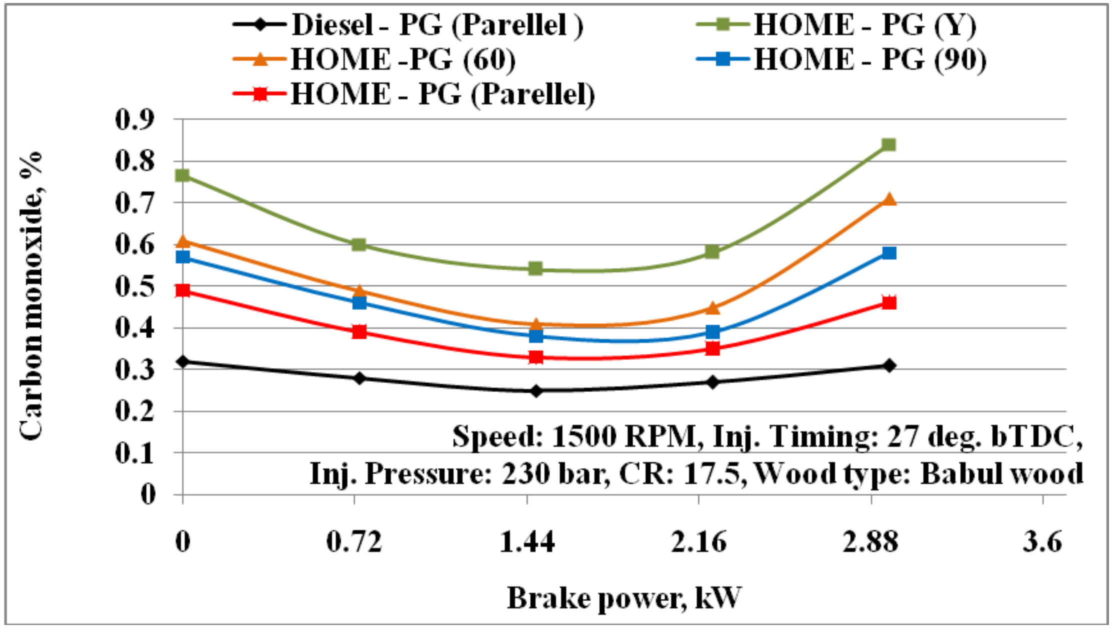

Fig. 21 CO emissions

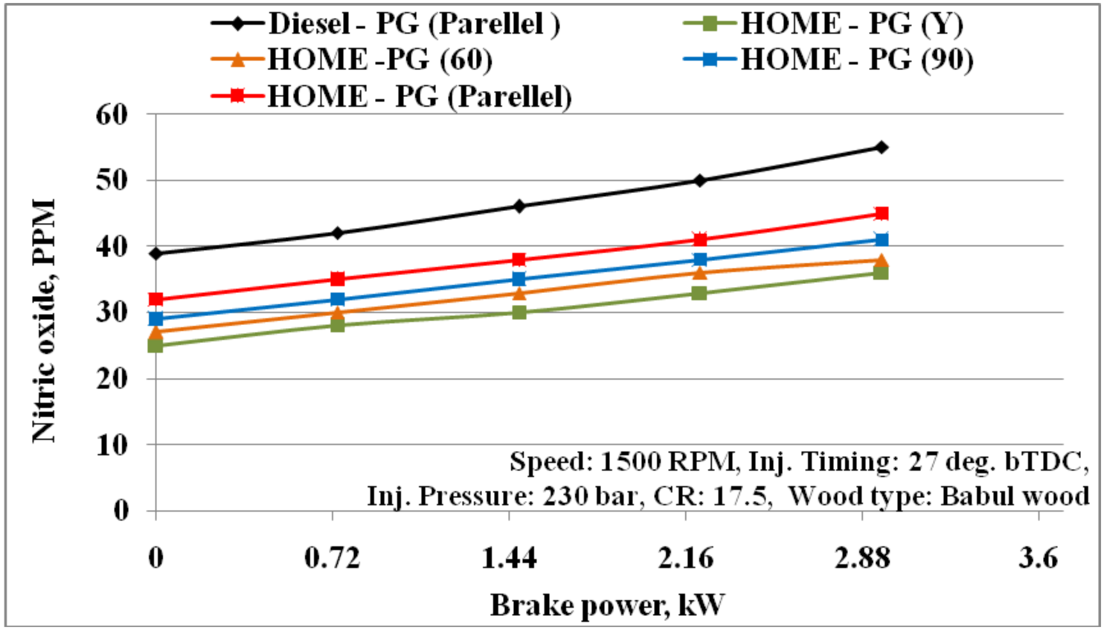

Fig. 22 NOx emissions

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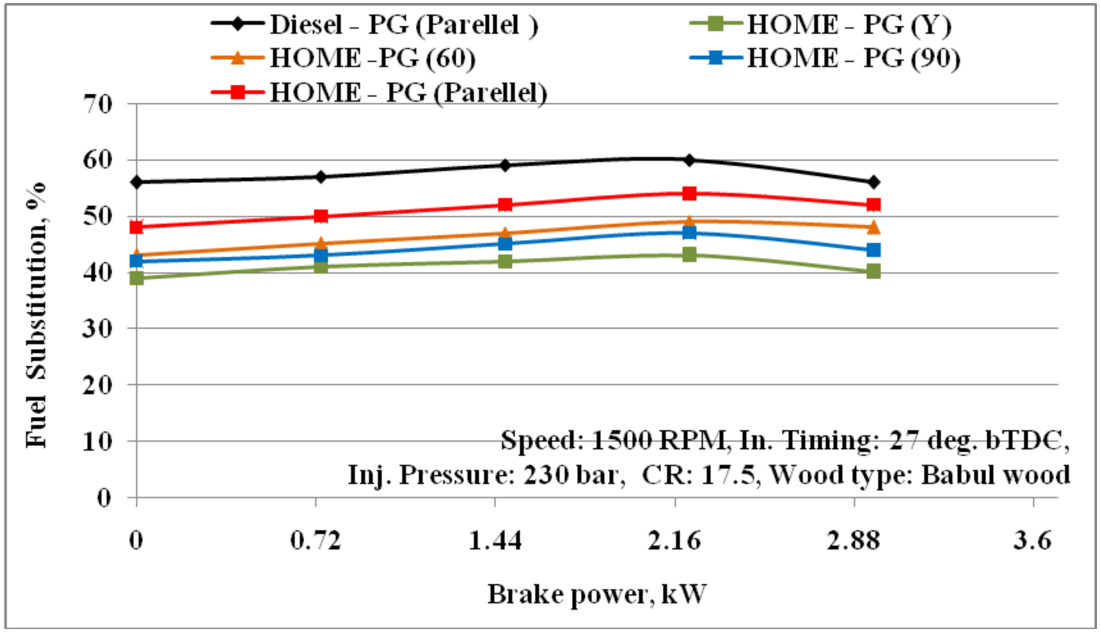
Fig. 23. Fuel substitution



CONCLUSIONS

Following are the conclusions made out based on the present work,

1. Three dimensional CFD computations on producer gas carburetor made have been able to capture the detailed functional features of fluid flow in the carburetor configurations considered and the results on engine are found to be consistent at different engine operating conditions. Turbulent model based on k-ε theory with the CFD predictions of the producer gas mass fraction and the carburetor flow analysis has been evaluated leading to bringing out of an optimal design of the Producer gas carburetor that is used for prototype testing and real–time testing.
2. The experimental results tests from gasifier – engine system showed that parallel flow gas entry carburetor was found to be optimum compared to other carburetor shapes.
3. Operating the Gasifier – engine system with optimum carburetor, and HOME and Producer gas makes the system completely independent from fossil fuel.
4. Utilization better carburetor improves the dual fuel engine performance with reduced HC and CO emission levels.

REFERENCES

- Banapurmath N.R., Tewari P.G., Comparative performance studies of a 4-stroke CI engine operatedon dual fuel mode with producer gas and Honge oil and its methyl ester (HOME) with and without carburetor, Renewable Energy, 34 (2009) 1009–1015.
- Anil T.R., Ravi S.D., Shashikanth M.,.Rajan N.K.S., Tewari P.G., CFD Analysis of a Mixture Flow in a Producer Gas Carburetor, International Conference On Computational Fluid Dynamics, Acoustics, Heat Transfer and Electromagnetics CFEMATCON-06, July 24-25, 2006, Andhra University, Visakhapatnam – 530003, INDIA.
- Sridhar G., Sridhar H. V., Dasappa S., Paul P. J., Rajan N. K. S., Mukunda H. S., Development of Producer Gas Engines.
- Banapurmath N.R., Tewari P.G., Hosmath R.S., Experimental investigations of a four-stroke single cylinder directinjection diesel engine operated on dual fuel mode with producer gas as inducted fuel and Honge oil and its methyl ester (HOME)as injected fuels, Renewable Energy 33 (2008) 2007–2018.
- Srivastava A, Prasad R. Triglycerides-based diesel fuels. Renewable and sustainable Energy Reviews 2000, 4:111–33.
- Vellguth G., Performance of vegetable oils and their monoesters as fuels for diesel engines. SAE 1983, Paper No.831358.
- Gajendra Babu MK, Chandan Kumar Das LM. Experimental Investigations on a Karanja Oil Methyl Ester Fuelled DI Diesel Engine. SAE 2006-01-0238, 2006.

- Deepak A., Kumar A.A., Performance and emission characteristics of a Jatropha oil (preheated and blends) in a direct injection compression ignition engine. International Journal of Applied Thermal Engineering 2007;27:2314–23.
- Scholl KW, Sorenson SC. Combustion analysis of soyabean oil methyl ester in a direct injection diesel engine. SAE 1993;930934.
- Nwafor OMI. Effect of advanced injection timing on the performance of rapeseed oil in diesel
- Banapurmath N.R., Tewari P.G.,. Yaliwal V.S., Satish Kambalimath , Basavarajappa Y.H., Combustion characteristics of a 4-stroke CI engine operated on Honge oil, Neem and Rice Bran oils when directly injected and dual fuelled with producer gas induction, Renewable Energy 34 (2009) 1877–1884.
- Vyarawalla F, Parikh PP, Dak HC, Jain BC. Utilization of biomass for motivepower generation: gasifier engine system. Biomass 1984;3:227–42.
- Parikh PP, Bhave AG, Kapse DV. Shashikantha. Study of thermal and emission performance of small gasifier dual fuel engine systems. International Journal of Biomass 1989;19:75–97.
- Bhattacharya SC, Hla SS, Pham H-L. A study on a multi-stage hybrid gasifierengine system. International Journal of Biomass and Bioenergy 2001;21:445– 60.
- Sridhar G, Dasappa S, Sridhar HV, Paul PJ, Rajan NKS. Gaseous emissions using producer gas as fuel in reciprocating engines. SAE 2005-01-1732 2005.

- Uma R, Kandapal TC, Kishore VVN. Emission characteristics electricity generation system in diesel alone and dual fuel modes. International Journal of Biomass and Bioenergy 2004;27:195–203.
- Bridgwater AV, Toft AJ, Brammer JG. A techno-economic comparison of power production by biomass fast pyrolysis with gasification and combustion. International Journal of Renewable and Sustainable Energy Reviews 2002;6:181–248.
- Klimstra J., Carburetors for Gaseous Fuels –on Air to Fuel ratio, Homogeneity and Flow restriction. SAE paper 892141
- Vinay S.S., Ravi S.D., PremaKumar G., Rajan N. K.S.,Numerical and Experimental Modeling of Producer Gas Carburettor, Proc. of the International Conference on 'Advances in Mechanical Engineering, 2008, S.V. National Institute of Technology, Surat – 395 007, Gujarat, India, pp 1 – 9.
- Fukui T, Tamura Y, Omori S, Saitoh S. Accuracy of A/F calculation from exhaust gas composition of SI engines. Mitsubishi Motors Corp, SAE Paper 891971.
- [Spindt RS. Air fuel ratios from exhaust gas analysis. SAE 1965;650507.
- Tseng TC, Cheng WK. An adaptive air/fuel ratio controller for SI engine throttle transients. Massachusetts Institute of Technology 1999-01-0552; 1999.
- Azzoni P, Minelli G, Moro D. Air-fuel ratio control for a high performance engine using Throttle angle information. SAE paper 1999;011169.
- Ohyama Y. Air/fuel ratio control using upstream models in the intake system. SAE Paper 1999;0857(vol. 1).
- Berggren P, Perkovic A. Cylinder individual lambda feedback control in an SIengine. Technical Presentation at Lynkoping, Reg: LiTH-ISY-EX-1649; 1996.
- Douglas G. Janisch patented work on producer gas carburetor; US Patent 5070851 December 10 1991, www.freepatentsonline.com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