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EFFECT OF CNG FLOW RATE ON DUAL FUEL ENGINE OPERATED WITH ARGEMONE BIODIESEL AS THE PILOT FUEL

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Abstract

In the present research work, effect of compressed natural gas (CNG) flow rate, on the performance of modified dual fuel engine powered with two biodiesels is studied. Biodiesels derived from Argemone oil and their B20 blends are used as pilot injected fuels while CNG is used as the manifold inducted fuel in the modified dual fuel engine. Further influence of CNG gas flow rate on the modified dual fuel engine by using conventional mechanical fuel injection for optimal performance of engine is investigated. Increasing the CNG gas flow rates reduces brake thermal efficiency (BTE), smoke and nitric oxide (NOx) emissions while, CO (Carbon monoxide) and HC (Hydrocarbon) emissions increased. The engine operated with present fuel combinations can facilitate partial as well as complete substitution for fossil fuels and reduce the greenhouse gas emissions.

Keywords: Argemone biodiesel; Dual fuel engine; Compressed natural gas; CNG flow rate.

1. Introduction

Internal combustion (IC) engines are important power resources in our day-to-day life mainly in the field of transportation, power generation and agricultural segments. Faster exhaustion of petroleum assets and environmental problems increased due to more use of it and potential behind the hunt for change of petroleum products with innovative consistent alternative fuels. B20 blend is most generally accepted renewable fuel for pure diesel and the production of biodiesel differs expressively regarding topographical location. Recent diesel engines include an electronic injection system with variable several injection programs for applications of light and heavy-duty engines. Hence, research on new biodiesel feedstock with optimal injection strategy is difficult and also time consuming. The difficulty of more amounts of NOx emissions by using biodiesel is unattractive [1-5]. CNG is most promising low reactive fuel in ICE because of its high octane number and abundance in resources. The ignition of CNG with the help of high reactive fuel which is directly injected during compression stroke has been considered as most efficient method to satisfy low NOx and smoke emissions [6-8].In engine research, fuel economy and reduction in emissions are given prime importance. In view of this, researchers have developed dual fuel concept. This will reduce both smoke and NOx emissions. However, dual fuel operation provides lower engine performance due to reduced volumetric efficiency. Further, researchers have developed various novel technologies to enhance the thermal efficiency with reduced smoke and NOx emissions [9-19].Increasing the hydrogen gas flow rates reduces brake thermal efficiency (BTE), smoke, CO (Carbon monoxide) and HC (Hydrocarbon) emissions while NOx (Nitric oxide) emissions from DF engine increased. The engine operated by renewable fuel combinations of biodiesels and H_2 in DF mode engine can facilitate partial as well as complete substitution for fossil fuels and reduce the greenhouse gas emissions [20].

1.1. Argemone biodiesel

Argemone species are plants that can withstand cold temperatures and droughts and are adapted to semi-warm, semi-dry, and temperate regions from the sea up to 2750 metres above sea level. They are linked with arid zones and low deciduous forests, and theygrow on roadsides, in agricultural regions, or on abandoned farmland. Some species have also been found in xerophytic scrub, pine, mixed pine-oak, juniper, and deciduous and evergreen tropical forests. The leaves are arranged alternately and have serrated edges that finish in spines. The many bud shapes include lobed, elliptical, spherical, and obovate. The apex of each sepal has a corniculate appendage, and the shape of the horns on each one can be used to distinguish between different species. Argemone species have actinomorphic flowers with six or, less frequently, nine petals. The petals of A. ochroleuca are six elliptical to obovate or bcuneiform, but those of A. albiflora, A. munita, and A. gracilenta are obovate or suborbicular. The flower's hues range from yellow to white and include lavender. Flowers have both sexes. The stamens in the various species are numerous; the number varies depending on the species; Karnawat and Malik mention that A. mexicana has between 30 and 50 stamens while A. ochroleuca has between 20-75. The anthers are linear and comprised of two dehiscent cells. The pistils are made up of a stigma and a short style. The several Argemone species produce dry, dehiscent fruits or capsules that contain many seeds and have between three and six carpels. The capsules could have an ovate, lanceolate, or narrowly elliptical-oblong shape. Argemone seeds range in size from 1 to 2.5 mm and are subspherical or slightly conical. The micropyle develops a thin, frequently noticeable peak, and the testa reticulate exhibits surface depressions. Seeds cannot be distinguished visually, and the size and colour ranges of the depressions do not have any taxonomic significance. The tap roots of the Argemone species are robust and slenderly branching. While other species generate lateral roots, the primary root of A. polyanthemos can reach depths of up to 60 cm. Due to their molecular makeup, the isoquinoline alkaloids found in argemone seeds exhibit the characteristics of auto-fluorescence. The molecular structure that sanguinarine acquires when it is dissolved in solution is what causes its absorptions and emissions. While the non-ionic form of sanguinarine exhibits a maximum peak at 450 nm, the ionic form as a quaternary ammonium salt has a maximum emission of about 580 nm [21].

2. Fuel properties

Various fuel combinations are used for the current study. The biodiesel and their blends derived from argemone oil are used as injected fuels while CNG is used as inducted fuel using a venture arrangement. **Table-1** provides properties of the pilot fuels used. **Table-2** provides the properties of the CNG fuel.

Table-1. Properties of pilot fuels used [22]

Properties	**Diesel**	**B20**	**B100**
Density (kg/m^3)	827	841	876
Kinematic Viscosity at	3.51	4.11	5.84

40°C (cSt)			
Flash point (°C)	52	83	171
Fire point (°C)	59	93	194
Calorific value (MJ/kg)	42.21	41.31	38.54

Table-2. Properties of CNG fuel [7]

Properties	**Values**
Octane number	>120
Lower heating value (MJ/kg)	50.0
Auto-ignition temperature (°C)	650
Stoichiometric air-fuel ratio	17.2
Carbon content (%)	75
Flammability limits (vol.% in air)	5–15

3. Experimental setup

This segment describes experimental setup used for testing. **Figure-1**shows dual fuel engine test rig. The diesel engine is operated on CNG induction in dual fuel operation. The two stage pressure regulator is fixed on CNG gas cylinder supplied at 2 bar. The CNG gas is permitted to flow through rotameter and it is adjusted to supply identified flow rate of CNG. Flash back arrester, dry flame arrester and wet type flame trap are coupled to avoid fire hazards also for inducting of metered gas into inlet manifold. The flow rate of CNG is varied from 0.10 to 0.25 kg/h. Wet flame trap controls any flame accidentally flowing back into the gas supply side. CNG induction system has proper venture and it is fixed inside intake manifold for supply of CNG gas.**Table-2** provides the information about test engine specifications.

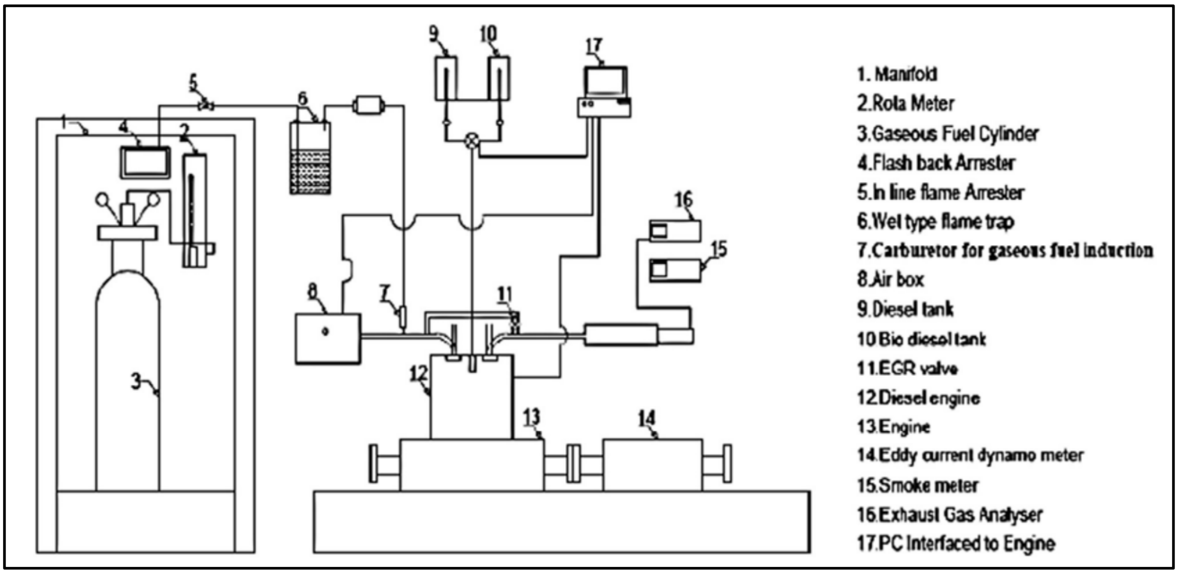

Figure-1. Line diagram of dual fuel engine

Table-2. Test engine specifications

Engine Type	Kirloskar
No. of Strokes	4
No. of Cylinders	1

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Type of Cooling	Water Cooling
Type of Injection	Direct Injection
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Rated Power	5.2 kW
Rated Speed	1500 rpm
Injection Pressure	230 bar
Injection Timing	23°bTDC

4. Results and discussions

This section highlights the effect of gaseous fuel flow rate on performance of dual fuel engine operated with flow rates of CNG varied from 0.1 to 0.25 kg/h respectively using 6 mm gas venture. The improved gas flow rates of CNG beyond 0.25 kg/h resulted into knock and poor performance of the engine.

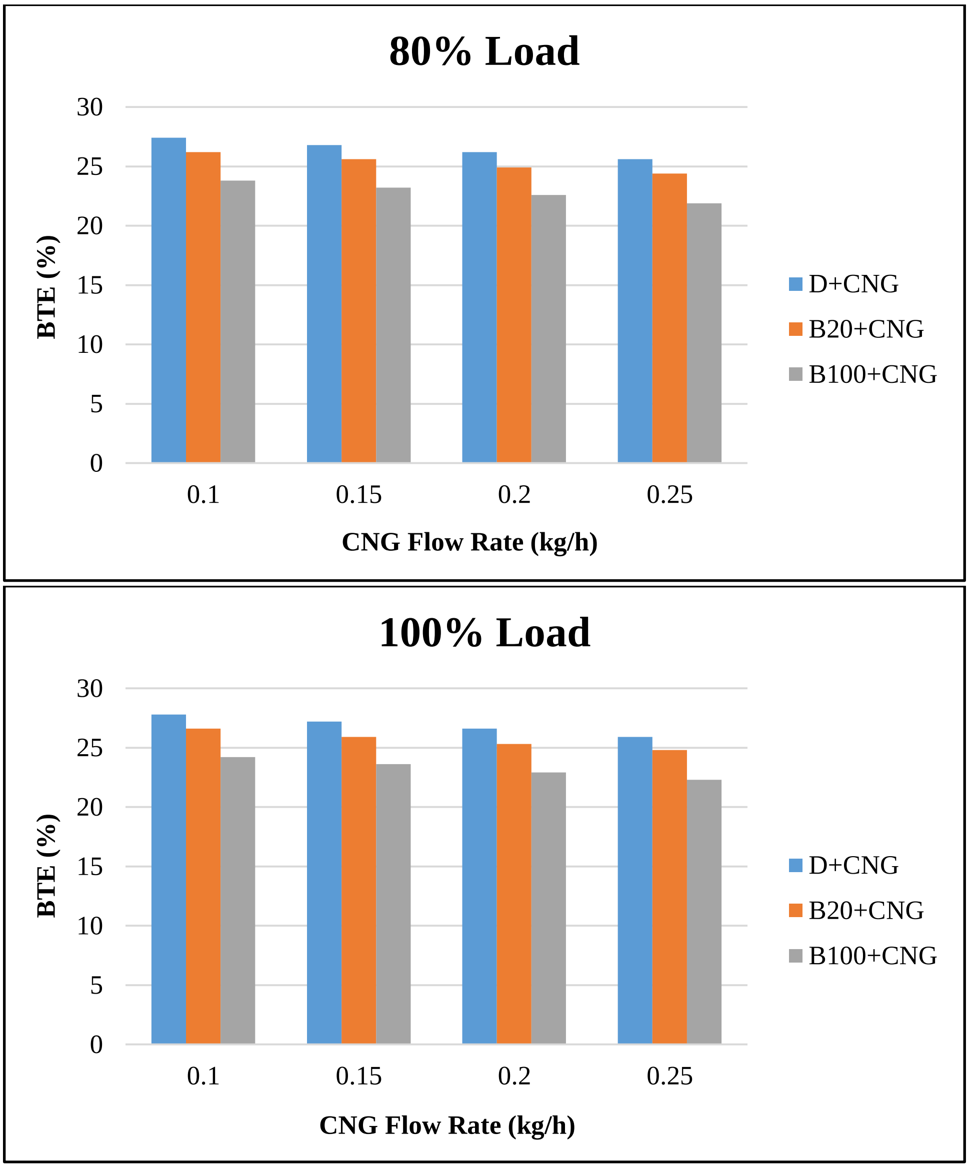

Figure-2. Variation of BTE with CNG flow rate

Figure-2 shows variation of BTE with CNG flow rates at 80% and 100% loads. Higher BTE was observed for D+CNG dual fuel combustion mode followed by B20+CNG and B100+CNG at all loads. The lower energy content and higher viscosity of biodiesel blended fuels leads to lower BTE. The increase in CNG flow rate from 0.1 to 0.25 kg/h, resulted in drop in volumetric efficiency in-turn reduced BTE. Incomplete combustion of injected pilot fuels of diesel, biodiesel and their B20 blends associated with reduction in air entrapment and decreased ignition source. This could be due to substantial quantity of gaseous fuel escaping the combustion process. At lower CNG gas flow rates more pilot fuel injection occurs hence improving the gaseous fuel utilization. CNG fuel enrichment tends to slow the process of combustion reaction rate.

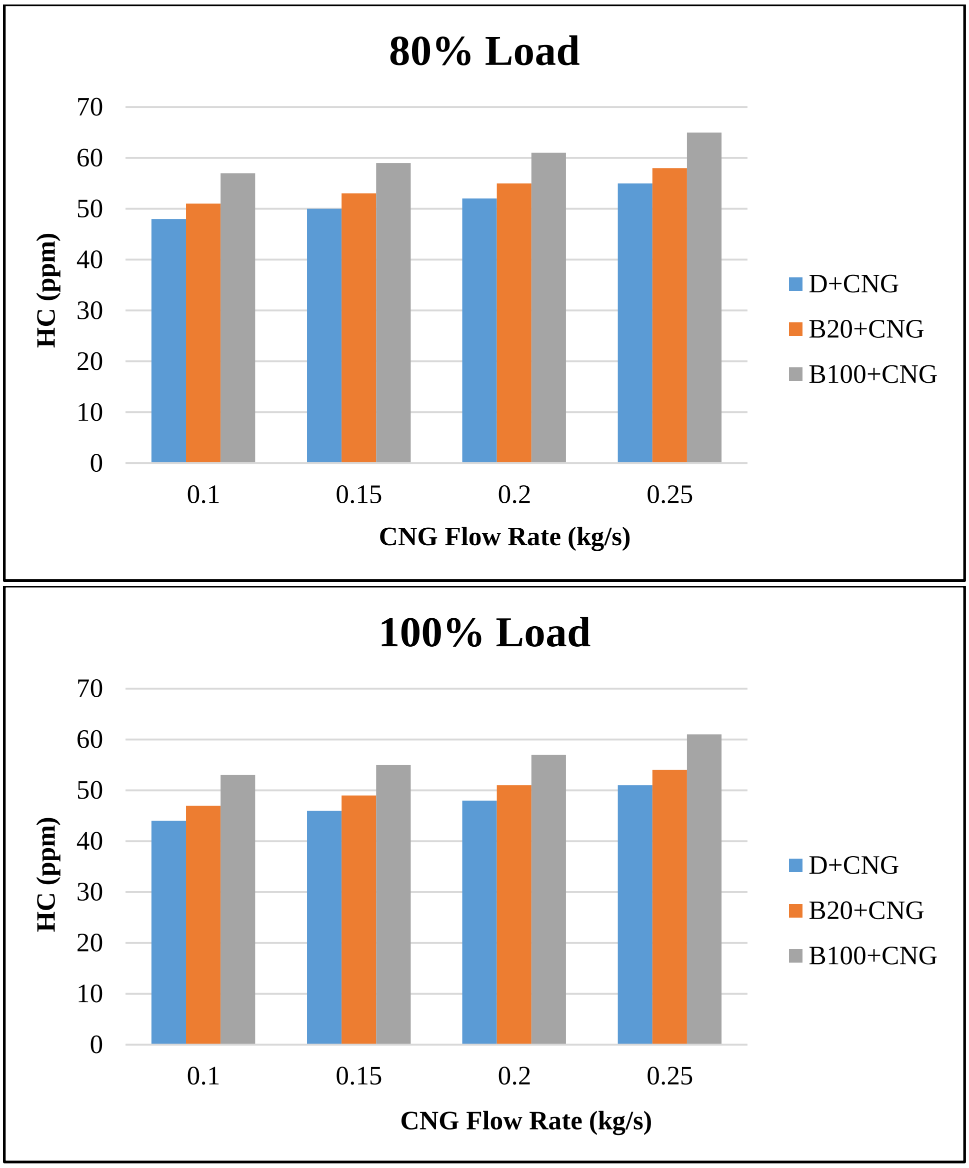

Figure-3. Variation of HC emissions with CNG flow rate

Figure-3 shows variation of HC emissions with CNG flow rates at 80% and 100% loads.HC emissions increasedas the CNG gas flow rates increased as the pilot injected fuels are found to be lower. Total HC emissions creating within areas of quench and are emitted during the process of exhaust. When slightly lean mixtures are there and area of quench is large then extra oxygen terminates many total HC emissions because they later mixed in exhaust system. CNG gaseous fuel being common, dual fuel engine fuelled with biodiesels show higher HC emissions as compared to diesel. This could be due to their lower BTE and calorific value of engine. Further wall wetting associated with viscous biodiesels could also be the reasons for higher HC emissions. However, B20 blends of the respective biodiesels show lower HC compared to pure biodiesels.

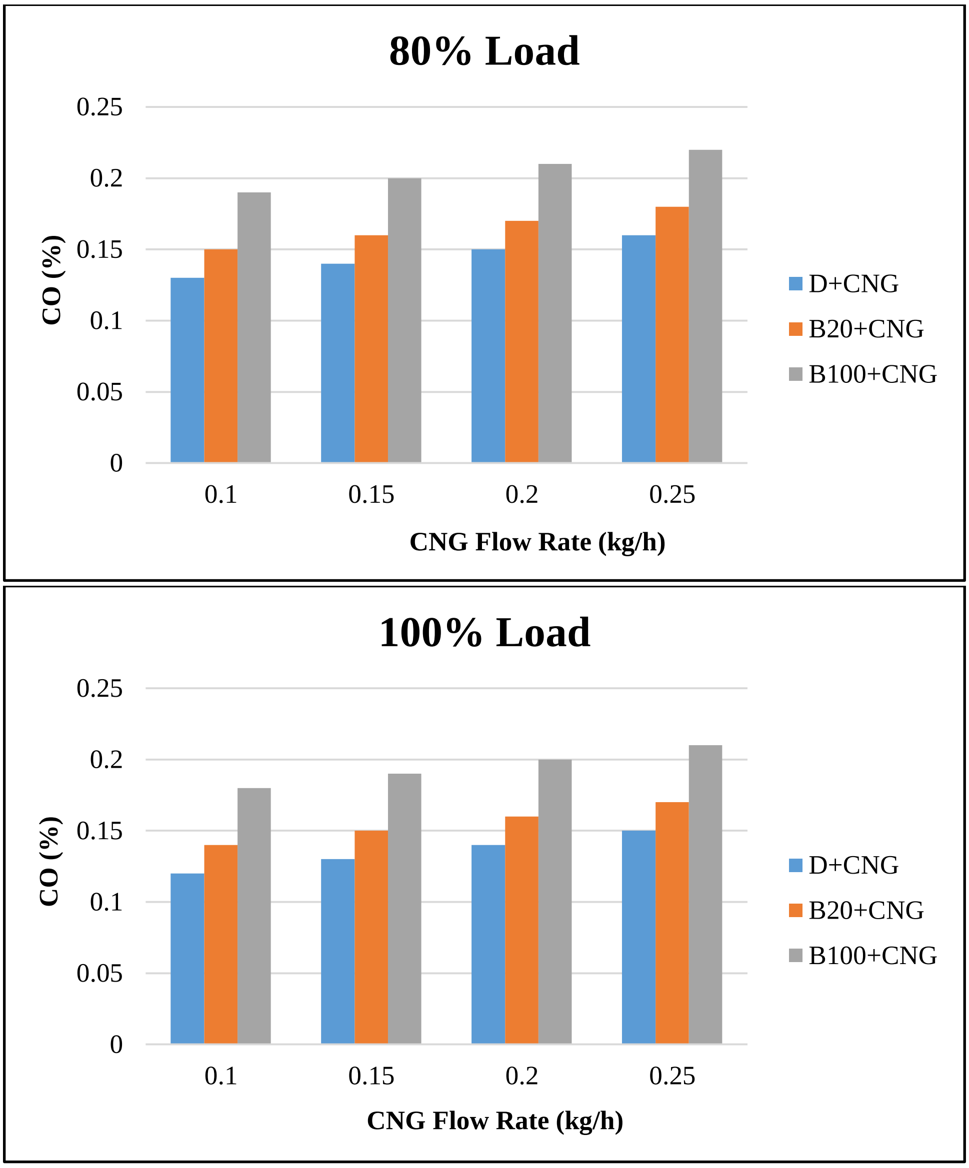

Figure-4. Variation of CO emissions with CNG flow rate

Figure-4 shows variation of CO emissions with CNG flow rates at 80% and 100% loads.Emissions of HC and CO initiate from different boundary layers and crevices which are cooler leading to incomplete consumption. CO emissions also show increasing trends for increased CNG gas flow rates as the pilot fuels are found to be lower. CO emissions of dual fuel engine powered with biodiesels are found to be higher due to incomplete combustion as compared with diesel. CO emission levels primarily depend upon stoichiometric A/F ratio and fuel rich mixture and further emissions of CO emissions increased with the CNG gas flow rates during dual fuel operation.

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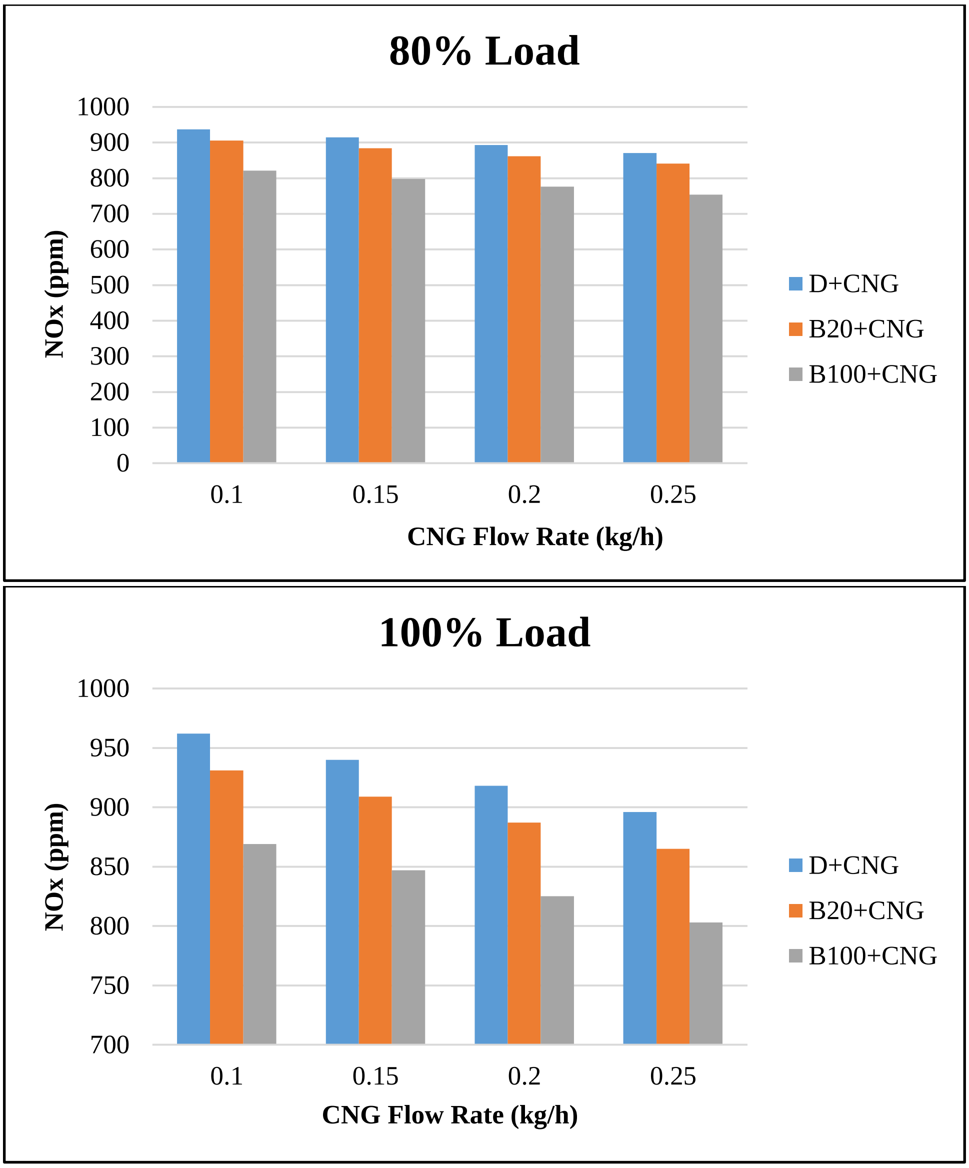

Figure-5. Variation of NOx emissions with CNG flow rate

Figure-5 shows variation of NOx emissions with CNG flow rates at 80% and 100% loads.The NOx formation in CI engine is mainly because of more oxygen supply and higher charge temperature inside the cylinder. For D+CNGdual fuel combustion operation, NOx emissions were higher followed by B20+CNG and B100+CNG fuel combinations. The lower calorific value and heavier molecular structure of injected biodiesels in dual fuel operation leads to higher NOx emissions. As gas flow rate increased for all the dual fuel combinations the NOx emissions levels decreased.

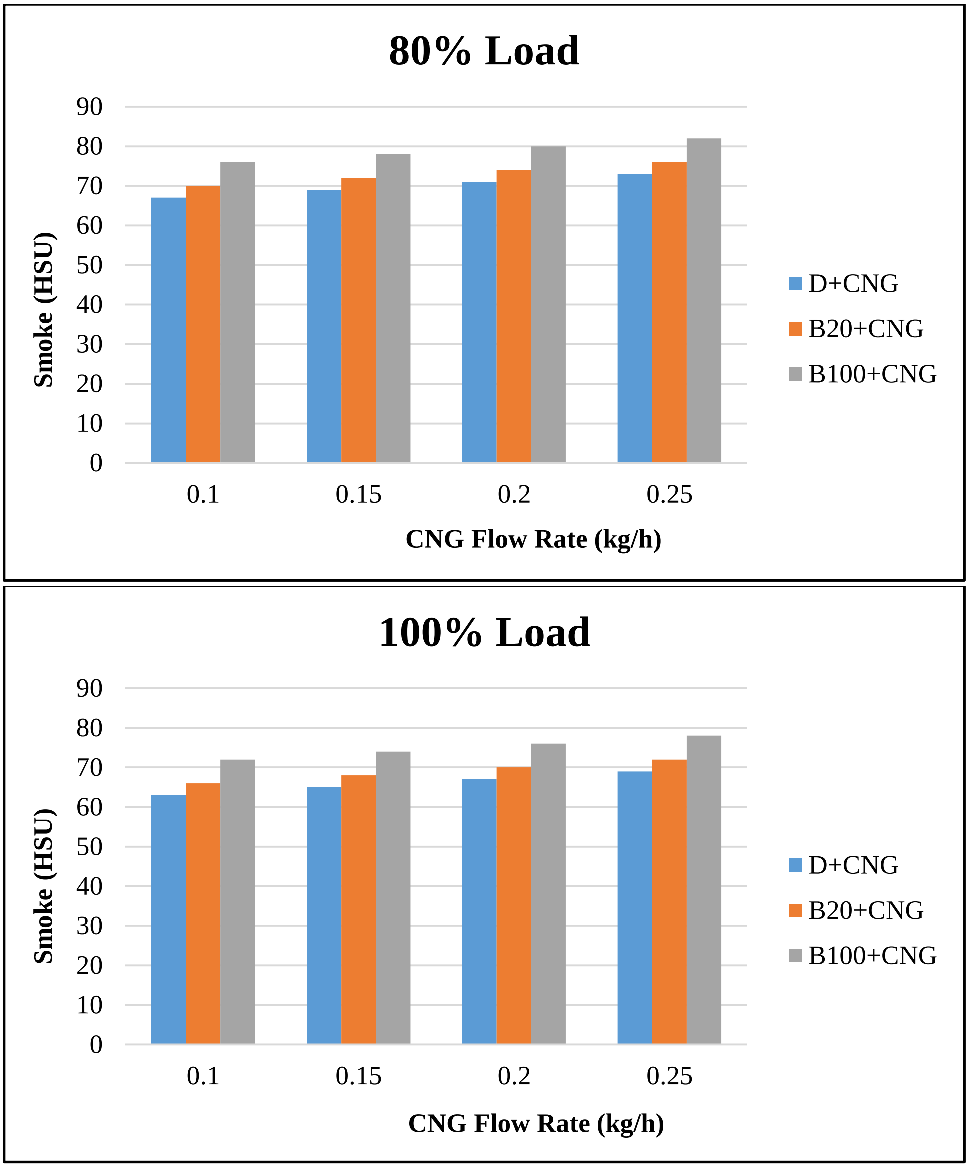

Figure-6. Variation of smoke emissions with CNG flow rate

Figure-6 shows variation of smoke emissions with CNG flow rates at 80% and 100% loads.More amount of smoke emissions are found with increased gas flow rates of CNG and this is due to lower carbon to hydrogen ratio in combinations of fuel. At lower gaseous fuel flow rate during induction the smoke emissions slightly decreased because of higher flow rate of pilot injected fuels resulting into better combustion. However more smoke emissions for the pilot fuels is observed with B100 blends when compared to B20 fuels because of lower viscosity and higher calorific value of B20 fuel.

5. Conclusions

In the present research work, effect of CNG flow rate, on the performance of modified dual fuel engine powered with argemone biodiesel is studied. B20 and B100 blends of argemone biodiesel are used as pilot injected fuels while CNG is used as the manifold inducted fuel in the dual fuel engine. Further influence of CNG gas flow rate on modified dual fuel engine by using conventional mechanical fuel injection system for optimal performance of engine is investigated. The CNG gas flow rate is varied from 0.10 to 0.25 kg/h by using 6 mm gas venture. From the experimental results following conclusions can be made.

- Higher BTE was observed for D+CNG dual fuel combustion mode followed by B20+CNG and B100+CNG at all loads.The increase in CNG flow rate from 0.1 to 0.25 kg/h, resulted in drop in volumetric efficiency in-turn reduced BTE.
- HC emissions increased as the CNG gas flow rates increased as the pilot injected fuels are found to be lower.CNG gaseous fuel being common, dual fuel engine fuelled with biodiesels show higher HC emissions as compared to diesel.
- CO emissions also show increasing trends for increased CNG gas flow rates as the pilot fuels are found to be lower. CO emissions of dual fuel engine powered with biodiesels are found to be higher due to incomplete combustion as compared with diesel.
- For D+CNG dual fuel combustion operation, NOx emissions were higher followed by B20+CNG and B100+CNG fuel combinations.As gas flow rate increased for all the dual fuel combinations the NOx emissions levels decreased.
- More amount of smoke emissions are found with increased gas flow rates of CNG. Higher smoke emissions for the pilot fuels is observed with B100 blends when compared to B20 fuels because of lower viscosity and higher calorific value of B20 fuel.

References

1. Nagesh S.B., Chandrashekhar T.K., Banapurmath N.R., and Khandal S.V., Effect of Injection Timing & Injector Opening Pressures on the Performance of Diesel Engine Fuelled With CeibaPentandra Oil Methyl Ester, Universal Journal of Renewable Energy, 5, 2017, 30-54.
2. Nagesh S.B., Chandrashekhar T.K., and Banapurmath N.R., Injection timing effect on the performance of diesel engine fueled with acid oil methyl ester, IOP Conf. Series: Materials Science and Engineering, 376, 2018, 012002, doi:10.1088/1757-899X/376/1/012002.
3. Nagesh S.B., Banapurmath N.R., Chandrashekhar T.K., and Khandal S.V., Biodiesels powered in-cylinder common rail direct injection (CRDi) Assisted Homogeneous Charge Compression Ignition (HCCI) engine, International Journal of Sustainable Engineering, 14(2), 2021, 147-161, https://doi.org/10.1080/19397038.2020.1811012.
4. Jatadhara G.S., Banapurmath N.R., Chandrashekhar T.K., Nagesh S.B., and Harari P.A., Effect of diesel engine modification operated with karanja biodiesel and its blends, Materials Today: Proceedings, 2022, https://doi.org/10.1016/j.matpr.2022.10.189.
5. Nagesh S.B., Somesha G.H., Tilak S.R., Sachin C., and Naresh H., Performance test on single cylinder diesel engine by lichens biofuel, 45(1), 2021, 161-164, https://doi.org/10.1016/j.matpr.2020.10.410.
6. Harari P.A., Yaliwal V.S., and Banapurmath N.R., Effect of CNG and CBG as low reactivity fuels along with diesel and TPME as high reactivity fuels in RCCI mode of combustion by varying different loads, Materials Today: Proceedings, 47, 2021, 2491–2494, https://doi.org/10.1016/j.matpr.2021.04.557.
7. Harari P.A., Banapurmath N.R., Yaliwal V.S., Khan T.M.Y., Badruddin I.A., Kamanagar S., and Mahlia T.M.I., Effect of Injection Timing and Injection Duration

of Manifold Injected Fuels in Reactivity Controlled Compression Ignition Engine Operated with Renewable Fuels, Energies, 2021, 14, 4621, https://doi.org/10.3390/en14154621.

8. Harari P.A., Yaliwal V.S., and Banapurmath N.R., Experimental investigation on the effect of gaseous fuels energy share on reactivity controlled compression ignition mode of combustion operated with gaseous fuels and liquid fuels, Materials Today: Proceedings, 52, 2022, 1121–1130, https://doi.org/10.1016/j.matpr.2021.11.006.
9. Yaliwal V.S., Banapurmath N.R., Gaddigoudar P., Patil N.D., Harari P.A., Performance and emission characteristics of a diesel engine operated on diverse modes using renewable and sustainable fuels derived from dairy scum and municipal solid waste, Materials Today: Proceedings, 47, 2021, 2592–2597, https://doi.org/10.1016/j.matpr.2021.05.078.
10. Harari P.A., Pattanashetti A., Experimental investigation on the effect of injection timing, carburetor type and exhaust gas recirculation on compression ignition engine fuelled with diesel–compressed biogas and rice bran oil methyl ester–compressed biogas, Integrated Research Advances, 4(2), 2017, 29-36.
11. Harari P.A., Banapurmath N.R., Yaliwal V.S., Khan T.M.Y., Soudagar M.E.M., Sajjan A.M., Experimental studies on performance and emission characteristics of reactivity controlled compression ignition (RCCI) engine operated with gasoline and ThevetiaPeruviana biodiesel, Renewable Energy, 160, 2020, 865-875, https://doi.org/10.1016/j.renene.2020.07.009.
12. Watgave S., Banapurmath N.R., Harari P.A., Comparative study on effect of hydrogen and hydrogen blended compressed natural gas on compression ignition engine operated under homogeneous charge compression ignition and reactivity controlled compression ignition mode of combustion, SAE Technical Paper 2021-28-0010, 2021, doi:10.4271/2021-28-0010.
13. Harari P.A., Banapurmath N.R., Yaliwal V.S., Soudagar M.E.M., Khan T.M.Y., Mujtaba M.A., Safaei M.R., Akram N., Goodarzi M., Elfasakhany A., Seesy A.I., Experimental investigation on compression ignition engine powered with pentanol and thevetiaperuviana methyl ester under reactivity controlled compression ignition mode of operation, Case Studies in Thermal Engineering, 25, 2021, 100921, https://doi.org/10.1016/j.csite.2021.100921.
14. Gaddigoudar P.S., Banapurmath N.R., Basavarajappa Y.H., Yaliwal V.S., Harari P.A., Nataraja K.M., Effect of injection timing on the performance of CeibaPentandra biodiesel powered dual fuel engine, Materials Today: Proceedings, 49, 2022, 1756–1761, https://doi.org/10.1016/j.matpr.2021.08.009.
15. Harari P.A., Yaliwal V.S., Banapurmath N.R., Experimental investigation on the effect of gaseous fuels energy share on reactivity controlled compression ignition mode of combustion operated with gaseous fuels and liquid fuels, Materials Today: Proceedings, 52, 2022, 1121–1130, https://doi.org/10.1016/j.matpr.2021.11.006.
16. Karthik T., Banapurmath N.R., Basavarajappa D.N., Ganachari S.V., Kulkarni P.S., Harari P.A., Effect of injection timing on the performance of dual fuel engine fueledwith algae nano-biodiesel blends and biogas, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.11.156.

17. Sateesh K.A., Gaddigoudar P., Yaliwal V.S., Banapurmath N.R., Harari P.A., Influence of hydrogen and exhaust gas recirculation on the performance and emission characteristics of a diesel engine operated on dual fuel mode using dairy scum biodiesel and low calorific value gas, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.11.187.
18. Muralidhara D.M., Udayaravi M., Reddy C.P., Banapurmath N.R., Harari P.A., Experimental injection timing studies on hydrogen and biodiesel powered dual fuel engines, Positif Journal, 22(11), 2022, 69-83.
19. Sateesh K.A., Yaliwal V.S., Banapurmath N.R., Soudagar M.E.M., Khan T.M.Y., Harari P.A., El-Shafay A.S., Mujtaba M.A., Elfaskhany A., Kalam M.A., Effect of MWCNTs nano-additive on a dual-fuel engine characteristics utilizing dairy scum oil methyl ester and producer gas, https://doi.org/10.1016/j.csite.2022.102661.
20. Muralidhara D.M., Banapurmath N.R., Udayaravi M., Reddy C.P., Harari P.A., and Karthik T., Effect of hydrogen flow rates on the performance of two biodiesels fuelled dual fuel engine, Materials Today: Proceedings, 49, 2022, 2189–2196, https://doi.org/10.1016/j.matpr.2021.09.090.
21. Delgado A.A.M., Anda J., Morales J.M.L., Díaz J.C.M., Mora A.G., Nava J.J.C., Argemonespecies: Potential source of biofuel and high-value biological active compounds, Environ. Eng. Res. 2022; 27(2): 200619, https://doi.org/10.4491/eer.2020.619.
22. Deokar A.J., Harari P.A., and Reddy C.P., Diesel Engine Operated with Various Blends of Argemone Biodiesel, International Journal for Modern Trends in Science and Technology, 8(07), 271-275, 2022.