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Performance Analysis of Enriched Biogas Fuelled Stationary Single Cylinder SI Engine

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Abstract: *This paper presents the performance results of a 7.5 hp Kirloskar Engine make TV 1 research engine which was converted into spark ignition mode and run on Enriched biogas and Petrol at compression ratio of 8 at constant narrow load range around 2 kg and RPM varying from 1100-1800. At constant lower load condition for 1100, 1500, 1800 RPM, Enriched biogas Brake Specific fuel consumption were 10.77%, 24.24 % and 35.63% higher than petrol. At narrow constant load (15%) condition for 1100, 1500, 1800 RPM Brake thermal efficiency were 4.91 %, 8.26 %, 9.41 % for petrol and for Enriched Biogas it were 4.57 %, 6.87 %, 7.13 % respectively, which clearly indicated Brake thermal efficiency is higher in petrol mode. Mechanical efficiency of enriched biogas is 42.93 over 30.87 for petrol which shows mechanical efficiency increase of 39.06% when using enriched biogas engine. Running cost showed tremendous percentage decrease from Petrol to Enriched Biogas of 30.02 %, 25.16 %, and 17.78 % on price bases accordingly. As the Enriched biogas produces advantages over fossil petrol, it could be used as auto fuel for spark ignition vehicles*

Key words: *Biogas, Methane Enriched Biogas, Petrol SI Engine, Compression Ratio, Alternative Fuel, Vehicular Fuel, Engine Performance, Engine Load, Engine Speed*

I. Introduction

Limited non renewable energy source and escalating costs of fossil fuels have forced many countries to consider the use of renewable energy technologies in internal combustion engines like biomass, biogas, solar, hydrogen, ethanol etc. By the year 2070, the world will eat up fossil fuels and hence the enormous increase in biomass research [19, 20]. Engines running on spark ignition or compression ignition are fitted with conversion kits to run on compressed natural gas and liquefied natural gas for use in power plant, transportation etc. CNG (85 % methane and other gases) showed the advantage of reduced exhaust emission and enhanced thermal efficiency in alternative fuel. Organic carbon based materials of plants and animals are called biomass. This biomass maybe transformed by physical, chemical and biological process to biofuels. Anaerobic digestion of organic materials is a combustible gas called Biogas which is composed of methane (60%) and Carbon dioxide (40 %). In most countries, the main biogas quality indicator is the methane concentration, which should be at least 96%, and carbon dioxide, which should not exceed 4%. The Wobbe index is another indicator for fuel that depends on higher heating value and can be used as a basis for comparison between different gases. The concentrations of sulphur, hydrogen and water vapor in gases are also restricted because reactions of these substances can corrode engines [15, 18]. Use of biogas expertise can put in at least 10% national energy requirement and approximately 50% to rural energy requirement [1]. Developing countries like ours India can reduce their import bill by using alternative fuel like biogas and become self dependant as it has 300 million cattle population. Presently India is on the second number position in producing biogas right after China. Almost 2.5 million plants have been built in India with a potential to build over 10 million more, Since the introduction of biogas in 1930. The Indian government views biogas technology as a vehicle to reduce rural poverty. The most popular biogas plants established in the Indian region are of types (i) floating drum type and (ii) fixed dome type plants [3]. A period of 15 days is adequate for anaerobic bacteria to convert organic carbon based biomass into biogas. Feedstocks used for biomethanation are normally animal and human wastes along with municipal wastes and agricultural crops [8].

For increasing the calorific value and to reduce unwanted components e.g. CO_2, Water, H_2S, which are detrimental to utilization systems, it is necessary to clean raw biogas and then upgrade it to a higher quality fuel. This process is called biogas cleaning and upgrading. Water scrubbing, cryogenic separation, physical absorption, chemical absorption, pressure swing adsorption, in- situ upgrading, membrane technology and biological upgrading methods are some of the methods for biogas enrichment [2].

TABLE 1: COMPOSITION OF RAW BIOGAS [2]

Parameter	Biogas from AD	Influence on biogas utilization
CH_4	60-70 %(mol)	
HC	0 %(mol)	
H_2	0 %(mol)	
CO_2	30-40 %(mol)	Declining calorific value, anti-knock properties of engines, corrosion
H_2O	1-5 %(mol)	Corrosion, damage due to formation of condensate and ice
N_2	0.2 %(mol)	Declining calorific value, anti-knock properties of engines
O_2	0 %(mol)	Corrosion
H_2S	0-4000 (ppm)	decay, catalytic converter poison, emissions and health
NH_3	100 (ppm)	Emissions, anti-knock properties of engines, decaying

II. Background For Biogas As An Alternative Fuel In Ic Engine

Papacz presented that biogas to be used as a transport fuel has to be upgraded to at least 95% methane by volume and it can then be used in automobile modified to run on natural gas. Biogas fuelled vehicles can reduce CO_2 emissions by between 75% and 200% compared with fossil fuels. There is a double benefit by reducing fossil emissions from burning diesel and reducing methane emissions from waste manure [4]. Masebinu et al. discussed that biogas is environmentally hazardous if emitted directly into the environment [5]. Prajapati et al. discussed that biogas generally has a high self-ignition temperature so reduced auto ignition delays and hence resists knocking but for that reason cannot be directly used in CI engine. Propatham et al. used mixture of air and biogas provided into engine, compressed and ignited by a spray of fuel with a low self-ignition temperature like diesel or biodiesel, which is called a pilot fuel [15]. Biogas premixed charge diesel dual fuelled compression ignition engine produces lower energy conversion efficiency and higher breaks specific energy consumption at any load [7]. Propatham et al. reported that enhanced swirl showed decrease in HC level and increase in NO level [10]. Furthermore, it improved the performance including brake thermal efficiency and power output. Makareviciene et al. concluded that when exhaust gas recirculation was turned off then excessive high air/fuel ratio results in higher fuel consumption and lower thermal efficiency, yet smokiness, HC, CO decreased and NO level increased [11]. Lim et al. summarized that, despite enriched biogas has a lower calorific value than the natural gases, NOx emissions were lower for the enriched biogas than for the natural gases and no noteworthy differences were seen in fuel economy between the gases in any of the driving cycle [12]. Farzaneh-Gord et al. studied the effects of storing CNG and found that the filling time required natural gas vehicle on-board cylinder to reach its final pressure (200 Bar) in the buffer storage system is 66 % less than the cascade storage system [13]. Bordelanne et al. developed prototype “Toyota Prius II Hybrid CNG Vehicle” and found that Green House Gas emissions from prototype are significantly lower than emissions of gasoline vehicles: approximately 17 % lower in the case of CNG Vehicle and 51 % lower in case of hybrid CNG vehicles. Moreover, in case of enriched biogas emission levels are lowered by 87 % in the case of the Toyota Prius CNG Hybrid prototype and also concluded 80% down green house gas emission in comparison with gasoline [14]. Propatham et al. modified diesel engine to run on spark ignition mode and found an increase in HC and NO level with rise in compression ratio [15]. In addition, lean misfire limit found with an equivalence ratio of 0.64 of compression ratio of 15:1 as opposed to 0.77 with a compression ratio of 9.3:1. Subramanian et al. found no noteworthy difference in fuel economy between enriched biogas (24.11 km/kg) and CNG (24.38 km/kg) [16]. Exhaust emissions such as CO, HC and NOx are slightly higher with enriched biogas than CNG meeting Bharat Stage IV Emission Norms. Alkesh et al. performed the experiment on variable compression ratio research engine and found out that Particulate matter, CO_2, NO_x, emissions are significantly reduced in dual fuel (diesel + CNG) mode as compared to diesel mode. Also, found slight thermal efficiency increased with increasing induction distance away from engine manifold which is 20 cm away from intake manifold rather than 20 cm and 40 cm [17].

In light of above context, objective of the present work was to determine the performance analysis of enriched biogas in variable compression research engine converted into spark ignition engine which can run both petrol and biogas using necessary modification.

TABLE 2: IMPORTANT PROPERTIES OF PETROL AND BIOGAS [9, 16]

Properties	Petrol	Enriched Biogas
Chemical formula	C_8H_{18}	CH_4- 93 % CO_2 -4% H_2-0.06% N_2-2.94% H_2S-20 ppm
State	Liquid	Gas
Lower heating Value (kJ/kg)	44000	42620
Octane rating	88-100	120-130
Cetane rating	-	--
Auto ignition temp.(K)	257	650-750
Stoichiometric ratio	14.7	17.2
Flash Point ° C	-42.77	-
Freezing Point ° C	-43	-
Boiling Point ° C	187-343	-82 to -161
Latent heat of vaporization kJ/kg	349	-
Density at 15^0 C, (kg/m^3)	720	0.9
Flame Speed (m/s)	4-6	0.34
Flammability Limits (volume % in air)	1.4-7.6	5-15

III. Modification Of Research Engine From Di To Si Mode

Engine cylinder head for DI mode was replaced with SI mode. For operating biogas mode, petrol fuel lines were removed and instead biogas is supplied after passing through pressure reducer (Diaphragm pump) with the help of flexible metal and rubber pipes. Control valve for controlling biogas is placed before going to the venturi gas mixer. Biogas fuel flow measurement was done with the help of weighing scale and stopwatch.

IV. Experimental Details And Methodology

A Experimental engine test rig.

Figure 1 show actual arrangement of experimental set-up of modified SI engine in to Biogas fuelled SI engine. Figure 2 indicates schematic of experimental setup.

The experimental engine setup involved following components:

- Variable Compression Research Engine: A 7.5 HP, four stroke, single cylinder, water cooled, multi fuel Kirloskar IC engine assembled by Apex innovation Pvt. Ltd having injection timing at 25^0c BTDC and connected to eddy current type dynamometer for loading.

Fig. 1: Actual Photo of experimental setup showing engine, cylinder, weighing scale

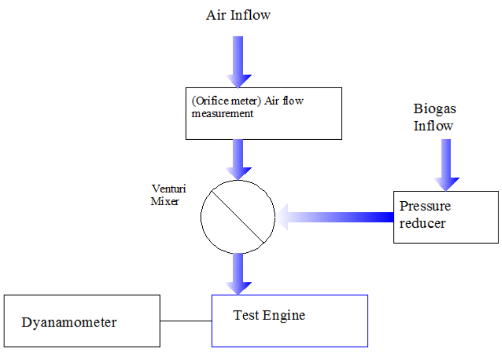

Fig. 2: Schematic Diagram of experimental setup

- Instruments are provided to capture readings of airflow, fuel flow, temperatures and load measurements. Stand-alone panel box consisting of air box, two fuel flow measuring device, system indicators and controllers. Rota meters are provided for cooling water and calorimeter water flow measurement.
- Compression ratio of research engine was varied by loosening allen bolts and then by roatating CR adjuster nut upward or downward and finally fitting lock nut as shown in figure 3.

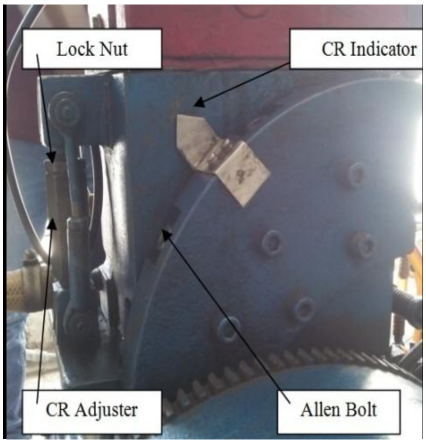

Fig. 3: Compression ratio setting

- Weighing scale for measuring biogas fuel consumption with 50 gram accuracy.
- Pressure reducer to convert Biogas from 200 bar to 1-2 bar.
- Carburettor to supply petrol fuel and air to the engine
- Air flow was provided at stand alone panel box with help of suitable volume air box (Due to pulsating nature of air box) and recorded at manometer.
- Thermocouples for measurement of water and exhaust gas temperature.

TABLE 3: TECHNICAL SPECIFICATIONS

Item	Specification
Make & Model	Kirlosker Research Engines, TV1
Type	Four stroke, Water cooled, Petrol
No. of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	6 to 10
Power rating	7.5 HP
Injection timing	$\leq$ ^{0}25BTDC
Valve Timing	Inlet valve opening (IVO): 4.5^0 before TDC Inlet valve closing (IVC): 35.5^0 after BDC Exhaust valve opening (EVO): 35.5^0 before BDC Exhaust valve closing (EVC): 4.5^0 after TDC
Load Capacity	0 to 20 kg

B Experimental procedure

Engine testing was performed with petrol first and then research engine modified for biogas. During experimental work 1100 to 1800 RPM was varied using accelerator knob keeping load constant at around 2 kg (15 % constant load).

Weight of biogas cylinder was taken step by step in the range of 1100-1700 keeping load nearly constant.

Performance parameters like brake specific fuel consumption (BSFC), Indicated power (IP), Brake power (BP), volumetric efficiency (VE), indicated thermal efficiency, mechanical efficiency(ME) and brake thermal efficiency (BTHE) were calculated later and confirmed with the research engine results.

V. Results and Discussion

The observation for engine performance on petrol and after modification on Enriched biogas for constant load conditions at 1100- 1800 RPM were taken. The results of performance parameters are presented below in detail.

A Brake power

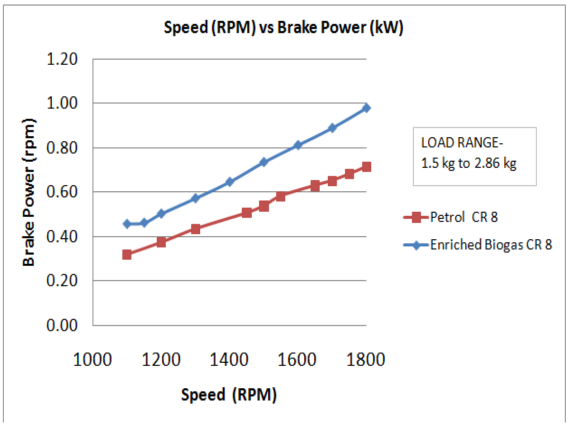

Fig. 4: Speed Vs Brake Power at Lower Constant Load for both Petrol and Enriched Biogas.

Figure 4 shows the correlation between the speed (RPM) and brake power (kW) developed by the engine while operating on Petrol and Enriched Biogas at Compression Ratio 8. It was found that with increase in speed brake power increases for both the cases.

B Brake specific fuel consumption

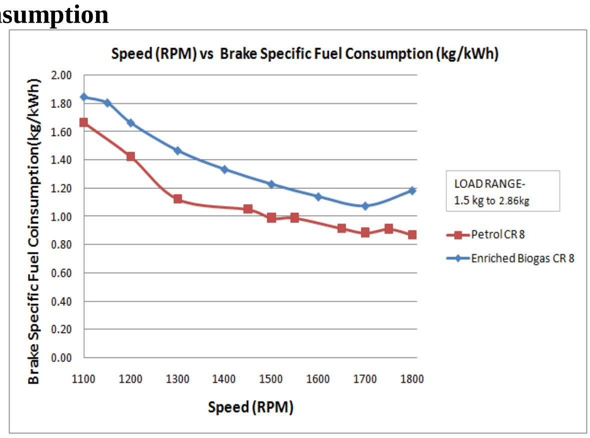

Fig. 5: Speed Vs Brake Specific Fuel Consumption at Lower Constant Load for both Petrol and Enriched Biogas.

As shown in Figure 5 at constant lower load condition for 1100, 1500, 1800 RPM petrol Brake Specific fuel consumption were 1.67 kg/kWh, 0.99 kg/kWh, 0.87 kg/kWh respectively and for Enriched Biogas were 1.85 kg/kWh, 1.23 kg/kWh, 1.18 kg/kWh respectively, which clearly indicates that fuel efficiency is higher in Petrol mode and at higher RPM fuel efficiency tends to increase due to the lower heat loss to the combustion chamber and increasing friction power.

C Brake thermal efficiency

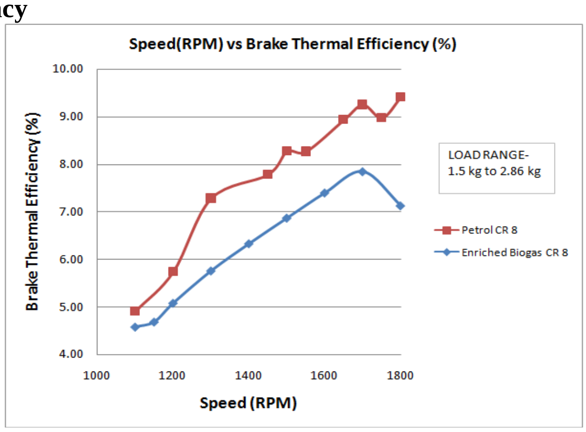

Fig. 6: Speed Vs Brake Thermal Efficiency at Lower Constant Load for both Petrol and Enriched Biogas.

As shown in Figure 6 at constant lower load condition for 1100, 1500, 1800 RPM Brake thermal efficiency were 4.91 %, 8.26 %, 9.41 % respectively for petrol and for Enriched Biogas were 4.57 %, 6.87 %, 7.13 % respectively which clearly indicates lower brake thermal efficiency of enriched biogas.

D Mechanical efficiency

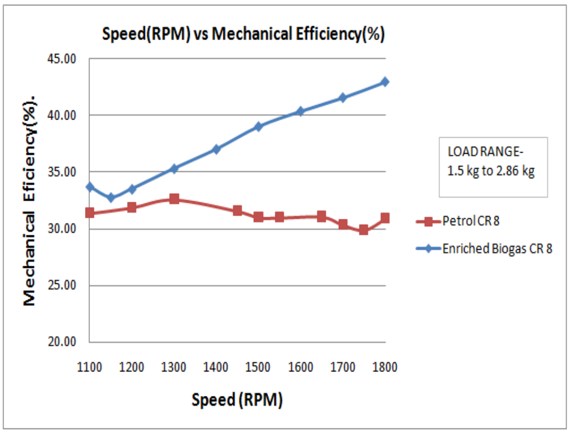

Fig. 7: Speed Vs Mechanical Efficiency at Lower Constant Load for both Petrol and Enriched Biogas.

Form Figure 7 We can see that in this narrow range of constant load mechanical efficiency is higher in enriched biogas and increasing with respect to speed whereas in petrol engine it remains almost constant. Mechanical efficiency indicates that how good an engine is in converting indicated power to useful power considering design and operating condition. Frictional losses are found clearly lower in case of Enriched biogas. At 1800 RPM mechanical efficiency of enriched biogas is 42.93 whereas for petrol it is just 30.87 which show mechanical efficiency increase of 39.06% when using enriched biogas engine.

E Running Cost

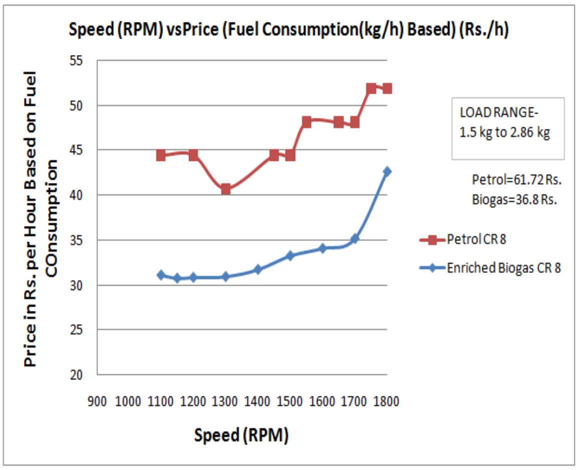

Fig. 8: Speed Vs Price (Rs. /h) at Lower Constant Load for both Petrol and Enriched Biogas.

Form Figure 8 It is found that if the engine run for one hour at 1100, 1500 and 1800 RPM, running cost based on fuel consumption (kg/h) is Rs. 44.43, Rs. 44.43 and Rs. 51.84 for petrol engine respectively and Rs. 31.09, Rs. 33.25, Rs. 42.62 respectively, which clearly indicates percentage decrease from petrol to Enriched Biogas of 30.02 %, 25.16 %, and 17.78 % on price bases accordingly.

VI. Conclusion

It is concluded that Brake specific fuel consumption, Mechanical efficiency in enriched biogas engine is higher compared to petrol engine and its brake thermal efficiency were found low. Running Cost of enriched biogas is very low compared to petrol mode which gives the most important benefit of using enriched biogas over petrol.

References

[1] Nijaguna, B. T. (2006). *Biogas technology*. New Age International.
[2] Sun, Q., Li, H., Yan, J., Liu, L., Yu, Z., & Yu, X. (2015). Selection of appropriate biogas upgrading technology-a review of biogas cleaning, upgrading and utilization. *Renewable and Sustainable Energy Reviews*, *51*, 521-532.
[3] Khoiyangbam, R. S., Kumar, S., Jain, M. C., Gupta, N., Kumar, A., & Kumar, V. (2004). Methane emission from fixed dome biogas plants in hilly and plain regions of northern India. *Bioresource technology*, *95*(1), 35-39.
[4] Papacz, W. (2011). Biogas as vehicle fuel. *Journal of KONES*, *18*, 403-410.
[5] Masebinu, S. O., Aboyade, A., & Muzenda, E. (2014). Enrichment of biogas for use as vehicular fuel: A review of the upgrading techniques.
[6] Prajapati, H. N., Patel, T. M., & Rathod, G. P. (2014). Emission analysis of biogas premixed charge diesel dual fuelled engine. *IOSR Journal of Engineering*, *4*(5), 54-60.
[7] Sorathia H. S., Zala B. H., Suthar D. L., Pipaliyadual V. K., Performance of biogas premixed charge constant speed diesel engines used in an agricultural field, International Journal of Advanced Engineering Technology, E-ISSN 0976-3945
[8] Bora, B. J., Saha, U. K., Chatterjee, S., & Veer, V. (2014). Effect of compression ratio on performance, combustion and emission characteristics of a dual fuel diesel engine run on raw biogas. *Energy Conversion and Management*, *87*, 1000-1009.
[9] Chandra, R., Vijay, V. K., Subbarao, P. M. V., & Khura, T. K. (2011). Performance evaluation of a constant speed IC engine on CNG, methane enriched biogas and biogas. *Applied Energy*, *88*(11), 3969-3977.
[10] Porpatham, E., Ramesh, A., & Nagalingam, B. (2013). Effect of swirl on the performance and combustion of a biogas fuelled spark ignition engine. *Energy Conversion and Management*, *76*, 463-471.
[11] Makareviciene, V., Sendzikiene, E., Pukalskas, S., Rimkus, A., & Vegneris, R. (2013). Performance and emission characteristics of biogas used in diesel engine operation. *Energy Conversion and Management*, *75*, 224-233.
[12] Lim, C., Kim, D., Song, C., Kim, J., Han, J., & Cha, J. S. (2015). Performance and emission characteristics of a vehicle fueled with enriched biogas and natural gases. *Applied Energy*, *139*, 17-29.
[13] Farzaneh-Gord, M., Deymi-Dashtebayaz, M., & Rahbari, H. R. (2011). Studying effects of storage types on performance of CNG filling stations. *Journal of Natural Gas Science and Engineering*, *3*(1), 334-340.
[14] Bordelanne, O., Montero, M., Bravin, F., Prieur-Vernat, A., Oliveti-Selmi, O., Pierre, H., ... & Muller, T. (2011). Biomethane CNG hybrid: A reduction by more than 80% of the greenhouse gases emissions compared to gasoline. *Journal of Natural Gas Science and Engineering*, *3*(5), 617-624.
[15] Porpatham, E., Ramesh, A., & Nagalingam, B. (2012). Effect of compression ratio on the performance and combustion of a biogas fuelled spark ignition engine. *Fuel*, *95*, 247-256.
[16] Subramanian, K. A., Mathad, V. C., Vijay, V. K., & Subbarao, P. M. V. (2013). Comparative evaluation of emission and fuel economy of an automotive spark ignition vehicle fuelled with methane enriched biogas and CNG using chassis dynamometer. *Applied Energy*, *105*, 17-29.
[17] Panchal, A. K., Patel, C. M., Rathod, G. P., & Patel, T. M. Performance and Exhaust Gas Emission of Compressed Natural Gas Fueled Internal Combustion Engine in Dual Fuel Mode.
[18] Shah, D. R., & Nagarsheth, H. J. (2015) Biogas Up Gradation Using Water Scrubbing For Its Use In Vehicular Application, International Advanced Research Journal in Science, Engineering and Technology, 2(6), 46-48. doi: 10.17148/IARJSET.2015.2611
[19] Patel, M. K. B., Patel, T. M., & Patel, M. S. C. (2012). Parametric Optimization of Single Cylinder Diesel Engine for Pyrolysis Oil and Diesel Blend for Specific Fuel Consumption Using Taguchi Method. *IOSR Journal of Mechanical and Civil Engineering*, *6*(1), 83-88.
[20] Patel, T. M., & Trivedi, M. D. Parametric Optimization of CI Engine for Specific Fuel Consumption using Diesel-Sesame Blend.