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Research Article

Development of a Dual Fuel System to Operate Tractor on Biogas

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ABSTRACT

The aim of this study was to develop an alternative green energy-based system to operate a tractor as the tractor is used for maximum farm operations. India is an agriculture-based country and the majority of Indians depend on agriculture for their livelihood. Farm tractors make the tasks easy, reduce labor, and give precise results in lesser time but on the other side, the increasing population and demand lead to depletion of conventional energy resources, and switching towards alternative clean energy is becoming a must thing in the present era. Among various renewable green fuels, biogas is getting much attention in the past few years for its use in stationary engines and has been proven as an alternative fuel to reduce petrol and diesel consumption. Considering this fact, a dual fuel system was developed to use biogas as an alternative fuel in the tractor. Biogas can be an excellent fuel with easy production but raw biogas emission can harm the environment as it contains H_2S pollutants. To overcome this problem, raw biogas can be converted into compressed bio-methane, which is a purified form of biogas and contains higher methane composition, decreased CO_2 composition, and eliminated hydrogen sulphide pollutants. This compressed bio-methane can be filled into cylinders, which serve as a fuel tank in vehicles to lower the conventional fuel consumption. In the present study, a diesel tractor (Swaraj 724) was modified by installing various components and operated on bi-fuel. The tractor was tested under on-load and no-load conditions to check the efficiency, and it was found that using biogas could replace the diesel consumption up to a good extent without knocking problem but the tractor could not be operated on pure biomethane or biogas only; it used both diesel fuel and biomethane fuel simultaneously to operate.

Keywords: *Tractor, biogas, bi-fuel, dual fuel, renewable energy, non-conventional fuel, noise level, bio methane*

Abbreviations: *hr., hour; dB, decibel; PVC, poly vinyl chloride; H_2S, hydrogen sulphide; CO_2, carbon dioxide; kg, kilogram; ml, millilitre; OSHA, occupational safety and health administration*

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INTRODUCTION

India is the fastest developing country and agriculture is the backbone of the rural Indian economy. Most of the Indian population directly or indirectly depends on agriculture for their livelihood. India's agriculture sector has grown very impressively in the last 70 years after independence. Also, mechanization in the agriculture sector is increasing farm efficiency and productivity resulting in huge profit. In terms of global farm and agriculture outputs, India stands in the third position. In mechanization, tractors are playing a vital role in lowering the labor cost, easy and precise operations. Tractors are used for broad farm applications from preparing land for sowing to transportation post-harvesting. Tractors are used for levelling, ploughing, sowing, tillage, spraying, harvesting, transportation, and operating other equipment & machinery.

On the other hand, the population is increasing day by day but the conventional fuels are limited and depleting excessively resulting in a huge energy crisis. It is a must move towards more reliable, clean non-conventional energy resources like solar energy, wind energy, geothermal energy, tidal energy, biogas, etc. Biogas can be an excellent option as it can be produced easily at the farm level. Also, Biogas energy is environment friendly and inexhaustible, which has been proven efficient for operating stationary engines and tractors[4,5,6]. Technologies are developed to increase the methane content in biogas up to 95% and eliminate H_2S pollutants[2]. Treated purified biogas is found better than untreated raw biogas as raw biogas contain methane from 50% to 75% only, whereas, in treated purified biogas, carbon dioxide composition is reduced as carbon dioxide reduces the heating value of a gas[1]. The compressed biogas, also known as biomethane, is filled into the large cylinders, which can serve as a portable fuel tank and can be used as tractor fuel. Although the tractor is not solely operated on biogas or biomethane and it takes some extent of diesel along with biomethane or purified compressed biogas. So, in a dual fuel tractor, the operation can be run on pure diesel fuel or bi-fuel (biomethane + diesel). Tractor can't be operated solely on biogas or biomethane fuel only.

MATERIALS AND METHODS

Tractor

The tractor model (Swaraj-724) 24-horse power, 2 cylinders with the water-cooled engine was selected for the experiment. It was a diesel fuel tractor, which was modified to make it dual fuel. The picture of the high clearance Swaraj-724 tractor is shown in Fig. 1

Fig. 1: Existed tractor used for the experiment

Vaporizer/Low-pressure regulator

A gas vaporizer or low-pressure regulator was used in the experiment as shown in Fig. 2. It was used to supply sufficient gas to the tractor engine. There were inlet-outlet ports for water and gas. It was made up of aluminum, rubber, copper, and iron alloy. It also helped to regulate the quantity of gas towards the engine according to the tractor speed and load variations. The vaporizer was installed between the air inlet manifold and biomethane cylinder for supplying gas to the engine. The radiator inlet hosepipe was modified to supply the hot water into the vaporizer. Thus, the hot water coming from the radiator through pipes flows in the vaporizer where it prevents the cooling of biomethane and then water flows back to the radiator through PVC pipe. As the speed of the tractor is increased, the air intake also increases and the diaphragm in the vaporizer increases the flow of biomethane to the air-fuel mixer.

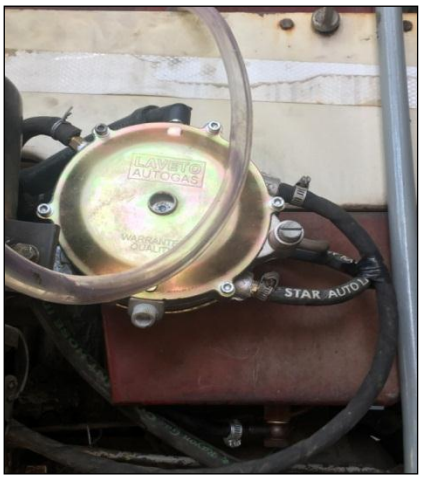

Fig. 2: Gas vaporizer

Throttle body, Air-fuel mixer

After reducing the pressure of gas in the vaporizer or low-pressure regulator, gas fuel was mixed with air for proper combustion. This mixing process was done with the help of an air-fuel mixer. It homogeneously mixes the air and biomethane fuel to produce a complete chemically combustion event in the cylinder. Also, it varies the gas flow according to the required performance and supplies sufficient fuel gas and air for operation of the tractor at maximum speed and load. The air-fuel mixing chamber is shown in Fig. 3.

Fig. 3: Air-Fuel mixing chamber

Gas cylinder

The cylinder was filled with the biogas under the pressure of 150 bars and a pressure regulator was used as shown in Fig. 4. The capacity of the cylinder was 22.2 litres, with a weight of 32.4 kg. It could hold up to 2.8-3 kg of biogas. The biogas cylinder was purchased from M/s Arc Bio-Fuel Ltd, Barnala, there was a long chain of processes for bottling of biogas. The biogas collected in the membrane was to be fed to a roots compressor where the pressure of gas was raised to 0.5 kg/cm^2, this gas was then fed to zeolite molecular sieves based purification unit which had a twin tower arrangement filled with a special arrangement to adsorb H_2S and CO_2 from the inlet gas. The outgoing gas was found free from H_2S and approx. 5% CO_2. One tower was purifying the gas and the other one was taken for regeneration. The composition of biogas is indicated in the table 1.

Table 1: Biogas compositions at inlet and outlet during the gas filling process in the cylinder

Gas composition/parameters	Inlet biogas flow composition	Outlet biomethane gas flow composition
Methane	55-70%	95%
H_2S	1%	Traces
CO_2	45-30%	5%(max)

Fig. 4: Biomethane cylinder

For mounting of the cylinder, Iron strips were hammered and welded on the tractor. The cylinder was mounted in between the strips and screwed with nut and bolt arrangement. In this arrangement, the un-mounting of a cylinder is very easy, just by unscrewing the bolts. A complete clear picture of the tractor after installing all the required components is shown in Fig. 9.

Diesel fuel shut-off solenoid valve

A Diesel fuel shut-off solenoid valve was fitted on the main fuel supply line of the modified tractor. It was used to regulate the supply of diesel to the injection pump. A solenoid valve is an electromechanical valve, which is controlled by electric current. It was fitted to the main supply line of diesel tank so that diesel supply could be stopped at any time during the operation by pulling the choke. Also, it makes the solenoid valve to close and shutting off the supply of diesel fuel to the engine if something goes wrong. Fig. 5 shows the clear picture of the solenoid valve attached to the tractor. Clamp sets were used for fixing the pipes and tightening them to prevent leakage.

Fig. 5: Diesel fuel shut-off solenoid valve

Change over switch

Change over switch was used to on/off the gas supply as shown in Fig. 6. The switch was wired into the tractor's electrical system and fixed on the dashboard of the tractor. There were three positions on changeover switch; for gas/diesel and neutral mode. It works on a pulse sensing mechanism, which cuts off the supply of gas if an engine fails to start within two seconds.

Fig. 6: Change over switch

Boom sprayer

A tractor-mounted air-assisted boom sprayer of make VETO CS-V80 was used to check the fuel consumption of tractor by operating it on biomethane mode. The solution tank capacity was 400 litres. The boom sprayer was linked with the tractor and spraying operation was performed using the boom sprayer (as shown in Fig. 7) and the fuel (biomethane and diesel) consumption was calculated.

Fig. 7: Air-Assisted Boom Sprayer

Portable Sound pressure level meter

The sound pressure level or noise level was noted with portable sound pressure level meter (of make CESVA instruments Spain model no SC-20c) while operating the tractor on bi-fuel and diesel fuel separately. Fig. 8 shows the picture of the noise level meter used for measuring the noise pressure level on the operator seat and near the muffler. It was done to compare the produced sound of a tractor on diesel fuel vs. bi-fuel (biomethane+diesel).

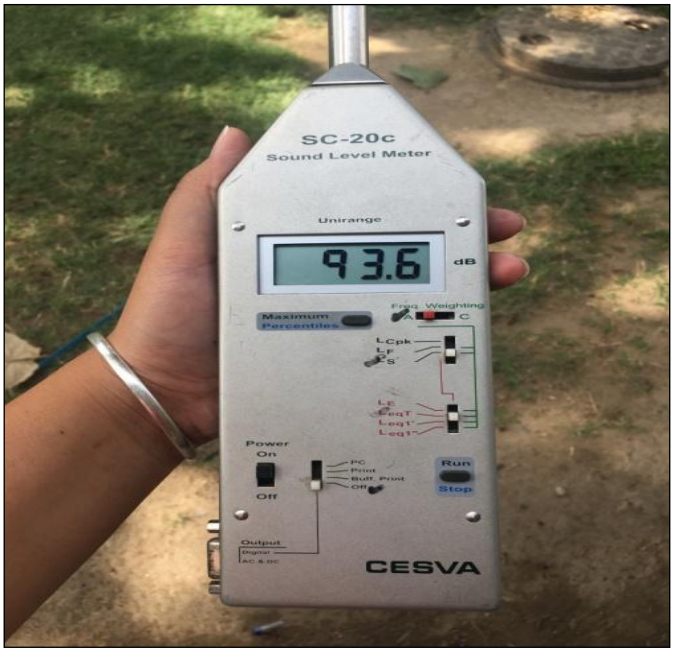

Fig. 8: Portable sound pressure level meter

Experimental procedure

The tractor was run on bi-fuel as well as on diesel fuel mode. For operating the tractor on bi-fuel, change over witch was put on gas mode. The weight of the compressed purified biomethane cylinder was taken both before and after an operation, which provided the available gas in cylinder or gas consumed during the test. Simultaneous consumption of diesel fuel was also noted, as there was still diesel supply by fuel injection system in a certain amount. It was very important to check

the biogas consumption under some heavy load because, in fields, a tractor is used to perform operations using heavy farm machinery. A boom sprayer was linked to the tractor. The tractor was run for 35 minutes under no-load condition but only 7 minutes on load condition because the availability of biomethane during the performed study was limited and the boom sprayer was very heavy which would have otherwise consumed a very high amount of fuel. The fuel consumption was calculated using the following formula

Fuel consumption = (amount of fuel consumed)/ (time for operation)

RESULTS AND DISCUSSION

A picture of the modified tractor with all the installed components mentioned can be seen as following (Fig. 9)

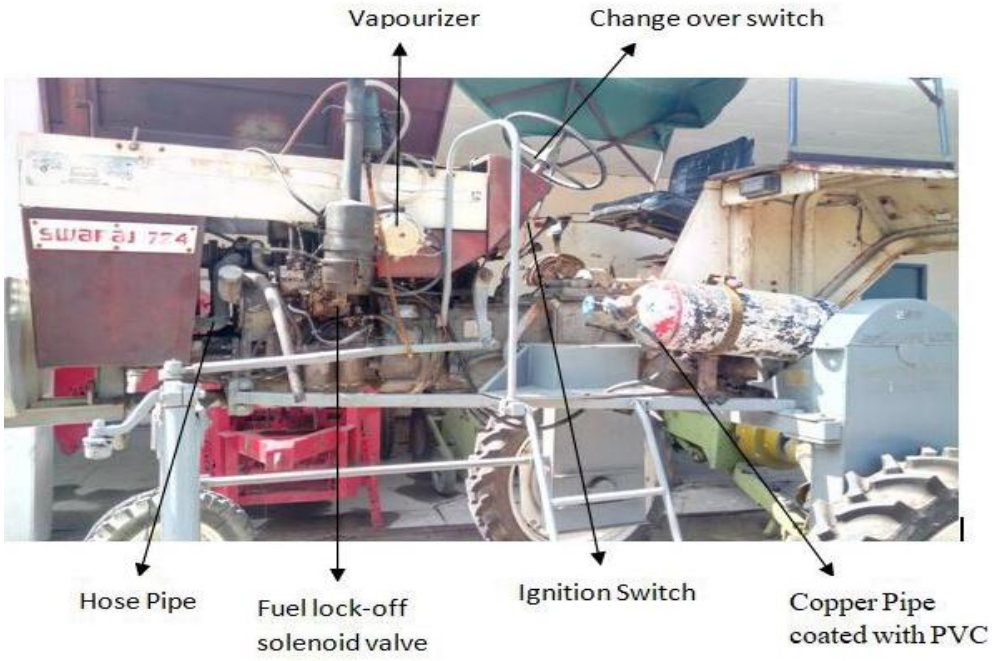

Fig. 9: Modified dual-fuel tractor

Fuel Consumption by the modified tractor

No-load

Table 2 and Fig. 10 show the quantity of fuel utilized by the tractor in 35 minutes of run under no-load condition. Based on it, fuel consumption in kg/hr and the percentage fuel used was calculated. The volume of diesel fuel consumed was converted from litres into kg. It can be seen from Table 2 and Fig. 10, biomethane replaced 66% of diesel consumption.

Table 2: Performance of dual fuel tractor at no-load condition

Mode of Operation	Fuel	Quantity consumed (kg)	Time taken (minutes)	Fuel consumption (kg/h)	Fuel used (%)
Bi-fuel	Biomethane	2.0	35	3.42	66.0
	Diesel	0.193 (235 ml)	35	0.33	34.0
Single fuel	Diesel	0.583 (710 ml)	35	0.99	100.0

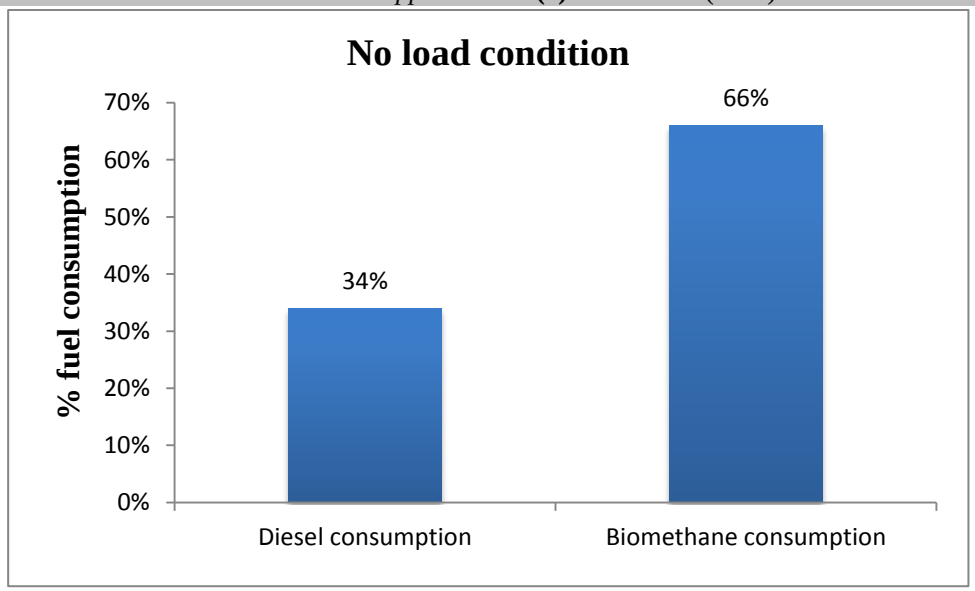

Fig. 10: Percentage fuel consumption by dual-fuel tractor under no-load condition

On-Load

When the boom sprayer of 400-litre capacity was operated with a tractor, biomethane fuel replaced only 31% of diesel consumption as shown in table 3 and Fig.11. This may be due to the reason that the boom sprayer was imposing a very high load on the tractor engine due to which a major part (69%) of diesel fuel was consumed instead of biomethane.

Table 3: Performance of dual fuel tractor under on load conditions

Mode of operation	Fuel	Quantity consumed (kg)	Time taken (minutes)	Fuel consumption (kg/h)	Fuel used (%)
Dual fuel	Biomethane	0.300	7.0	2.57	31.0
	Diesel	0.098 (120ml)	7.0	0.84	69.0
Single fuel	Diesel	0.144 (175ml)	7.0	1.23	100.0

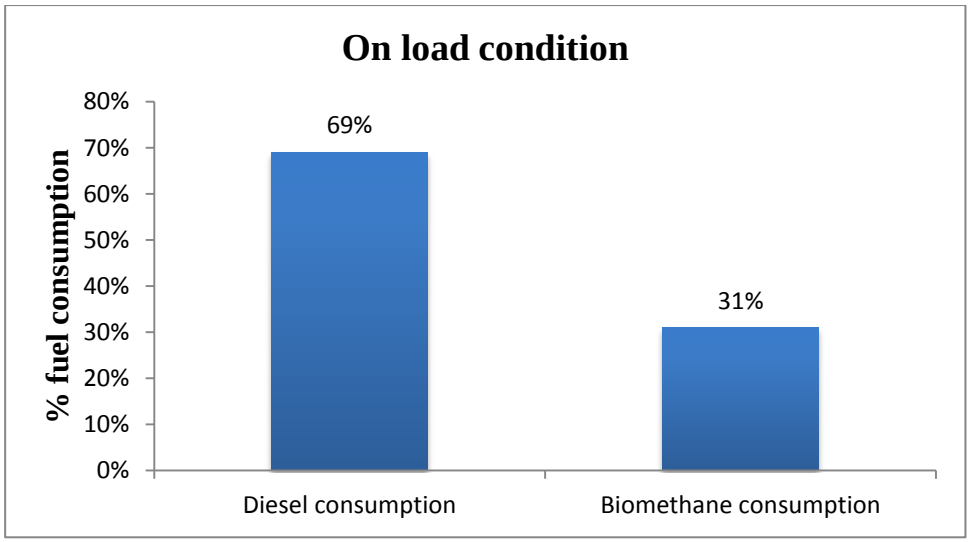

Fig. 11: Percentage fuel consumption by dual-fuel tractor under on-load condition

Sound pressure level

It was very important to check if there was any unnecessary noise level or knocking problem. The noise level was checked on operator seat, as human comfort is an important factor, which needs special attention as the farmer spends a huge time working in the farm, and most of the operations are tractor based. So, a farmer can only perform the tasks efficiently and safely, if human comfort factors are considered. Table 4 shows the permissible exposure time under different noise exposure levels proposed by OSHA.

Table 4: Limits for permissible noise exposure

Time	Permissible Noise Exposures (decibel, dB)
8 hr	90
6 hr	92
4 hr	94
3 hr	95
2 hr	97
1.5 hr	100
1 hr	102
30 minutes	110
15 minutes	115

(Source: OSHA technical manual[3])

Table 5 shows the noise level on the operator seat. The noise level was observed on load and under no-load conditions. The tractor was run on bi-fuel as well as on pure diesel fuel for checking the noise level.

Table 5: The noise level on the operator seat

Test	Bi-fuel (decibel)	Diesel (decibel)
Noise Level (on load)	91.40	93.6
Noise level (no load)	84.10	84.9

Fig. 12 and Fig. 13 show the sound level on the operator seat under no-load and load conditions respectively. It can be seen from the figures that the tractor was not producing any excessive noise or knocking while running on bi-fuel. Even it was noted that under no-load as well as load conditions, the sound produced while running the tractor on bi-fuel was a little lower than that of diesel fuel operation.

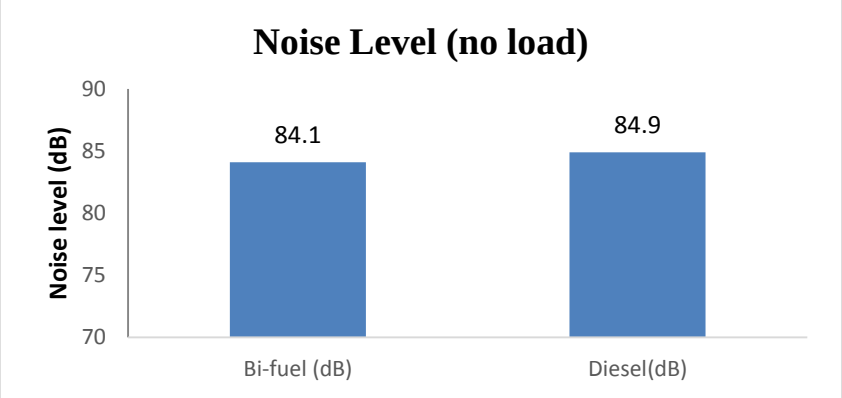

Fig. 12: Noise Level at operator seat (no load)

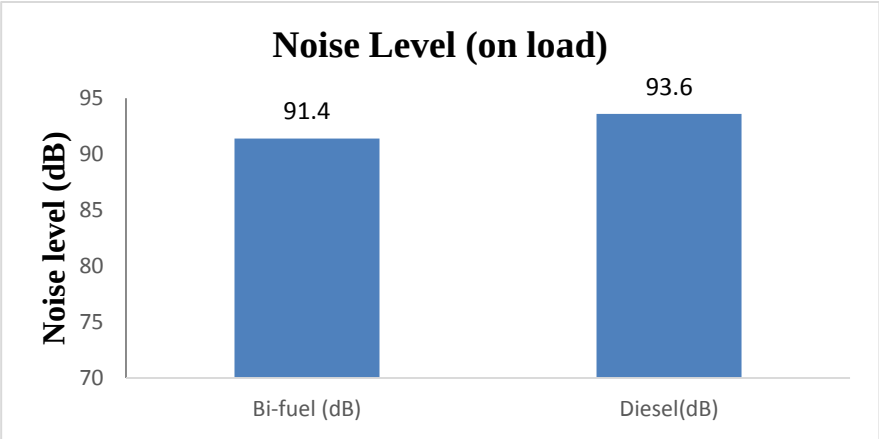

Fig. 13: Noise Level at operator seat (on load)

Table 6 shows the noise level near the muffler of a tractor. Similarly, Fig. 14 and Fig. 15 show the noise level near the muffler under no load and on load conditions respectively. It was observed that there was no knocking sign in case of the bi-fuel operation of the tractor. As noted on the operator seat, the noise level near muffler was also lower in the case of bi-fuel operation as compared to that of diesel fuel operation of the tractor.

Table 6: Noise level near the muffler

Test	Bi-fuel (decibel)	Diesel (decibel)
Noise level (on load)	101.20	102.00
Noise level (no load)	102.00	103.00

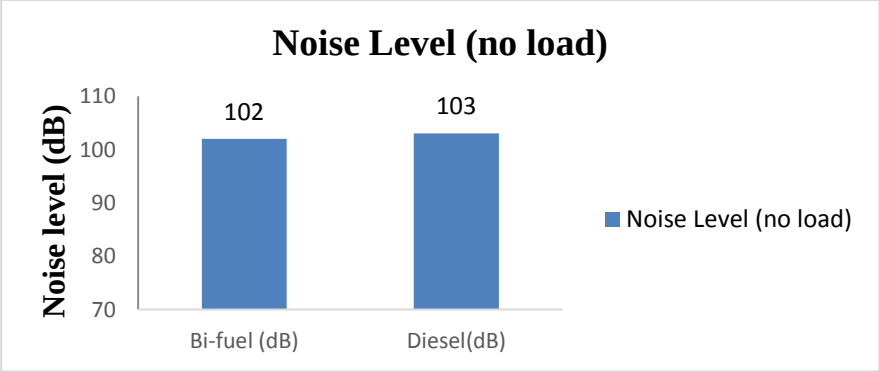

Fig. 14: Noise Level near muffler (no load)

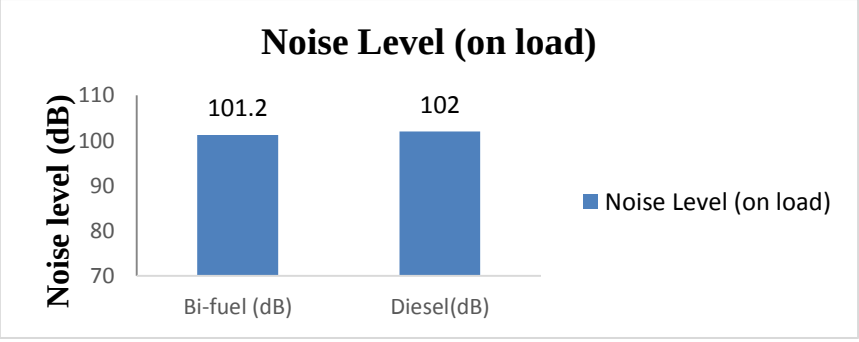

Fig. 15: Sound Level near muffler (on load)

CONCLUSION

The agricultural farm processing largely depends on diesel fuel for its motive power and to a very large extent for power applications. Increased farm mechanization in the agriculture sector further increased the requirement of this depleting conventional fuel. To overcome these associated problems, a diesel tractor was modified to operate it on biogas. Tests revealed that when the tractor was operated on dual fuel mode under no-load condition, gas replaced 66% of diesel which was the desired achievement. On load condition, the load used was a very heavy 400 liters boom sprayer, even then 31% of diesel fuel was replaced. Also, there was no knocking problem while operating the tractor on gas mode. The total cost of raw materials other than labor cost was less than Rs 10,000 /- which clears that the technology is cost-effective and farmers can easily adopt this technology. If this technology is adopted on a large scale, it can help in reducing environmental pollution, global warming, harmful gaseous emission, etc. by replacing conventional fuel.

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REFERENCES

1. Bajracharya, T.R., Dhungana, A., Thapaliya, N. and Hamal, G. Purification and Compression of Biogas: A Research Experience; Journal of the Institute of Engineering, **7(1):** pp. 1-9 (2009).
2. Horikawa, M.S., Purificação de Biogás - Remoção de H2S – MSc. dissertation, PEQ, Universidade Estadual de Maringá, Brazil (2001).
3. https://www.google.com/imgres?imgurl=http%3A%2F%2Fdownload.101com.com%2Fwa-mcv%2Fohs%2Fimages%2Foct7%2F112.gif&imgrefurl=https%3A%2F%2Fohsonline.com%2FArticles%2F2007%2F09%2FIndustrial-Noise-Control.aspx&docid=sUsdHr6jnt6NKM&tbnid=eGfDcZ_s8YHUeM%3A&vet=1&source=sh%2Fx%2Fim
4. Kruczyński, S.W., Pawlak, G., and Wołoszyn, R., The concept of the tractor powered by biodiesel and biogas, *Journal of KONES*, (2012).
5. Pawlak, G., The Concept of a Dual Fuel Highly Efficient Internal Combustion Engine, *SAE Int. J. Fuels Lubr.* **3(2):** 135-141, (2010). DOI: https://doi.org/10.4271/2010-01-1480.
6. Siripornakarachai, S. and Sucharitakul, T. Conversion of Large Diesel Engine to Run on Biogas for High Efficiency Electrical Power Generation. *AAMA, 15 April* (2014).