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Estimation of output parameters for 4-stroke c i engine using artificial neural network with pongamia and biogas as a fuel

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Abstract: -- This paper identifies the technical feasibility of using Pongamia (Honge) oil and Biogas under Dual-fuel mode. This technology can be applied in rural area for electricity generation in developing countries. The use of Honge oil and Biogas is considered as sustainable energy supply, when both are produced locally. The experiment is carried out to study the performance of diesel engine (CI Engine) under dual-fuel mode, which is carried out on 5KW diesel generator set. The esterified honge oil (EHO) blends with diesel and bottled biogas was used for experimentation, and the gas is directly added to inlet air by modifying the induction manifold. The experiment is carried out for varying lamp loads. The engine shows considerably high thermal efficiency for EHO and biogas combination. The mechanical efficiency was improved than diesel biogas operation. One more point noticed that introduction of biogas drastically reduces EHO blends and diesel consumption. The part of paper also describes application of Artificial Neural Network (ANN) to estimate Thermal efficiency and BSFC of the engine, from comparison and observation it clears that ANN estimates close to experimental value when 90% of data is at training set. Estimated Thermal efficiency and BSFC using Artificial Neural Network correlates well with measured value. The mass flow rate, speed temperature, fuel consumption rate and time are used as a input parameters.

Keywords: Bio-Gas, C I engine, esterified honge oil (EHO), Artificial Neural Network (ANN).

1. INTRODUCTION

The most peoples of developing countries don't have accessing modern energy sources for their daily energy needs. They are mainly depending on traditional fuels like coal, wood and petroleum fuels. In world the major part of all energy consumed from fossil sources. These fossil sources are limited and will be exhausted by the near future. Thus many countries looking for alternative sources such as, hydro, biomass, wind, solar etc. the nonconventional fuels have ability to solve many of current problems such as, air pollution, global warming and sustainability issues[1].Biogas and Vegetable oil is one of the renewable, non depleting sources of energy. The content of Vegetable oil close to diesel fuel. Recently Vegetable oils have become more attractive because of their advantage is more over petroleum fuels. The direct use of Vegetable oil in diesel engine leads to problem because of high viscosity and low volatility; doesn't burn completely and forms deposits in fuel injector and combustion chamber. This problem can be eliminated through various techniques;
Among those most important one is subjecting oil to transesterification with ethanol gives low viscous ethyl esters known as biodiesel (BD). The BD can be prepared by using several types of Vegetable oils such as honge, soybean, rapeseed, Sunflower and palm are most studied [2]. Pongamia is one of the nitrogen fixing tree which grows in dry area, produces seeds containing 30-40% of oil. This is medium sized ever green tree which can be planted banks of rivers or sea costs [3].

India is the largest cattle breeding country; there is abundance of raw material for producing biogas and also large quantity of municipal sewage that can be used for this purpose. Which is available at nook and corner of every village and town. One of the alternate methods 'Sulabh' propagates the use of biogas plant that utilizes human excreta as its raw input. Since 35 years India has setup more than thousands of such plants throughout. Biogas obliquely replaces the fossil fuels as it contains methane in natural form. The methane, thus collected is utilized for production of electricity as well as it can be utilized for domestic and automotive sectors also. Recent life cycle assessment studies carried by Ministry of non-renewable Energy Resources of India have demonstrated that methane derived from biogas is one of the most energy efficient derivative and eco-friendly for use in automotive applications. India occupies second position in the world for biogas utilization and fifth in wind energy and also utilizes solar energy abundantly. Renewable energy is contributing about 7-9% of the total power generation in the country [4].

ARTIFICIAL NEURAL NETWORKS

In order to estimate the output parameters of IC Engine when tested with combination of pongemia and biogas, the artificial neural network (ANN) is used. The software of neural network can perform the tasks, to that of a super-computer, which is capable of doing, the way the brain manages exceptionally well. The structure of the brain is found to be of a highly developed network mechanism, which is capable of performing immensely complicated tasks.. The idea behind imputing ANN is that by modeling the major features of the brain and its operation. The computers that exhibit many of the useful properties of SIMULATIONs that are derived from brain. Though the structure of the brain is complex mechanism, but it can be viewed as a highly interconnected network. It consist of relatively simple processing elements. The ANN model is developed for simulation is based on analysis of brain function. However, the developed model must deliberately ignore many small effects. The aim of a model is to introduce simplified version in the system. The topology of neural network consists of framework in which neurons are interconnected. The framework is often designed by the number of layers and each layer equipped with certain nodes per layer. The layers are specified as Input layer, Hidden layer and Output layer. The nodes have interconnection at different layers which is called as 'interlayer connection'. The term 'connectivity' refers to the way nodes are interconnected. Full connectivity means that every node in one layer is complexly connected to every node in its adjacent layer. Yusuf Cay incorporated ANN model, to gasoline engine for prediction of engine performance the predicted values are closely conforms to experimental values [5]. There are numerous published works in various national and international journals (elsever) on successful application of ANN approach in automotive field. Example, Kiani et al. Estimated six out put parameters of a gasoline engine using Back-Propagation ANN [6] with RMSE values are equal to 0.98, 0.96, 0.90, 0.71, 0.99 and 0.96 for carbon monoxide (CO), carbon dioxide (CO2), unburned hydrocarbon (HC), nitrous oxide (NOx) , torque and brake power, respectively. Likewise many models have been developed successfully to model engine output response. Accurate predictions are usually achieved by application of. Back-propagation neural networks with Levenberg–Marquardt's (LM's) learning algorithm [7–13].

The application of ANN architecture varies depends on specific investigation as desired. The data is processed by ANN on selection of number of neurons in the hidden layer, the transfer functions for hidden layer and output layer. Example Kamyar et al., successfully investigated the effect of operational parameter on CRDI engine using back-propagation network with Bayesaian training algorithm [14].For Similar applications in order to attain accurate results a modified approach was developed by Togun and Baysec. Where in individual network architecture was built for each output to improve the accuracy of the ANN predictions [8]. Brahma et al., on the other hand, successfully developed physical model for segregation of data based on the physical processes, to attain accurate ANN predictions for measurement of cylinder pressure [13].. Harun Mohamed Ismail et al., modeled a light duty diesel engine powered with biodiesel blends to predict engine output response using back-propagation feed forward ANN was used with combination of Tansigpurelin transfer functions, TRAINLM training algorithm with neuron value of 10 are the optimum configuration to predict the correlations between four engine control parameters and nine engine output responses [15]. Sayin and Ertunc used ANN for the modeling of test parameters of gasoline engine for prediction of BSFC, BTE, exhaust gas temperature and exhaust emissions. They observed that mean relative errors for the whole of training data and the test data were within 2 to 7% [16].

2 Experimental Procedures

Experiment was conducted in energy conversion laboratory at Sambhram research center, Bangalore. The selected engine broad specification is 5HP, water cooled 4-stroke diesel engine. It was coupled with single phase alternator through universal joint. Fig.1 shows the experimental set-up.the technical specifications of the engine are listed in table 2.1.

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Fig.2.1 experimental set-up

Engine	4-Stoke, Direct injection, Engine
Rated Power	3.6KW
RPM	1500
Compression Ratio	16.5:1
Manufacturer	Kirloskr

The engine is started by manual cranking using diesel fuel and ran above idling RPM for few minutes without load which allows the warming up of engine and also to stabilize all the parameters. The required

engine speed was achieved by altering governor mechanism. Then biogas was introduced at mean time into inlet manifold and ensured that no parameters are altering. Subsequently the different loads are applied gradually in steps the salient parameters are recorded. The recorded parameter for diesel biogas combination is treated as standard base line. The biogas flow rate of 0.02 LPM was fixe adjusting the knob in gas flow meter and recorded the time taken to consume fixed quantity of fuel for different loading . The experiment is conducted for constant engine speed of 1500 RPM. Temperature is monitored using thermocouples and also air consumption was measured using air box method. The above procedures were repeated for different trials or loads. The properties of EHO are determined by different testing procedure and which is tabulated in table 2.2 similarly the composition of biogas is shown in table 2.3

Table 2.2: Properties of 100% Pongamia oil

Sl. No	Composition	Percentage	Testing Procedure
1.	Density@15°C, kg/m^3	892.19	IS 1448(Part-16)
2.	Flash Point, °C	104	IS 1448(Part-66)
3.	Fire Point, °C	110	-
4.	Kinematic Viscosity @40°C,cSt	7.48	IS 1448(Part-25)
5.	Sulphur content, ppm	Nil	IS 1448(IP-336)
6.	Pour Point, °C	-9	IS 1448(Part-10)
7.	Cloud Point, °C	+4	IS 1448(Part-10)
8.	Calorific Value, Cal/g	8134.33	IS 1448(Part-7)
9.	Specific Gravity	0.89	IS 548(Part-1)

Table 2.3: Properties of Biogas

Sl. No	Biogas Composition	Percentage	Testing Procedure
1.	Methane, %	90.64	By Gas Chromatography
2.	Carbon dioxide, %	5.96	By Gas Chromatography
3.	Oxygen, %	0.10	By Gas Chromatography
4.	Hydrogen sulphide, ppm	BDL	By Gas Chromatography
5.	Nitrogen, %	2.48	By Gas Chromatography
6.	Hydrocarbons(C_2 to C_3),ppm(other gases)	BDL	By Gas Chromatography
7.	Moisture, ppm	2.0	By Gas Tube Analyzer

3 Construction of ANN model

In this experiment feed-forward back propagation network was designed and applied. This network equipped with six input layers, ten hidden layers and two output layers. The input data sets and corresponding output data sets are required to train and test the network. To develop ANN model the available experimental data set has been divided into two sets. One set for training the network and the other was used to verify the capabilities of network. Haykin has presented a mathematical model for testing and training ANN [17]. The weights which are in the hidden layers are adjusted by training the network. The weights are stabilized by training the ANN using input and output data sets which are obtained by experiment. The weights are adjusted to minimize the error between outputs of network to actual value. Once the training is completed, estimation of new set of data may be obtained by using the already trained network. The input parameters are load, rate of gas flow, percentage of biodiesel and the out put parameters are BSFC, thermal efficiency. The neural network toolbox of MATLAB07 is used to develop the network and tangent sigmoid transfer function was used in the hidden layers. The network is trainined by using Levenberg-Marquardt method. The performance index of TrainLM algorithm is the mean squared error (MSE) [18] and it is formulated as given below.

$$\text{MSE}=\frac{1}{\text{N}}\sum_{i=1}^{N}(y_i - y_k)^2 \quad (1)$$

Where, yi is the predicted value of the ith pattern, yk is the target value of the ith pattern and N is the number of patterns.

Network	Feed forward back propagation
Means Square Error [MSE]	4.16
Epoch	100000
R	0.97797
Gradient	1.00
Performance	4.16
Training Algorithm	Levenberg Marquardt
Topology	6-10-10-2

4 RESULT AND DISCUSSION

The performance of diesel engine was studied using Pongamia oil and biogas with varying load. The behavior of the engine for various operating condition are discussed.

4.1 Specific Fuel Consumption (SFC)

Specific fuel consumption by the engine for a hour is calculated on varying the load and the relation is drawn. From graphs it is clear that specific fuel consumption decreases with increase in load which is normal behavior of diesel engine. Fig.4.1, it shows that SFC for pongamia and biogas combination is slightly high compared to diesel, biogas mixture. This is because of low heating value of Pongamia (EHO) and biogas combination.

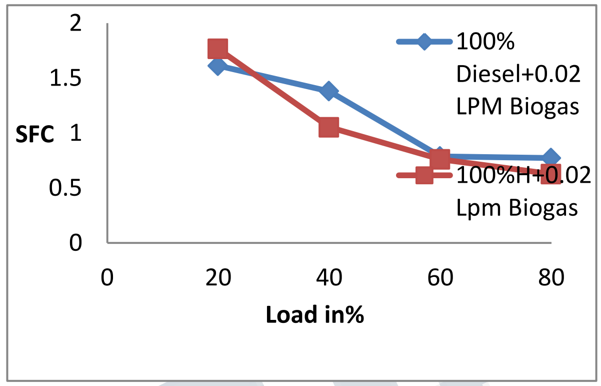

Fig.4.1 SFC esterified pongaimai oil + 0.02 LPM biogas

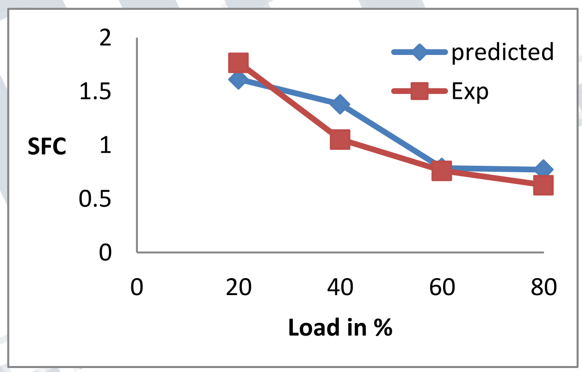

Fig4.2 comparison of predicted and exp. Vales of SFC

Fig.4.2, Shows the comparison between actual Specific Fuel Consumption (SFC) and with ANN predicated SFC. The predicted values are correlating well with experimental data at lowest mean square error (MSE) of 0.0099662.

4.2 Brake Thermal Efficiency (BTE)

Generally brake thermal efficiency increases with increase with optimum load. From fig.4.3 it clearly shows that the maximum BTE were observed for diesel and biogas combination at a load of 800w to 1000w, brake thermal efficiency for Pongamia and biogas considerably higher as compared with diesel. The maximum thermal efficiency at full load may be due to complete combustion of the fuel. [5]. Fig.4.4 indicates the predicated value of thermal efficiency is close to measured value but a slight

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deviation was observed at predicted value this is because of less data used for training network at load of six hundred watts.

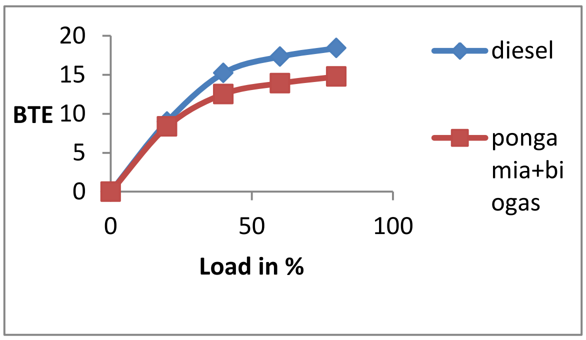

Fig.4.3 BTE for esterified pongaimai oil + 0.02 LPM biogas

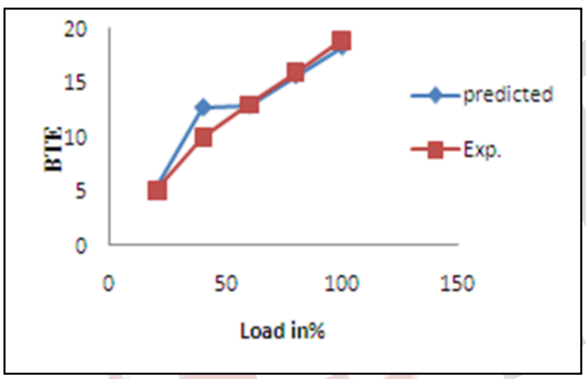

Fig4.4 comparison of predicted and experimented. BTE

4.3 Mechanical Efficiency (ME)

Improved mechanical efficiency was observed, at full load and engine speed of 1500 RPM. From the fig. 4.5 & fig. 4.6, it clearly shows that diesel and biogas blend is giving considerably high mechanical efficiency than pure diesel. Similarly improved mechanical efficiency was noticed at 100% esterified pongamia oil and biogas. The slight improved mechanical efficiency was noticed due to biodiesel has good lubricating property than diesel.

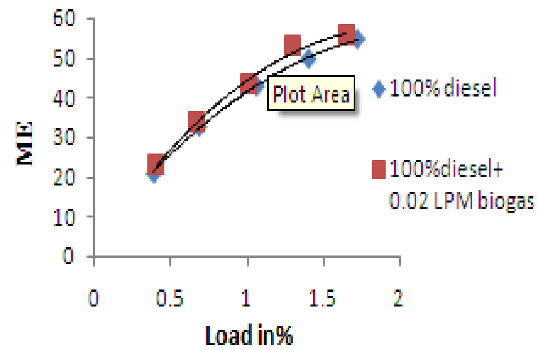

Fig.4.5 ME for esterified pongaimai oil + 0.02 LPM biogas

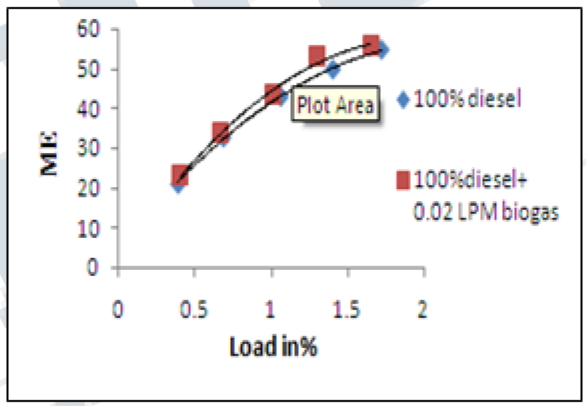

Fig.4.6 ME for 100% biodiesel + 0.02LPM biogas

CONCLUSIONS:

- The experiment was conducted to study the Practical feasibility of biogas application with pongamia in C.I.Engine. It was observed and dual-fuel mode was recommended for biogas operation.
- From results it is evident that there is a reduction in diesel and pongamia oil consumption was noticed when biogas was introduced.
- There is an improved thermal efficiency and reduced total fuel consumption was observed for biogas flow rate of 0.5LPM.

- The improved mechanical efficiency is noticed for 100% pongamia and biogas combination.
- The rise in exhaust temperature was observed with biogas and also rough engine noise was noticed when supplement fuel (biogas) proportion was gradually increased.
- It was also observed that there is significant reduction in CO, HC and smoke emissions for all Pongamia blends when compared to diesel fuel. However, NOx emission of Pongamia is marginally higher than that of diesel.
- The CO and HC emission was higher with biogas, Pongamia combination at full load condition
- NOX emissions at full load was lower under dual fuel mode with biogas
- Dual fueling with biogas reduces the smoke at full load.
- The ANN model is developed to predict the engine performance such as BSFC and BTE.
- The predicated values are with in the acceptable range when more data was used for trainin the network.
- The Predicated BTE and BSFC are correlates well with experimental values.

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