PREDICTION OF PERFORMANCE PARAMETERS USING ARTIFICIAL NEURAL NETWORK FOR 4-STROKE CI ENGINE FUELED WITH ESTERIFIED NEEM OIL AND BIOGAS

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Abstract: Experiments on the technical feasibility of the use of esterified neem oil and biogas under dual fuel mode have been carried out in a 3.7 kW diesel engine. Esterified neem oil (ENO) blends and bottled biogas were used for the experimentation. Biogas is directly mixed with the inlet air in the induction manifold and tests were carried out for varying loads and pressures. The performance parameters obtained from test were within the acceptable range for ENO and biogas combination. Mechanical efficiency was improved and ENO consumption was reduced due to higher biogas introduction; however, a distinguishable noise was noticed when further increase in supply of biogas. Artificial neural network (ANN) technique was also applied for prediction of thermal efficiency and BSFC of the engine. The input parameters for ANN method were speed, gas flow rate, temperature, total fuel consumption, and load. It was seen that ANN predicted performance values were close to experimentally obtained data when 90% of data were in training set.

Key words: Biogas, CI engine, esterified neem oil, artificial neural network.

1. Introduction

Our nation is in the middle of a radical change, that is propelling the nation to intermediary phase in many areas of planetary interaction. A huge suffrage in nation is covering over 1/6th of the planetary population and it has biggest economy which occupies third place in the world. From past three decades, Hindustan modernization has been accelerated up and few protocols have been popularized to speed up future expansion. The country has more openings in various areas with challenges, the income of people and standards of living are on progress. Nation is still stands in third place in the sphere as an indigent country and GDP of the nation is below the intercontinental average. The planetary power demand since 2000 has
been increased almost 10% for which India is responsible; its power need in this time period has almost multiplied. India’s share of energy demand globally raised from 4.4% to 5.7 between 2000 and 2013.

In 2014, the country’s oil consumption stood at 3.8 mb/d, approximately 40% of which is used as a fuel for transportation sector. The diesel need has been shot up and 70% of which accounting as a propellant for road shipment use. This is because of huge share of goods transportation by road. The union government is giving financial support for diesel, that place the financial value of diesel relatively low but from end of 2014 government is taken back subsidy on diesel. Since 2000, Liquid Petroleum Gas use has increased gradually, by reducing 0.5 mb/d of gasoline in 2013. This will down the gasoline usage and pushed it to third position. The increasing in Liquid Petroleum Gas need is due to amplifying urbanization and continued financial support. Natural gas is one more alternative source whose contribution was comparably little of the total energy mix. Now a days we are starting to use renewable energy sources such has solar, geothermal and wind are used predominantly in the power sector their role is relatively small in the total energy mix.

The depleting nature of fossil fuel and increasing demand resulting a steady rise in price of petroleum fuels and gas directly or indirectly affects on economic stability of the country and also affects common man’s lifestyle. India imports 70% of petroleum products from other countries spending more on foreign exchange. The growing populations and governmental subsides demand more energy compared to last few decades. To overcome this increasing energy need and also to minimize the harmful emissions by petroleum fuels, the best way is optimum dependency on exhaustible fuels and look for non-exhaustible resources; such has solar energy, biomass, and wind energy.

The methyl or ethyl esters of fatty acids are commonly termed as “biodiesel”. The biodiesels made from vegetable oils, because of good property and quality, can be adequately used in diesel engines [1]. Biodiesel has been considered as an ideal alternative for diesel fuel because of its environmental friendly property and it has huge potential to provide comparable engine performance results. Biogas and Natural gases can be the better substitute fuel for gasoline engine and diesel engine engines [2, 3]. Many research data propose that it is achievable to enhance the compression ratio of biogas fuelled engine when CO2 is present in biogas [4, 5]. When bio fuels are used, it releases only fractional amount of carbon in its emission [6], so that biogas can be used for heating purposes, power generation etc. [7, 8]. Usage of biogas in engine promote the engine efficiency because of complete combustion in the engine cylinder [9].

1.1 Artificial Neural Networks

Neural Network is used as a predictor of engine output parameter in this experiment; the neural network can perform the multiple tasks like a super-computer, which is capable of doing, the way the brain can manage exceptionally well. The structure of the brain is found to be of a highly complex network mechanism, which is capable of performing immensely complicated tasks.

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.

A gasoline engine was modeled by ANN to estimate engine performance. The estimated values are near to experimental values [10]. There are number of works published in various national and international journals on fruitful function of Artificial Neural Network approach in automotive sector. A network was designed to estimate six output parameters of a gasoline engine using Back-Propagation network[11] with RMSE values are equal to 0.98, 0.96, 0.90, 0.71, 0.99 and 0.96 for CO, carbon dioxide,
unburned hydrocarbon, nitrous oxide, torque and BP respectively. Likewise, many models have been
developed successfully to model engine output response. Predictions with Accurately are achieved by
application of feed forward back-propagation networks with Levenberg–Marquardt’s (LM’s) learning
procedure [12–18].

The application of ANN architecture varies, depending on specific investigation as desired. The
data are processed by ANN selection, number of neurons in the hidden layer and transfer functions.
Kamyar et al. successfully researched the effect of operational parameters on CRDI engine using back-
propagation network with Bayesain training algorithm [19]. For Similar applications, in order to attain
accurate results, a modified network was developed by Togun and Baysec. Other researchers are fruitfully
developed a model for segregation of data based on the physical processes, to attain accurate ANN
predictions for measurement of cylinder pressure [18]. Harun Mohamed Ismail et al. modeled a diesel
engine powered with blends of biodiesel to predict engine output response using back-propagation feed
forward ANN. The Tansig / Purelin transfer functions, TRAINLM training algorithm is used with 10
neuron, to predict the correlations between engine control parameters and engine output responses [20].
Sayin and Ertunc applied ANN for modeling the parameters of spark ignition engine such as brake
specific fuel consumption, thermal efficiency, burnt gas temperature and emissions. They found that
maximum MRE reached for whole set of training data and test data was within 2 to 7% [21].

2. Experimental Set-Up and Procedure

Experiments have been carried out on naturally aspirated, four-stroke, single-cylinder, water
cooled compressed ignition engine (Fig. 1). Table 1, shows the technical specification of the engine is.
Diesel is delivered by high pressure pump to the multi-hole orifice. A fuel switching system is used to
operate two separate fuel tanks. The diesel utilization by engine can be monitored with the help of a
burette. The diesel engine is coupled to an electrical loading, sensors are provided to measure water
temperature and exhaust temperature. The air consumption rate was measured using air-box method by
taking monometer head differences and also an entry is provided after the air-box on intake manifold for
biogas. Bottled biogas is connected to the engine through pressure control valve and rotometer. Emission
of exhaust gas is measured by an AVL Digas 444 analyzer which measures the HC and NOx.

Initially neat diesel is used to run the engine with the compression ratio of 16.5:1 at a injection
angle of 26° BTDC. An electrical load is applied on engine starting from null load to 80% with an
increment of 20% of load in each run up to 80%. When an engine reach the steady state the parameters
such as time taken for 10cc diesel consumption, voltage, current and exhaust emissions were measured.
Then blends of NOME (Neem Oil Methyl Ester) with percentage of 25%, 50%, 75%, and 100%. Is used
to run the engine by which the Performance parameters and emissions were measured. The gas flow at 0.5
LPM was supplied to the engine for all blends. The entire experiments were repeated for injection
pressures of 180bar, 200bar and 220 bar. The properties of NOME are determined by different testing
procedure and which is tabulated in Table 2. The composition of biogas is shown in table 2.
Table 1: Technical Specification of Engine

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

Fig. 1 Experimental set-up

Table 2: Properties of NOME

| 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( C₂ to C₃), ppm( other gases) | BDL       | By Gas Chromatography               |
| 7.      | Moisture, ppm      | 2.0        | By Gas Tube                         |
3. Construction of artificial neural network model

In this proposed work, feed-forward back propagation network was designed and applied. This network is equipped with four 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, available experimental data set is divided into two groups. One group of data for training the network and the other was used to validate the network. Haykin has presented a mathematical model for testing and training ANN [22]. 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 predicted outputs to actual value. The input parameters are load, percentage of biodiesel, injection angle, injection pressure. The output parameters are BSFC, thermal efficiency. The toolbox of MATLAB07 is used to develop the network and tangent sigmoid transfer function has been used in the hidden layers. The network is trained by using Levenberg-Marquardt method. The performance index of TrainLM algorithm is the mean squared error (MSE) [23] and it is formulated as given below in Table 4.

| Properties          | Neem oil | NOME | Diesel |
|---------------------|----------|------|--------|
| Density (gm/cm³)    | 0.920    | 0.868| 0.830  |
| Viscosity CST       | 35.83    | 3.8  | 2.9    |
| Heating value MJ/Kg | 44.65    | 39.81| 43     |
| Cloud point °C      | 19       | 09   | -2     |
| Flash point °C      | 100      | 73   | 58     |
| Fire point °C       | 109      | 78   | 63     |
| Pour point °C       | 10       | 02   | -16    |

Table 2.2 properties of biogas

Table 4. Neural Network Parameters

| 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                     |
Where, \( y_i \) is the predicted value of the \( i \)th pattern, \( y_k \) is the target value of the \( i \)th pattern and \( N \) is Number of pattern.

The architecture of ANN employed is shown in Fig. 2.

4. Results And Discussions

A number of experiments are conducted on diesel engines fuelled with diesel, biodiesel blends and biogas. The experiment is carried out for standard injection timings (26° BTDC) with injection pressure of 180bar, 200bar and 220bar. The found results of experimental work are presented in the following sections. The configuration of different biodiesel blends and biogas with diesel was described earlier.

4.1 Specific Fuel Consumption

The variation of specific fuel consumption with load at different pressures for diesel and NOME+biogas is presented in Figs. 3 to 5. The BSFC decreases with increasing loads, which is a normal behavior of diesel engine for all pressures. By the experiment it is observed that SFC increases as the NOME percentage increases. This is because of high viscosity and low heating value of both NOME+biogas. The SFC of B25+biogas combination is almost close to diesel for all injection pressures. A slight decrease in SFC was observed at 200bar pressure compared to 180bar and 220bar. The reduced
SFC is due to proper mixing of air and fuel particles and also at 200bar all the fuel particles undergo combustion process without escaping and sticking to wall of combustion chamber.

![Fig 3: Brake SFC for NOME+0.5LPM](image)

![Fig 4: Total Fuel Consumption for NOME+0.5LPM Biogas](image)

![Fig 5: SFC for NOME+0.5LPM Biogas](image)

4.2 Brake Thermal Efficiency

Figs. 6 to 8 show the fluctuation of computed thermal efficiency with various injection pressures for different percentage of biodiesel blends and constant flow of biogas.
The found result for blends of NOME is compared with diesel fuel. It shows that Injection pressure is one of the governing parameters, which affects on thermal efficiency [22]. The BTE is computed for three different injection pressure such as 180 bar, 200 bar, and 220 bar. It is found that maximum thermal efficiency is reached when injection pressure is 200 bar. This is because of proper atomization, this leads to formation of fine fuel particles which mixes uniformly with air. At higher injection pressure of 220 bar, wall-wetting problem will be created. This because of high velocity diesel particles impinges to the walls of combustion chamber. This will decrease the overall performance of the engine. At lower injection pressure (180 bar) penetrating velocity of diesel particles decreases, this will generates more unburnt hydrocarbon. So injection pressure of 200 bar is found as the optimum value to achieve maximum efficiency in present work.

5. ANN prediction of BSFC and BTE

Based on the experimental work an Artificial Neural Network (ANN) model was developed to predict BSFC and BTE. The input parameters were load, percentage of biodiesel, injection angle, injection pressure. The predictive ability of the developed network model for BSFC and BTE is excellent. The selected input parameter for this work is based on a review of the literature [23–26].
The Figs. 9 and 10 indicate that comparison between experimental and predicted BSFC and BTE, by graphs. It is clear that both predicted and experimental values correlate well within an acceptable deviation from mean value, as shown in Figs. 11 and 12.

The comparison is made between network predicted Thermal efficiency with experimental data and which is shown in Fig. 11. The percentage of deviation between ANN predicted BTE with experimental BTE is exhibited in Fig. 12. The developed ANN model for Brake Thermal Efficiency (BTE) has a very low MSE content of 0.0069 along with RMSE of 0.66522% and MEP of 1.12% across all the test points. The correlation coefficient (R) for network estimated values is 0.995355.
6. Conclusions

The objective of this experimental work was to investigate the technical feasibility of the use of NOME with diesel oil and biogas in a dual fuel diesel engine. This was executed by assessing two performance parameters. The two performance parameters are: brake specific fuel consumption, brake thermal efficiency. Maximum Thermal efficiency of 22% was reached when the injection pressure of 200bar. Experimental data clearly indicates that as the injection pressure and biodiesel percentage increase, decreased thermal efficiency and increased fuel consumption result. Good correlation of BSFC and BTE with diesel fuel was noticed at B25+0.5LPM Biogas combination. Increase in Biogas flow rate leads to rough engine operation, and hence the flow rate was limited to 0.5LPM.

The present work also exhibits fruitful application of ANN model to estimate the output parameters of compression ignition engine fueled by NOME and Biogas with varying injection pressures. The results of developed ANN model is compared with actual results found by experimentation. From the error analysis, it was evident that the ANN predicted data matched the experimental data with high accuracy and correlation coefficient (R) values ranging from 0.977 to 0.999. The MEP was observed to be in the range of 1.1–4.57% with very low MSE. Study of proposed Back propagation network results concludes that ANN is one of the powerful predictor tools.

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