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Prediction of Single Cylinder Diesel Engine Emission Characteristics Using Pongamia Oil Blends With Artificial Neural Network

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Abstract— ***In this study, an artificial neural network, an artificial intelligence technique, is developed to predict the exhaust emissions (CO, CO_2, HC and NOx) of the four stroke, single cylinder, vertical, air cooled diesel engine. A single cylinder, four-stroke test engine was fuelled with diesel fuel with various percentages of pongamia oil (0, 5, 15 and 20%) to acquire the data's for training and testing of the proposed ANN. To acquire data's for training and testing of the proposed ANN, the test engine was operated at different speeds and loads. A standard back-propagation algorithm which is ANN model based for the engine was developed using some of experimental data's for training and testing for the proposed ANN. The emission parameters of the single cylinder diesel engine were validated by comparing the proposed ANN's prediction dataset with the experimental results. Results showed that the ANN gives the best accuracy for predicting the emission parameters for the single cylinder diesel engine with the minimum errors with the average range of 0.03998, 0.0002, 0.0002 and 0.0001 for CO, CO_2, HC and NOx respectively.***
Keywords— ***Artificial neural networks, Single cylinder diesel engine, Emission characteristics, Pongamia oil blends***

I. INTRODUCTION

Lin C.Y et al (2006) stated that the vegetable oil was used as a fuel around 100 years ago by the inventor of diesel engine Rudolph Diesel. Rudolph Diesel used peanut oil in his CI engine. After exploration of fossil fuels they were continued to be major conventional energy source. With the increasing trend of industrialization and modernization the world energy demand are also increasing at a faster rate. Most of the countries import crude oil to fulfil their energy demands. Also these fossil fuels are dominant sources of carbon monoxide (CO), carbon dioxide (CO_2), sulphur oxides (SOx). Hidayet Oguz et al (2010) observed that the scarcity of fossil based fuel resources in Turkey increases the importance of new and renewable energy resources for the country. The high number of diesel motors used in land transport and in agriculture made the use of biodiesel and bioethanol as mixtures to diesel fuel a current issue. In the studies conducted, it was seen that biodiesel and bioethanol are renewable alternative fuels for diesel motors. They can be used instead of diesel fuel or mixed to the diesel fuels to be used as fuels and lubricators in diesel motors. Ghobadian B et al (2004) stated that an alternative fuels for diesel engines are becoming increasingly important due to diminishing petroleum reserves and the environmental consequences of exhaust gases from petroleum fuelled engines. Agarwal A.K et al (2007) discussed that the industrialization and growing population have pushed the nation to confront with twin crisis of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of petroleum reserves have led to reduction of carbon resources. Adnan Parlak et al (2006) observed the digital computer provided a rapid means of performing many calculations involving the artificial neural network (ANN) methods. Along with the development of high speed digital computers, the application of ANN approach could be progressed a very impressive rate. In recent years, this method has been applied various disciplines including automotive engineering, in forecasting of engine thermal characteristics for different working conditions. Some researchers studied this method to predict internal combustion engine characteristics. Oztemel E et al (2003) said that an ANN is the algorithms which are developed in order to explore and generate new knowledge via learning without taking any external help. Zhang G et al (1998) discussed that an ANN it is a synthetic network which imitates biological neural network. ANN and biological neural network have significant differences in terms of both architectures and capabilities. ANN constitutes of a mathematical model for prediction of new problems. Negarestani S et al (2003) analyzed that an ANN has been a notable and commonly used method for engine performance tests, cutting mechanics; signal processing, data decomposition and image processing. Taheri M et al (2008) discussed that the method is able to produce new solutions for some problems. ANN was preferred as control strategy due to its high reliability and efficiency. Xu K et al (2003) stated that the Artificial neural networks (ANNs) have found applications in different areas of science and engineering over the years. The ANNs can be used to achieve solutions, since a range of experimental data set will be used to train the network. The network trained with certain range is then used to predict the

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parameters that have not been used anywhere in the network system.

II. EXPERIMENTAL WORKS

Experimental investigation is carried out on a typical single cylinder, four stroke, vertical, constant speed and air cooled diesel engine operating with different pongamia oil blends with respect to the increasing external load condition. Different nomenclature which is used in this study is given in the talbe.1. The technical specifications of the test engine are given in table.2. Test engine used in this study is shown in Fig. 1. Test engine is coupled with a loading rheostat along with load cell. Load on the engine is varied by using the controller provided on the loading rheostat with different load cells. Exhaust gas emissions such as CO, HC, CO_2, and NOx were measured by using Automotive Emission Analyzer (QRO-402) which is made in Korea. For comparison purpose engine is started with no load condition and then allowed to attain the rated speed of 1500 rpm and all the readings are taken under the rated speed conditions. Engine emission parameters such as CO, HC, CO_2, and NOx are measured using Automotive Emission Analyzer (QRO-402) which is made in Korea. Test engine is run at a rated speed of 1500 rpm and the various exhaust emissions such as CO, HC, CO_2, and NOx are collected with respect to the various loads of 0, 1.5, 2.5, 3.5, and 4.5 KW respectively.

TABLE 1 Different nomenclature used in this study

ANN	artificial neural network
CO	carbon monoxide
CO_2	carbon-di-oxide
HC	hydrocarbon
NO_X	nitrogen oxide
PPM	parts per million

TABLE 2 Specifications of the test engine

Engine type	Four stroke, single cylinder, air cooled, vertical, diesel engine
Rated speed	1500 rpm
Power	6 HP
Made	kirloskar oil engines Ltd, Pune, India
Loading device	Alternator with resistance load

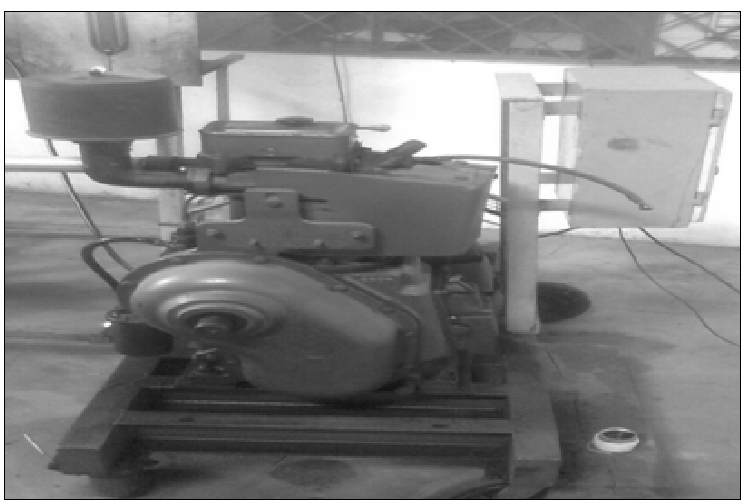

Figure 1 Test Engine

III.ARTIFICIAL NEURAL NETWORK DESIGN

Artificial Neural Network's performance is evaluated by comparing the error obtained from the trained neural network

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data and the measured data. Error was calculated at the end of training and testing processes based on the differences between measured and trained data's. Error between this data's can be minimize by using the back-propagation algorithm which is used to minimizes an error function defined by the average of the sum square difference between the output of each neuron in the output layer and the desired output. In this study, the back-propagation neural networks (BPNN) were trained using the training sets formed by including 70 percent of data. After training, the BPNNs were tested using the testing datasets including 20 samples. There were two input and four output parameters in the experimental tests. The input variables are engine load in KW and the percentage of pongamia oil blending with the conventional diesel fuel in percentage. The four outputs for evaluating engine's emission parameters include carbon monoxide (CO), carbon-di-oxide (CO_2), hydrocarbon (HC) and nitrogen oxide (NO_X). Therefore the input layer consisted of 2 neurons while the output layer had 4 neurons. The number of hidden layers and neurons within each layer is determined by the complexity of the problem and dataset. To ensure that each input variable provides an equal contribution in the ANN, the inputs of the model were scaled into a common numeric range of (0-1).

IV. RESULT AND DISCUSSION

The following discussions have been made based on the results obtained from experimental and trained ANN data's.

A. Carbon monoxide emissions

Comparison between the experimental and trained ANN values for CO emissions is shown in fig.2. It is observed that there is no significant difference between the experimental and ANN values and also fig.2 shows that the CO level is minimum up to 2 KW load after that there is a drastic change of CO at a load of 2KW-5KW condition. Based on the trained ANN results it shows that resulting error between the experimental and ANN values is in the range of 0.0098 for 0.5 and 1.5 KW load and the errors is increased in the range of 0.0198 for 2.5 and 3.5 KW, error range for 4.5 KW(full load condition) is in the range of 0.03998.

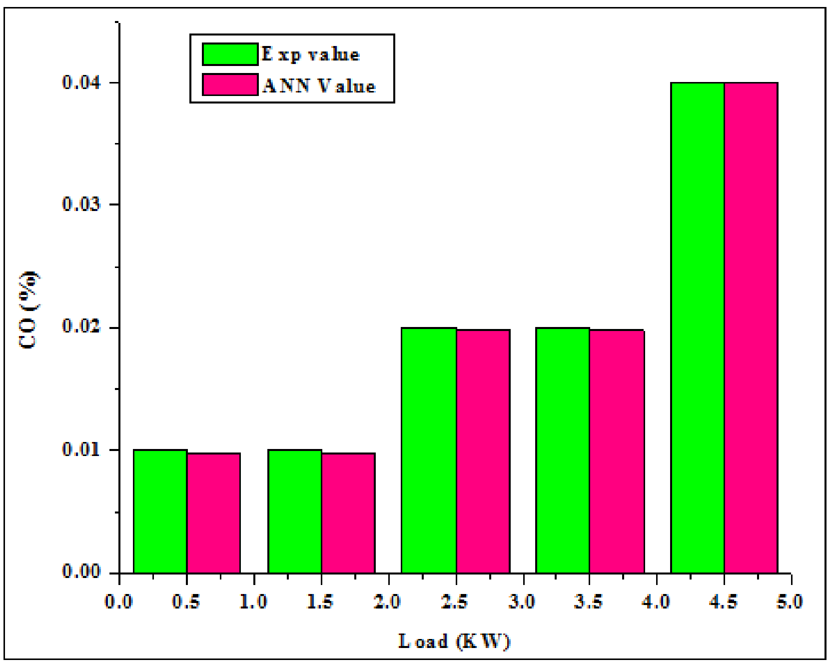

Figure 2 Comparison chart for carbon monoxide (CO)

B. Carbon-di-oxide emissions

Comparison between the experimental and trained ANN values for CO_2 emissions is shown in fig.3. It is observed that there is no significant difference between the experimental and ANN values and also fig.3 shows that the CO_2 level is minimum up to 1.0 KW load after that there is a gradual increment of CO_2 level up to the load range of 1.5KW-5KW load range. Based on the trained ANN results it shows that resulting error between the experimental and ANN values is in the range of 0.0002 for 0.5 load and the errors is increased in the range of 0.0001 for 1.5-3.5 KW, error range for 4.5 KW(full load condition) is in the range of 0.0002.

C. Hydrocarbon emissions

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Comparison between the experimental and trained ANN values for HC emissions is shown in fig.4. It is observed that there is no significant difference between the experimental and ANN values and also fig.4 shows that the HC level is minimum up to 1.0 KW load after that there is a gradual increment of HC level up to the load range of 1.5KW-5KW load range. Based on the trained ANN results it shows that resulting error between the experimental and ANN values is in the range of 0.0001 for 0.5 KW load and the errors is increased in the range of 0.0002 for 1.5-2.5 KW, error range for 3.5 KW is 0.0001 and error range for (full load condition) is in the range of 0.0002.

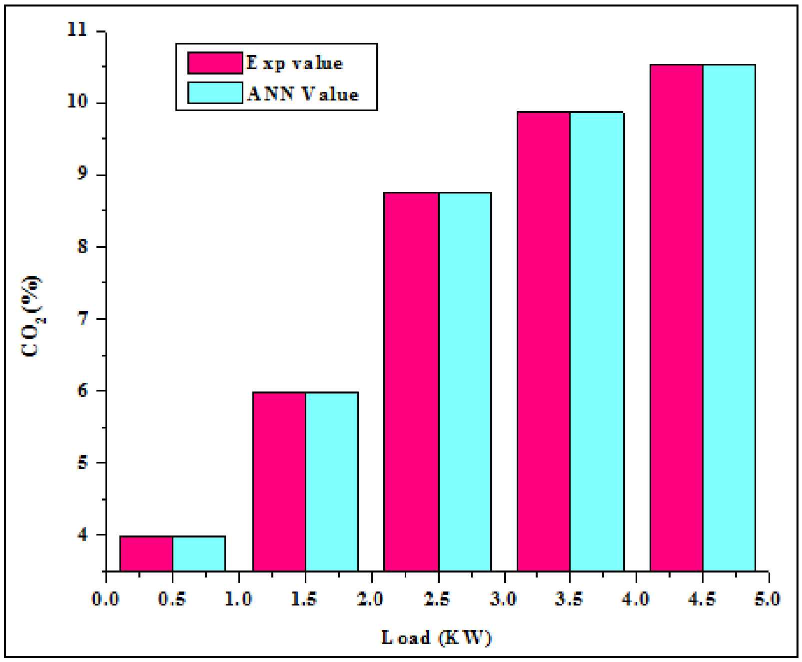

Figure 3 Comparison chart for carbon-di-oxide (CO_2)

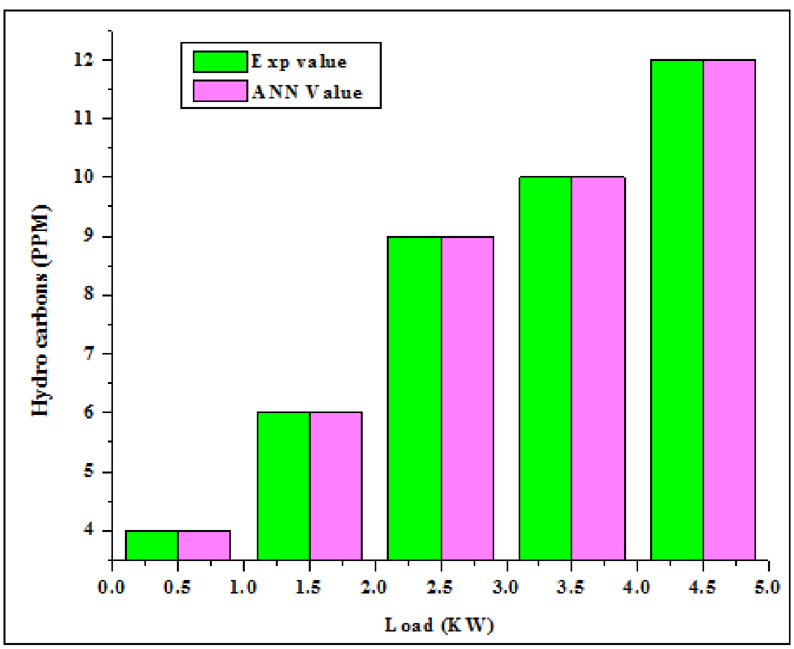

Figure 4 Comparison chart for hydrocarbons (HC)

D. Nitrogen oxide emissions

Comparison between the experimental and trained ANN values for NO_X emissions is shown in fig.5. It is observed that there is no significant difference between the experimental and ANN values and also fig.5 shows that the NO_X level is minimum up to

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1.0 KW load after that there is a gradual increment of NO_X level up to the load range of 1.5KW-5KW load range. Based on the trained ANN results it shows that resulting error between the experimental and ANN values is in the range of 0.0001 for 0.5 KW load and the errors is increased in the range of 0.0002 for 1.5-2.5 KW, error range for 3.5 KW is 0.0001 and error range for (full load condition) is in the range of 0.0002.

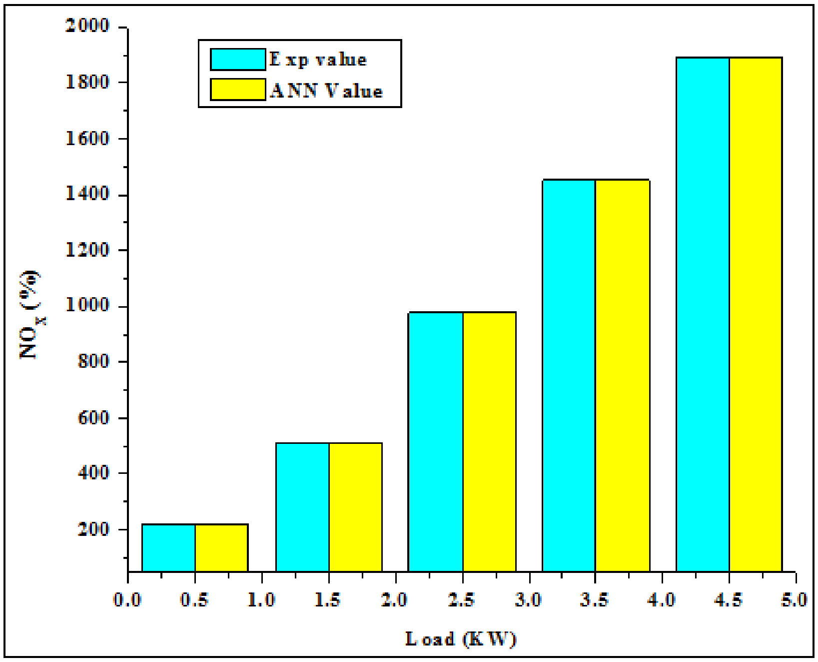

Figure 5 Comparison chart for Nitrogen oxide (NO_X)

V. SUMMARY

From the above experimental and ANN comparison following are the conclusions in this study. It is generally shows that Artificial Neural Network as a powerful modeling tool which is predicts the engine emission parameters exactly even in the all non linear conditions. The results of this study clearly showed that there is no significant difference between the experimental and ANN values. Because ANN is well trained with the appropriate experimental results. Resulting error between the experimental and trained ANN values for exhaust emissions of the test engine such as CO, HC, CO_2, and NOx like are lies between in the range of 0.0001 to 0.0002.

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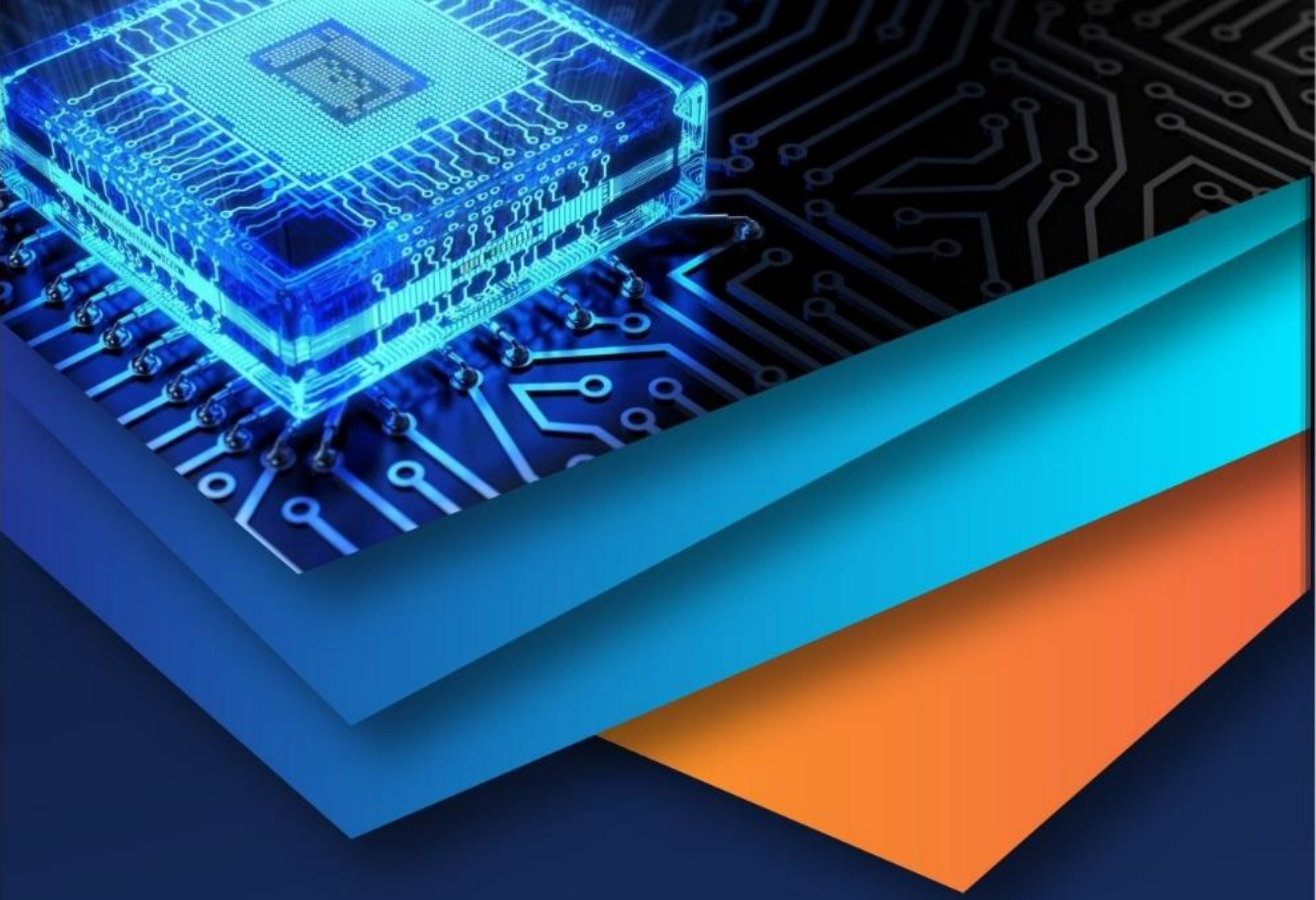

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