IACSIT International Journal of Engineering and Technology Vol. 2, No.1, February, 2010
ISSN: 1793-8236

Performance and Exhaust Emissions Analysis of a Diesel Engine Using Methyl Esters of Fish Oil with Artificial Neural Network Aid

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***Abstract*— This study deals with artificial neural network (ANN) modeling of a diesel engine to predict the exhaust emissions of the engine. To acquire data for training and testing the proposed ANN, a single cylinder, four-stroke test engine was fuelled with biodiesel blended with diesel and operated at different loads. Using some of the experimental data for training, an ANN model based on feed forward neural network for the engine was developed. Then, the performance of the ANN predictions were measured by comparing the predictions with the experimental results which were not used in the training process. It was observed that the ANN model can predict the engine exhaust emissions quite well with correlation coefficients, with very low root mean square errors. This study shows that, as an alternative to classical modeling techniques, the ANN approach can be used to accurately predict the performance and emissions of internal combustion engines.**

***Index Terms*— Artificial neural network; diesel engine; biodiesel; methyl esters of fish oil; Exhaust emissions.**

I. INTRODUCTION

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. Artificial neural network approach has been used by Xu et al. [1], in forecasting engine systems reliability, Yuanwang et al. [2], to analyze the effect of cetane number on exhaust emissions from engine, Korres et al. [3], to predict diesel lubricity, Lucas et al. [4], to model Diesel particulate emission, Hafner et al. [5], for diesel engine control design, Shayler et al. [6], in automotive engine management systems, Tan and Saif [7], to model the intake manifold and throttle body processes in an automotive engine. In the existing literatures, it was shown that the use of ANN is a powerful modeling tool that has the ability to identify complex relationships from input–output data. However, no investigation to predict specific fuel consumption and exhaust temperature for Diesel engine using ANN approach appears to have been published in the literature to date.

In this study, the applicability of an ANN for determining the performance and exhaust emissions of a diesel engine fueled with biodiesel blends was investigated. Then, after showing the applicability of ANNs, the performance and exhaust emissions from a diesel engine using biodiesel blends with diesel fuel up to 100% – namely 0% 20%, 40%, 60%, 80%, and 100% – have been predicted. All the experiments are at constant engine speed of 1500-rpm

II. ARTIFICIAL NEURAL-NETWORKS

Neural-networks are non-linear computer algorithms and can model the behavior of complicated non-linear processes. ANNs do not need an explicit formulation of physical relationships for the concerned problem. In other words, they only need examples of the subject in the relevant context. Neural-networks have been trained to perform complex functions in various fields of application, including pattern recognition, identification, classification, speech, vision, and control systems. Today neural-networks can be trained to solve problems that are difficult for conventional computers or human beings to solve. Neural-networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems of the human being. As in nature, the network function is determined largely by the connections between elements. A neural-network can be trained to perform a particular function by adjusting the values of the connections called weights between the adjacent elements. The basic processing element of a neural-network is a neuron. Fundamentally, a biological neuron receives inputs from certain sources, combines them in some way, and performs a generally non-linear operation on the results, and presents them as the output. Neural-networks operate like a 'black box' model; the user does not need to know any detailed information about the system. On the other hand, they have the ability to learn the relationship between the input and

Manuscript received September 29, 2009.

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the output. The network usually consists of an input layer, some hidden layers, and an output layer.There are different learning algorithms used in training the ANNs. A popular algorithm is the back-propagation algorithm, which has different variants. Algorithms such as conjugate gradient, quasi-Newton, and Levenberg–Marquardt (LM) use standard numerical optimization techniques. We have used these methods in our application. Errors during the learning process can be calculated using statistical error evaluation techniques: root-mean-squared (RMS), R2, and mean % error values are widely-used techniques [8,12] and are employed in our application. In applications, the input and output layer values are normalized within the range of (1,1) or (0,1).

In the present work feed forward neural network is used with two hidden layers is used. Algorithms such as conjugate gradient, quasi-Newton, and Levenberg–Marquardt (LM) are used. The fuel used for the engine is methyl esters of fish oil blended with diesel.

III. EXPERIMENTAL DETAILS

In the present study, kirlosker, single-cylinder, four stroke, water cooled, diesel engine was used. A schematic diagram of the experimental setup, and the test engine picture used or gathering data are shown in Figs. 1

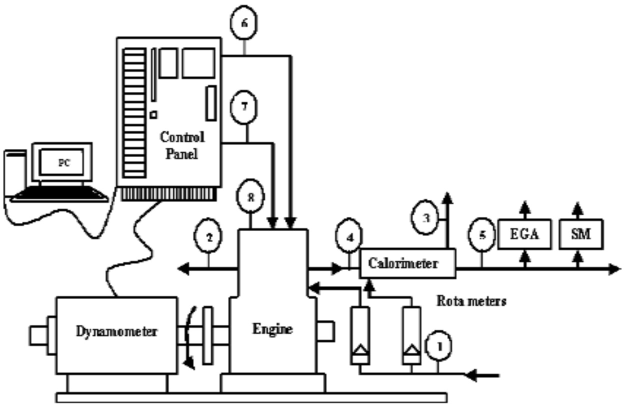

Fig.3.1 Experimental set up

(1. Water inlet to the calorimeter and engine ($T_1{}^0C$), 2. Water outlet from the engine jacket ($T_2{}^0C$), 3. Water outlet from the calorimeter ($T_3{}^0C$), 4. Exhaust gas inlet to the calorimeter ($T_4{}^0C$), 5. Exhust gas out let from the calorimeter ($T_5{}^0C$). 6. Atmospheric air temperature (($T_6{}^0C$), 7. Fuel flow, 8. Pressure Transducer, EGA. Exhaust gas analyzer, SM. Smoke Meter)

The engine specifications are listed in Table 1. The tests were conducted with variable loads at constant engine speeds of 1500 rpm and at constant injection timing and at constant injection pressure.

TABLE3.1 THE ENGINE SPECIFICATIONS

Engine type	4 stroke, single cylinder, water cooled diesel engine
Make	Kirloskar
Rated power	3.7Kw (5 HP)
Bore diameter	80mm
Stroke length	110mm
Connecting rod length	234mm
Swept volume	562cc
Compression ratio	16.5:1
Rated Speed	1500 rpm
Dynamometer	Eddy current dynamometer

IV. RESULTS AND DISCUSSIONS

The aim of this paper has been to show the possibility of using the neural networks for predictions of engine exhaust emissions from, a diesel engine. Results show that, in most of the cases, the network produces results parallel to the experimental ones: therefore they can be used as an alternative way in these systems. The RMS error values are smaller than 0.02 and R2 values are about 0.999, which may easily be considered within the acceptable range. One deduction made from our experimental results and the prediction produced by ANNs is that, if the experiments are producing steady results (i.e. repeating an experiment under the same conditions produces almost the same result), the usage of ANNs may be highly recommended. However, in some cases (i.e. such as in the case of %N) – due to the complexity of combustion operation, we may not get similar results even under the same experimental conditions. In such cases, the usage of neural networks may not be appropriate. To be able to train a neural network, there must be either a logical linear relation or a logical non-linear relation between the input and the output.

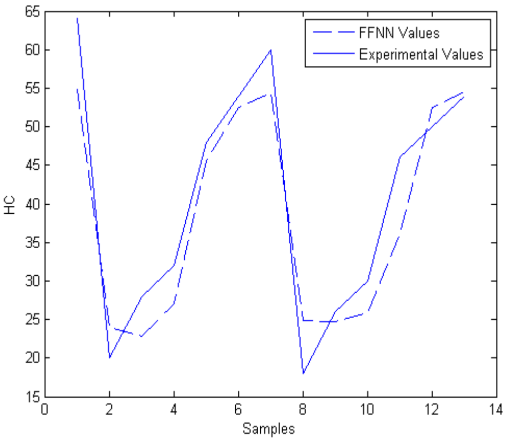

Figure4.1 Comparisons of experimental values with neural network values of HC emissions

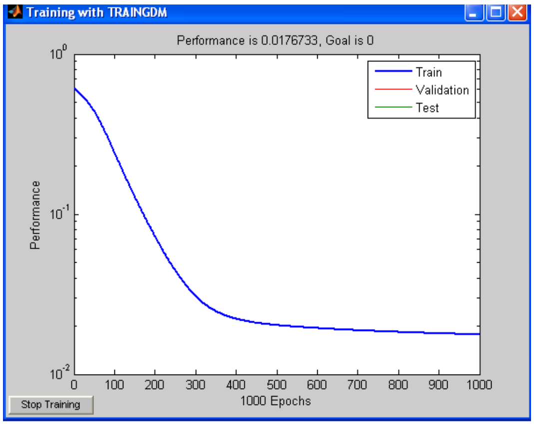

Figure4.2 Training the neural network for HC emissions

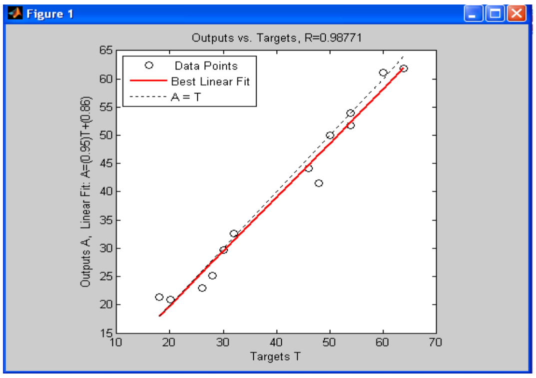

Figure4.3Neural network performances Analysis for HC emissions

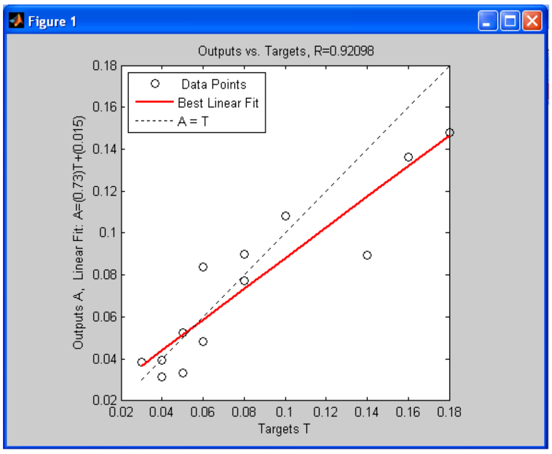

Figure4.4 Neural network performance Analysis for CO emissions

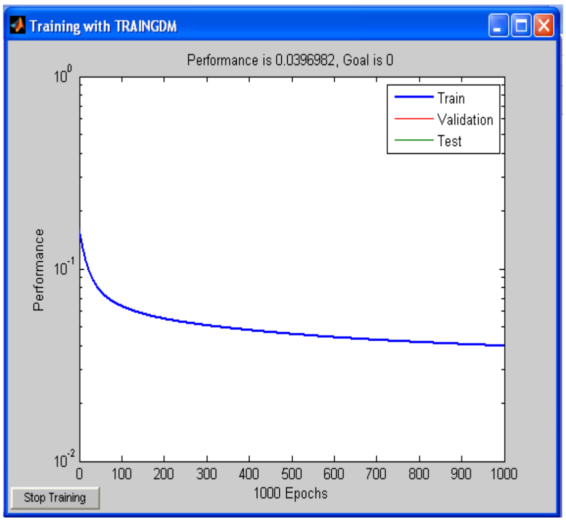

Figure 4.5 Training the neural network for CO emissions

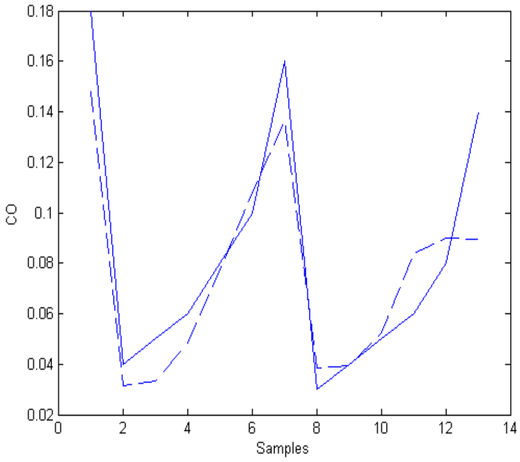

Figure4.6 Comparison of experimental values with neural network values of CO emissions

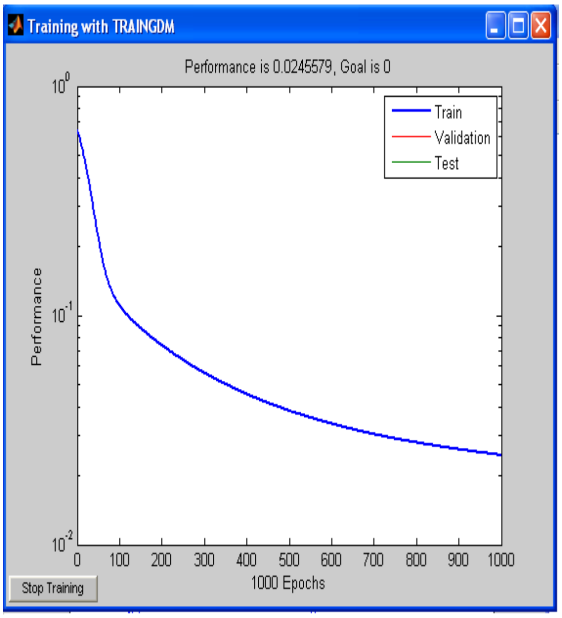

Figure4.7 Training the neural network for CO2 emissions

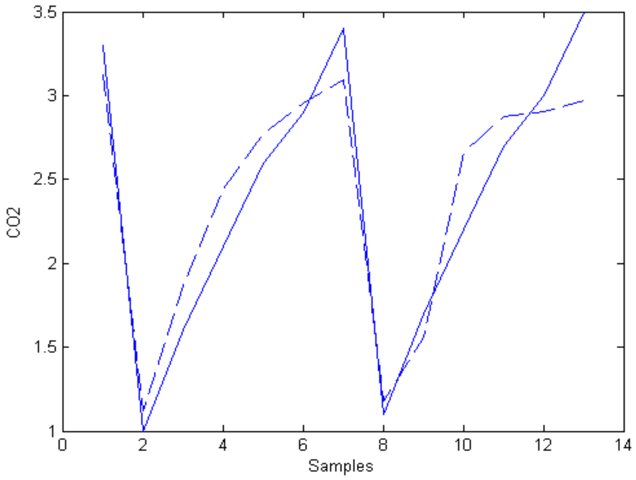

Figure4.8 Comparisons of experimental values with neural network values of co2 emissions

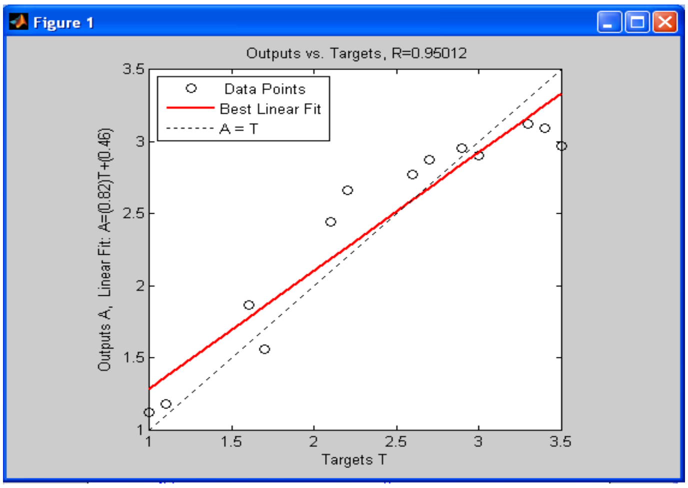

Figure4.9 Neural network performance Analysis for CO2 emissions

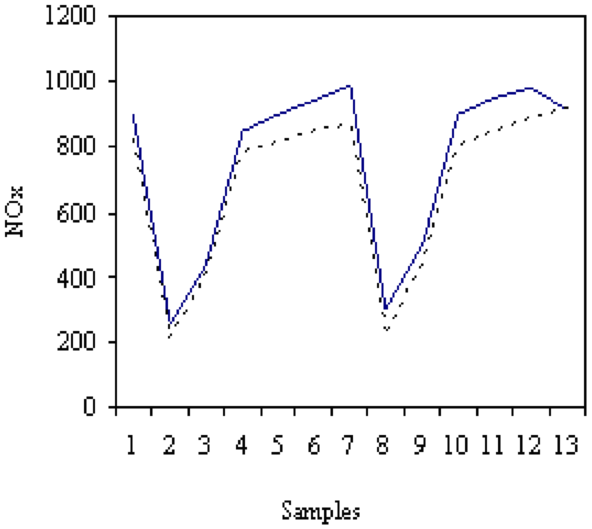

Figure4.10 Comparison of experimental values with neural network values of NOX emissions

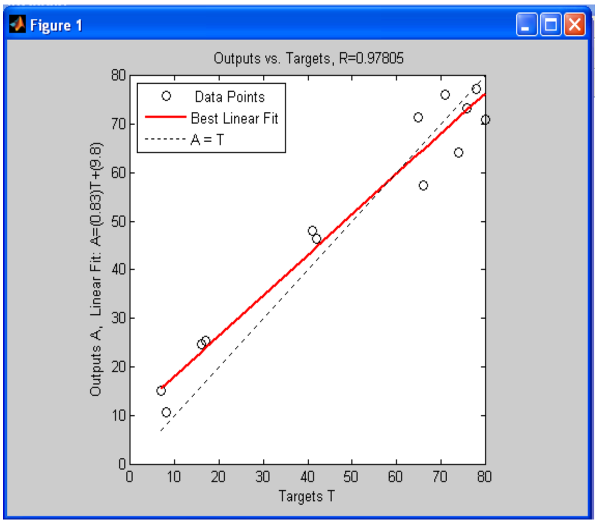

Figure4.11 neural network performance Analysis for NOX emissions

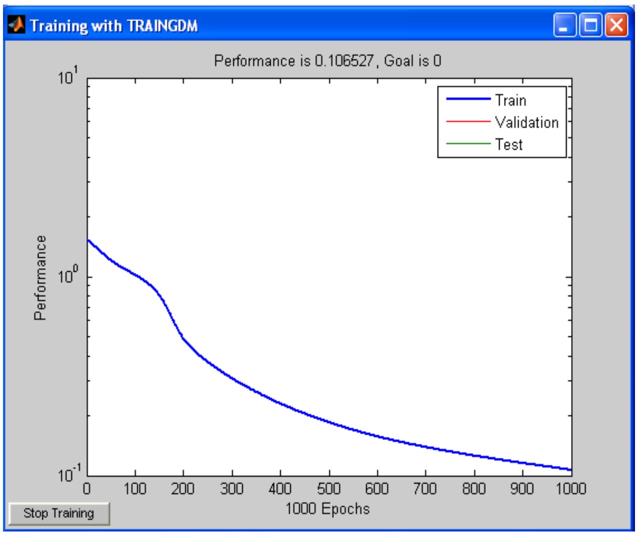

Figure4.12 Training the neural network for NOX emissions

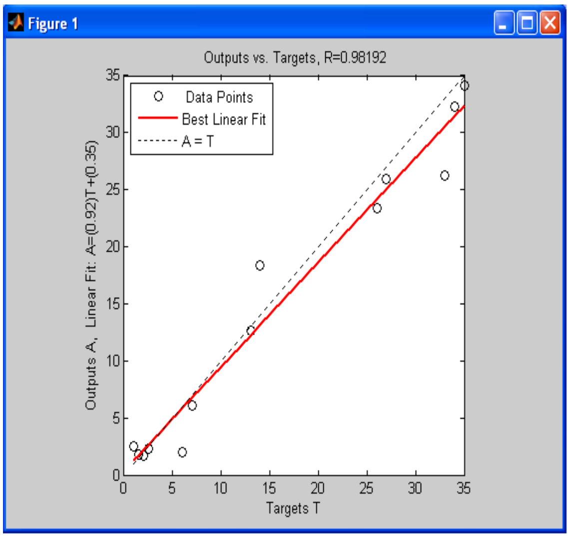

Figure4.13 neural network performance Analysis for SMOKE

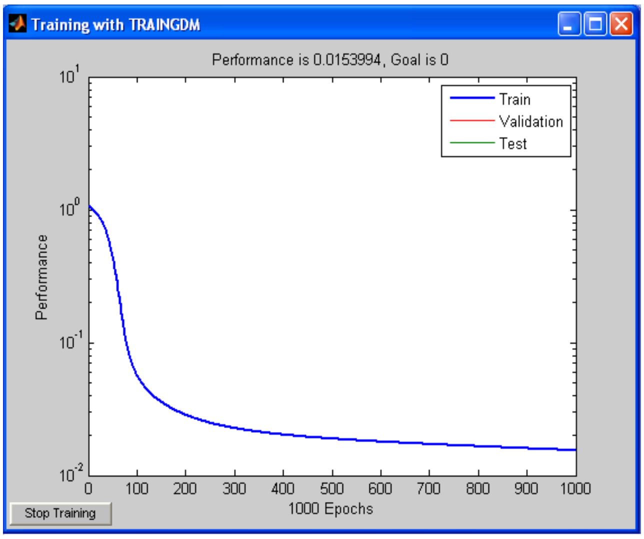

Figure4.14 Training the neural network for SMOKE

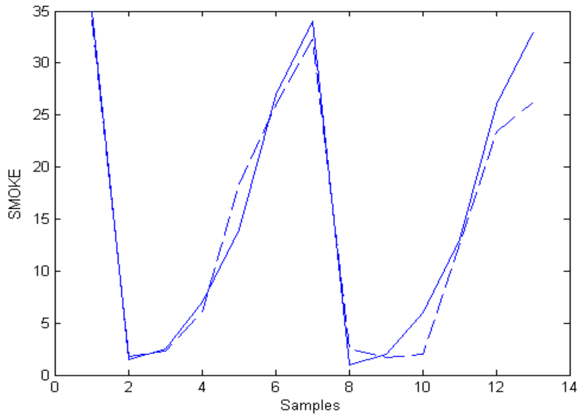

Figure4.15 Comparison of experimental values with neural network values of smoke

V. CONCLUSIONS

From the experimental results we infer that there is a significant reduction in the CO, CO2 and HC emission levels due to better combustion characteristics exhibited by the test fuels. NOx level a considerable amount of increase due to excess oxygen present in the biodiesel. Here we can observe that the emissions values predicted by FFNN that follow a definite trend have a lower error percentage value than compared to those that doesn't follow a definite flow. Further the emissions that vary more or less in a linear fashion have a very minimal percentage of error than those that follow a quadratic or a cubic curve. Thus based on the nature and the trend of emission graph we can use FFNN to predict the emission levels depending upon the required level of accuracy and thus providing the necessary emission values without carrying out the actual experimental analysis

ACKNOWLEDGMENT

Authors thank the management of Sri Venkateswara College of Engineering, Chittoor for providing the necessary experimental setup to perform this research.

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