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PREDICTION OF ENGINE PERFORMANCE AND EMISSIONS CHARACTERISTICS BY USING ARTIFICIAL NEURAL NETWORKS

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*Abstract**: The technical analysis conducted in this study manages the modelling of diesel engine exhaust emissions using artificial neural networks. Target of this study is to comprehend the adequacy of different biodiesel fuel properties and engine working conditions on diesel engine ignition towards the development of fumes discharges. The experimental investigations have been did on a single cylinder Direct Injection (DI) combustion ignition (CI) engine utilizing mixes of biodiesel methyl esters from Cotton seed, Jatropha, Mahua, Karanja and Neem oils. The execution parameters, for example, brake power (BP), brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), exhaust gas temperature (EGT) were measured alongside managed and unregulated fumes outflows of CO, HC, NOx and smoke density.***

An Artificial neural network (ANN) was made in perspective of the available exploratory data. Multi layer recognition neural framework was used for nonlinear mapping amidst data and yield parameters of ANN. Biodiesel blend rate, calorific quality, thickness, Cetane number of each biodiesel blend and working burden were used as inputs to set up the neural framework. The fumes gas outflows - CO, HC, NOx and smoke thickness are foreseen for the new fuel and its mixes. Particular start limits and a couple of standards were used to get ready and endorse the institutionalized data plan and a satisfactory rate goof was expert Levenberg-Marquardt outline enhancement calculation. The results exhibited that readiness through back engendering was adequately satisfactory in suspecting the motor surges. It was found that R (Regression Coefficient) qualities were 0.95, 0.99, 0.99 and 0.98 for CO, HC, NOx and Smoke thickness outflows, individually. Along these lines, the made model can be used as a definite instrument for evaluating the emanations of biodiesels and their blends under changing working conditions.

*Keywords**: Artificial neural system, Biodiesel, Engine Performance, Exhaust Emissions, Regression Coefficient..***

I. INTRODUCTION

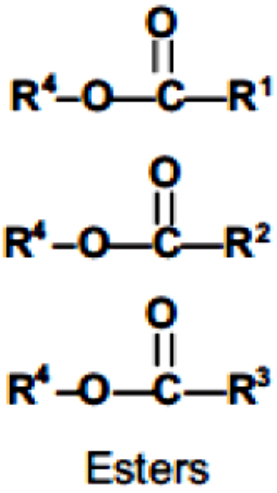
Biodiesel is positively seen as a potential green option fuel and can enhance the money related advancement of the country as business in provincial and rustic territories. Biodiesel fuel implies a non-petroleum-based fuel comprising of short chain alkyl (methyl or ethyl) esters, typically made by transesterification of vegetable oils or creature fats, which can be used (alone, or blended with customary petroleum diesel) in unmodified diesel-motor vehicles. In spite of the way that there are some positive biological impacts of the usage of biodiesels in diesel motors, there is a need to examine their execution and discharges for the upside of human wellbeing and other common concerns. Making and seething of biodiesel inside the diesel motors as fuel, adds to climatic carbon dioxide, sulfur dioxide, NOx, smoke and particulate matter surges to a humbler degree than smoldering the traditional diesel. The estimation of biodiesel releases is a non-direct complex issue in view of assortments in compound and thermodynamic properties of biodiesels that impact the ignition process. Various examiners have done trials to evaluate diesel motors execution and an emanation for diverse biodiesel blends. Finishing the examinations which incorporate the estimation of releases of the diesel motor is troublesome and extreme. This investigation work examinations and models the exploratory data of three various biodiesels and their blends (up to B30) worked at diverse working conditions.

In this work, a counterfeit neural system based processing model is made to gauge diesel motor execution and emanations through setting up the ANN with open test data. The made model could anticipate the execution and emanations for another biodiesel fuel and its blends with suitable precision.

II. DEFINITION OF BIODIESEL

Biodiesel is portrayed as the mono alkyl esters of long chain unsaturated fats got from vegetable oils or animal fats, for use in diesel motors. Biodiesels are called CO2 fair as carbon in biofuels was as of late separated from ecological carbon dioxide by creating plants. Biodiesel contains alkyl esters of unsaturated fats conveyed by transesterification of

vegetable oils. The structure of a regular biodiesel molecule involving alkyl gathering as showed up in the Fig.



1.

Fig.1. Structure of alkyl group methyl ester

Biodiesels are created through a compound procedure known as transesterification in which an ester is responded with liquor to deliver another ester and long chain hydrocarbons known as unsaturated fats. This procedure likewise lessens the thickness of oil and delivers glycerin alongside mono alkyl esters.

III. Influencing Fuel Properties for Analyzing Exhaust Emissions

Biodiesels are described by properties, for instance, thickness, streak point, fire point, carbon store, sulfur content, cetane number and calorific estimation of the fuel. Thickness, Calorific worth and cetane number are determined in lab for distinctive biodiesel blends of Neem oil, Karanja oil, Mahua oil, Jatropha oil and Cotton seed oil. The effect of fuel properties on fumes emanations is inspected in this work. Thickness of biodiesel is a fundamental variable for showing radiations as it augmentations with biodiesel rate. Warm proficiency of a diesel motor is upgraded with higher calorific estimation of the fuel and supports better ignition achieving high temperatures inside the barrel. These outcomes in higher NOx course of action. Various experts have shown that extending the cetane number through biodiesel blends would tend to lessening carbon monoxide and oxides of nitrogen. Cetane number (CN) is a non-straight dimensionless parameter that impacts ignition deferral of diesel fuel upon implantation into the smoldering chamber. For hydrocarbon releases, the effect of cetane number is superfluous.

IV. Experimental Setup

Extraction of fluid biodiesel fuel from the non- edible oils is finished by mechanical crushers known as oil expellers. At that point the oil is dealt with for transesterification, refinement and smaller scale emulsification to lessen fuel consistency such that biodiesel would suitable to be keep running in a diesel engine. As given in table.1, investigations are performed on a single cylinder, four stroke, constant speed, water cooled direct injection CI engine coupled to a rope brake dynamo meter with the chose biodiesels and their mixes.

Table.1. Details of the experimental setup for biodiesel emission test rig

Engine Specifications	
Model of engine	Kirloskar
Combustion chamber	Direct injection
Engine type	Single Cylinder, Water-cooled, four strokes and naturally aspirated
Bore x stroke	80 X 110 mm
Compression ratio	16.5:1
Injector opening	210 bar pressure
Maximum power	38.8 kW at 4250 rpm
Exhaust gas analyzer	HORIBA-MEXA-324 B (CO and HC) MRU DELTA 1600L (NO_x)
Cetane Tester	Koehler K-88600

V. Discharges Arrangement in Single Cylinder CI Engine Worked with Biodiesel Mixes

Carbon monoxide is shaped at whatever point carbon or substances containing carbon are blazed with a lacking air supply. Despite the fact that the measure of air required for ignition is speculatively sufficient, the reaction is not for the most part wrap up. The ignition gasses still contain some free oxygen and carbon monoxide. Biodiesel also contains free oxygen in its structure and rate of oxygen augmentations with the rate of biodiesel blend. The aggregate hydrocarbon (THC) and carbon monoxide (CO) emanations have a tendency to decrease by virtue of the oxygen content and the enhanced cetane number of biodiesel fuel which helps for a more complete ignition.

In this study, outpourings were determined for an on a solitary barrel CI motor, worked at different burdens with chose biodiesels and their blends. As the blend rate is growing close by the working burden, CO and HC releases were found extending for biodiesels, yet were not precisely those of when worked with diesel as the fuel. Tao Y, et.al viewed that higher CN has been compared with diminished NOx emanations (Tao Y). For the chose biodiesels and their blends, cetane numbers were assessed and were used as inputs to the ANN model to anticipate the outpouring emanations.

VI. Simulated Neural Networks as a Demonstrating Apparatus for Investigating Debilitate Emanations:

The combustion and emission formation is inherently non-linear and the conventional mathematical models fail to give solutions. Artificial Neural Networks is a real time diagnostic, displaying, control and streamlining instrument that can catch non-linearties of framework variables. ANNs remove the required data straightforwardly from the information due to their remarkable learning capacity. They are fit for gaining from nonlinear information of an unpredictable issue and can foresee the craved qualities with high precision. An ANN consists of an input layer, some hidden layers, and an output layer. The input layer comprises of all the information components and data from the input layer is then handled over

the span of one hidden layer, and a taking after output vector is registered in the output layer. Generally the hidden and the output layers have an activation function.

The Sigmoid actuation capacity applies a sigmoid exchange capacity to its information designs, speaking to a decent non-linear component to construct the hidden layers of the neural network, such a layer is named as sigmoid layer. A vital stage while pleasing a neural network is the preparation venture, in which an information is acquainted with the system together with the desired outputs, the weights and predisposition qualities are at first picked arbitrarily and the weights are balanced, so that the system endeavors to create the wanted yield. At the point when an agreeable level of execution is come to (an execution objective estimation of 0.00001), the preparation stops, and the system utilizes these weights to decide. In the managed taking in, a neural system figures out how to determine an issue just by changing its inner associations (predispositions of the Desired Output Layer and weights) by back-proliferating the contrast between the present yield of the neural system and the sought reaction. The readiness calculation chase down a perfect blend of framework's slants or weights by moving a virtual point along a multidimensional error surface, until a good slightest is found, as appeared to by the figure.2

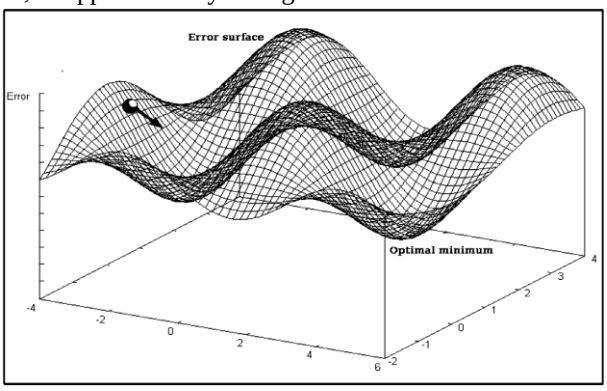


Fig. 2 Multi dimensional representation of Error Propagation

It changes the Layers' predisposition and the Synapses' weight, as showed by the edge discovered by the teacher neuron and is back-propagation by the retrogressive transportation instrument. Such an algorithm is known as feed forward back-propagation procedure. Various progression looking strategies are available in light of the strategy for processing the inclination. In this work, Levenberg-Marquardt Optimization calculation is used for get ready and testing the data outlines. This calculation is snappiest framework for setting up the moderate-sized food forward neural systems up to a couple of hundred weights. The Levenberg-Marquardt calculation uses the going with appraisal given as a piece of (1) to the Hessian lattice in discovering the angle (MATLAB).

$$X_{k+1} = X_k - [J^T J + \mu I]^{-1} J^T e \ldots\ldots\ldots (1)$$

Where J is the Hessian Matrix that contains first derivatives of the network errors with deference to the weights and biases, μ is the scalar and e means the error registered in the iterative procedure.

The above preparing algorithm known as trainlm and is executed in Neural Network Toolbox of MATLAB. This algorithm utilizes the accompanying parameters to work: the learning rate that represents to the "speed" of the virtual point along the error surface spoke to by the network in the figure, and the momentum, that speaks to the "inertia" of that point. There are 100 information designs accessible from the exploratory information relating to diesel engine keeps running with the pure diesel and biodiesel mixes. 33% of the aggregate information designs have been utilized for acceptance and testing. All the data and target qualities were standardized to fall in the scope of [0, 1]. Neurons in the data and output layers have no exchange capacity and a sigmoid exchange capacity have been utilized for the neurons as a part of hidden layers. The quantity of concealed layers is expanding taking into account the many-sided quality of the issue and the degree of nonlinear relationship in the middle of inputs and target values. Yield values amid testing stage for the fifth new fuel and its mixes, best structural planning is figured out to be 5-12-9-6-3 with 3 hidden layers and with an objective of 0.00001 which was come to in 473 training epochs. The predictions got with a few architectures have been investigated for Levenberg-Marquardt algorithm and the system structural planning appeared in fig.3 had given high regression coefficients during the assessment procedure of the neural network. Aim was to deduce the littlest and most straightforward neural network that deals with quicker advancement method offering ascend to minimization of the error within the least possible epochs. Errors during learning and testing stages portrayed as RMSE, R^2 and mean average percentage error (MAPE) are given as follows:

$$\mathbf{RMSE} = \left(\sum_j | (t_j - o_j)|^2 \right)^{1/2}$$

$$\mathbf{R^2} = 1 - \left[\frac{(\sum_j (t_j - o_j)^2}{\sum_j (o_j)^2} \right]$$

$$\mathbf{MAPE} = \sum_j \left[\frac{(t_j - o_j) * 100}{t_j} \right]$$

Where tj is target esteem and oj is yield esteem.

VII. Results and Discussions:

The exploratory examination was finished for assorted blends of Neem, Jatropha, Karanja Mahua and Cotton seed oils methyl esters (biodiesel), the releases were assessed and contrasted and diesel. This paper gives the outcome of ANN based desires of outpourings for the new biodiesels and its blends. A relapse investigation is done to evaluate the execution of the balanced neural framework model.

A. Fuel Properties:

Transesterification of the biodiesel oils has diminished the thickness by more noticeable degree and therefore the biodiesel has been used as a piece of diesel motor test rig without making any adjustments to the motor. Calorific estimation of the biodiesel blends diminishes with the blend rate of biodiesel yet is equivalent with diesel. Cetane number and thickness of

the biodiesel blends are growing with the extension in the rate of biodiesel blend. Biodiesels and their blends have higher cetane numbers higher than diesel realizing better ignition advance for the motor. Biodiesels contain more oxygen rate by weight, more thickness than diesel and in this way more measure of fuel can be imbued realizing diminished outpouring outflows. The effect of properties of the biodiesel blends on fumes releases close by the anticipated qualities by ANN is showed up in fig 4, 5.

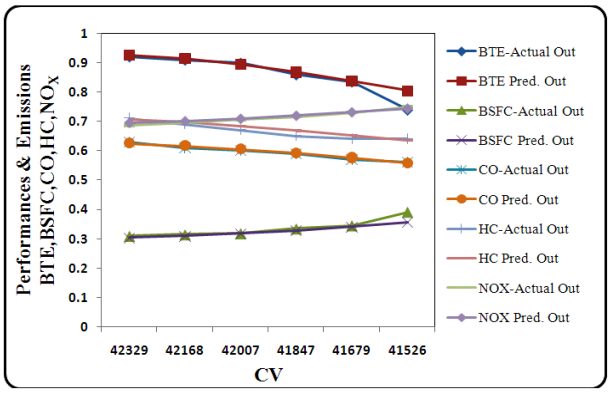


Fig. 3. Performance & Emissions versus calorific values

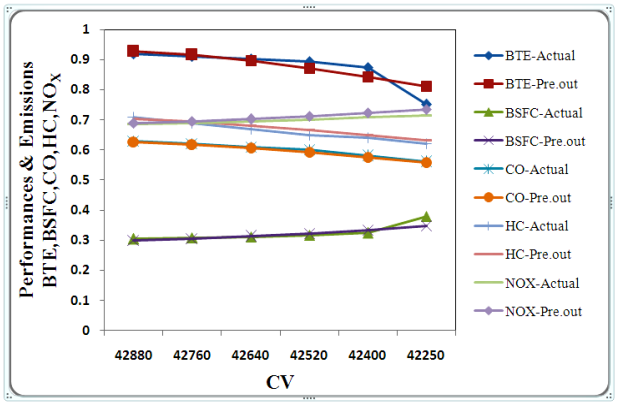


Fig.4. Performances & Emissions versus calorific values

B. Effect of Load with biodiesel mixes rate on outflows:

At 75% of full load, CO and HC outflows of biodiesel mixes are lower than those of diesel by almost 60%. Be that as it may, NOx discharges are higher if there should arise an occurrence of biodiesels because of expanded temperature in view of the higher cetane numbers offering ascend to effective ignition when the mix rate is expanding. Impact of load on diesel engine exhaust discharges worked with biodiesel mixes is appeared in fig 6 and 7.

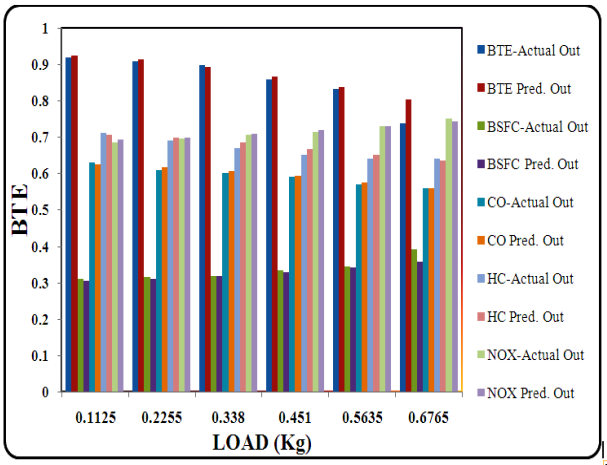


Fig.6. Actual versus predicted performances and emissions at Different Loads

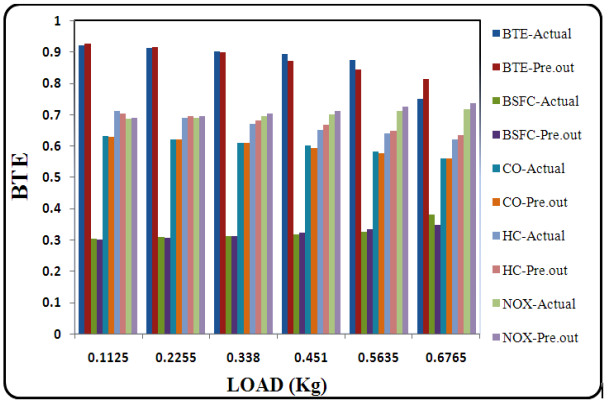


Fig.7. Actual versus predicted performances and emissions at Different Loads

C. Neural Network Performance Parameters:

Different preparing algorithm, for example, Gradient-Descent (traingdx), Conjugate-Gradient (traincgf) were utilized to obtain predictions for the desired outflows. During experience, it was discovered that the ideal neural network structural engineering would conceivable with Levenberg-Marquardt algorithm as appeared below that has given enhanced regression coefficients. The objective for the training was set to 0.00001 and it took 473 epochs for accomplishing it. An acceptable performance was seen with the given number of neurons in the hidden layers for the selected neural network algorithm.

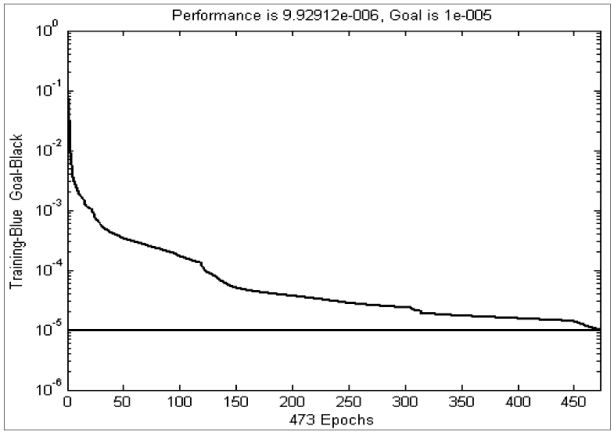


Fig.8. RMSE amid preparing process in MATLAB

D. Performance assessment of the created ANN utilizing Regression Analysis:

Regression statistics output characterizes the goodness of the neural network model adjusted as a whole. The regression analysis completed to relate the actual and predicted information has demonstrated that there is a high connection between's real test values and predicted values. Regression Coefficient (R) which demonstrates the measure of variety of actual and predicted values for NOx, CO, HC and Smoke density was discovered to be 0.99, 0.95, 0.99 and 0.98 respectively. It infers that the model has succeeded in the expectation of diesel engine exhaust emissions. The lower estimation of R, R^2 for CO discharges may be because of incomplete ignition or any concealed varieties in working conditions. Noise in the trial information is caught by ANN and has given reduce regression error for CO. It was additionally watched that the bend fitting plot for each of the predicted discharges of Neem oil, Jatropha oil, Mahua oil, Karanja oil and Cotton seed oil a large portion of the MAPE values are under 15%.

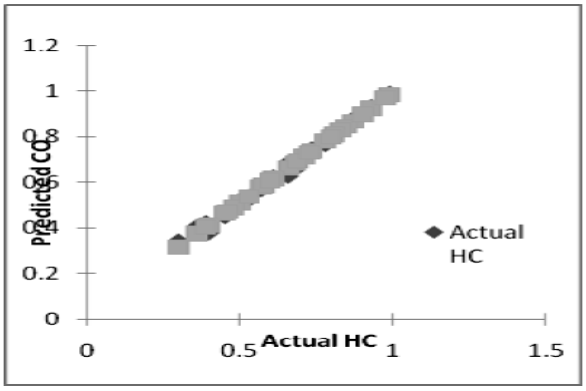


Figure.9. Curve fitting plot for CO actual & predictions

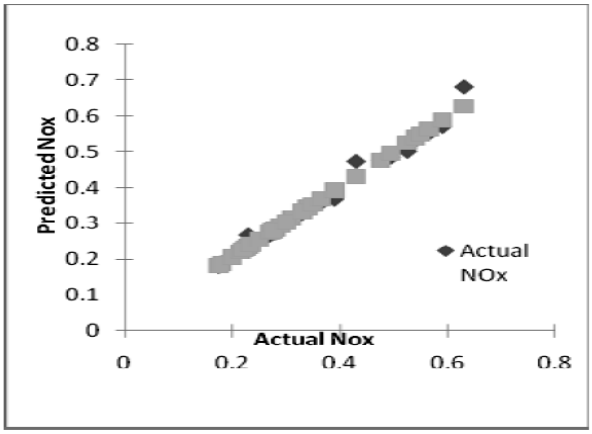


Figure.10. Curve fitting plot for HC actual & predictions

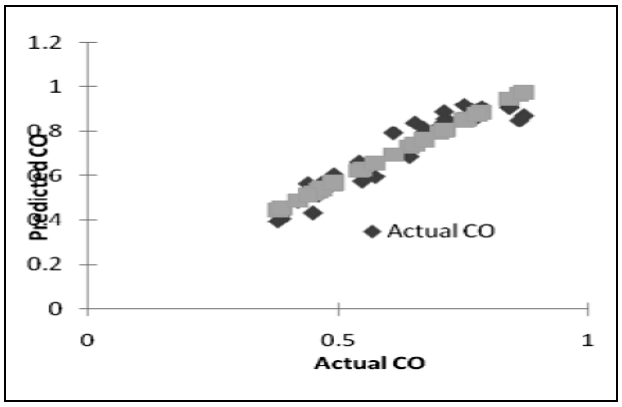


Figure.11. Curve fitting plot for NOx actual & predictions

VIII. CONCLUSION

Following are the conclusions based on the experimental results and their simulation utilizing artificial neural networks to predict the emission attributes of another biodiesel and its mixes worked at distinctive load conditions on a single cylinder diesel engine.

1) Biodiesel properties are like diesel fuel. Transesterification of biodiesel methyl esters helps not just in expanding the execution of the diesel engine additionally in decreasing CO and HC outflows.

2) Density, Calorific Value and Cetane Number are significant factors that impact the arrangement of exhaust outflows. Biodiesels and their mixes give lower emissions compared with diesel. Higher the cetane number, higher will be the flame formation and the operating temperatures which will have a direct effect on increase of NOx emissions. Similar trend is observed for emissions under increasing operating load on the engine.

3) In this work, ideal counterfeit neural system structural engineering is intended to display the intricate conduct of diesel motor fumes outflows worked with biodiesels. The model created depends on the most productive and quicker processing outline enhancement method - Levenberg-

Marquardt (trainlm). The other preparing calculations, for example, Gradient-Descent (traingdx), Conjugate-Gradient (traincgf) were observed to be mediocre compared to trainlm that could anticipate CO, HC and NOx outflows for the new biodiesel and its mixes with enhanced precision.

4) This examination work has demonstrated that, for investigating complex issues of outflow investigation of biodiesels and their mixes, manufactured neural system is suitable, versatile and adaptable processing apparatus that can be utilized for indicative purposes. There by, tedious, dull and excessive examinations can be evaded.

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