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Application of ANN to Optimize the Performance of CI Engine Fuelled With Cotton Seed Oil- A Review

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ABSTRACT
This study is deals with the Artificial Neural Network (ANN) modeling to optimize the performance of CI engine. ANN can learn from example, are fault tolerant in the sense that this is able to handle noisy and incomplete data and able to deal with non-linear problem. This is particularly useful in system modeling such as in implementing complex mapping and system identification. The major objective of this paper is to illustrate how ANN technique might play an important role in modeling and optimization of the performance of CI engine fuelled with cotton seed oil. And also to understand the effect of cotton seed oil properties on CI engine performance.
Keywords- Artificial Neural Network (ANN), Cotton seed oil, Optimization, Performance.

I. INTRODUCTION

1.1 Artificial Neural Network (ANN)

Neural networks obviate the need to use complex mathematically explicit formulas, computer models, and impractical and costly physical models.. They can learn from examples, and are able to deal with non-linear problems. Furthermore, they exhibit robustness and fault tolerance. The tasks that ANNs cannot handle effectively are those requiring high accuracy and precision as in logic and arithmetic.

ANNs have been applied successfully in a various fields of mathematics, engineering, medicine, economics, meteorology, psychology, neurology, and many others.

Neural networks obviate the need to use complex mathematically explicit formulas, computer models, and impractical and costly physical models. Some of the characteristics that support the success of ANNs and distinguish them from the conventional computational techniques are:

- The direct manner in which ANNs acquire information and knowledge about a given problem domain (learning interesting and possibly non-linear relationships) through the 'training' phase.
- Neural networks can work with numerical or analogue data that would be difficult to deal with by other means because of the form of the data or because there are so many variables.
- Neural network analysis can be conceived of as a 'black box' approach and the user does not require sophisticated mathematical knowledge.
- The compact form in which the acquired information and knowledge is stored within the trained network and the ease with which it can be accessed and used.
- Neural network solutions can be robust even in the presence of 'noise' in the input data.
- The high degree of accuracy reported when ANN are used to generalize over a set of previously unseen data (not used in the 'training' process) from the problem domain [1].

MODEL OF AN ARTIFICIAL NEURON:

The human brain no doubt is a highly complex structure viewed as a massive, highly interconnected network of simple processing elements called Neurons. Every component of the model bears a direct analogy to the actual components of a biological neuron and hence is termed as Artificial Neuron. It is this model which forms the basis of the Artificial Networks as shown in fig. 1.1.

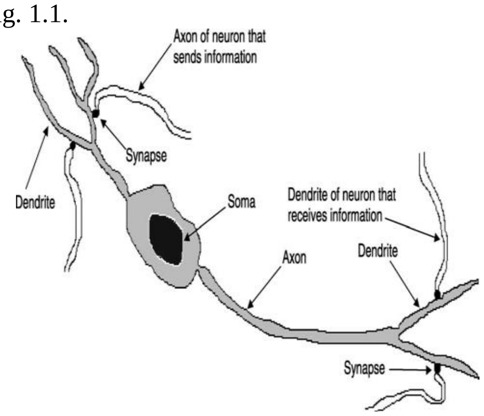

Fig. 1.1 Structure of Biological Neuron [1]

From fig. 1.2, $x_1, x_2, x_3, \ldots$ care the n inputs to the artificial neuron. $w_1, w_2, w_3, \ldots w_n$ are the weights attached to the input links.

A biological neuron receives all inputs through the dendrites, sums them and produces an output if the sum is greater than the threshold value. The input signals are passed on to the cell body through the synapse, which may accelerate or retard an arriving signal. It is this acceleration or retardation of the input signals modelled by the weights. An effective synapse, which transmits a stronger signal, will have a correspondingly larger weight while a weak synapse will have smaller weights. Thus, weights here are Multicative factors of the inputs to account for the strength of the synapse. Hence, the total input I received by the soma of the artificial neuron is

$$I= w_1 x_1 + w_2 x_2 + \ldots\ldots + w_n x_n = w_i x_i \quad \ldots\ldots\ldots\ldots\ldots(1)$$

To generate the final output y, the sum is passed on to the non-linear filter Φ called as Activation function or Transfer function or Squash function, which releases the output [7].

$$Y= \Phi(I) \quad \ldots\ldots..(2)$$

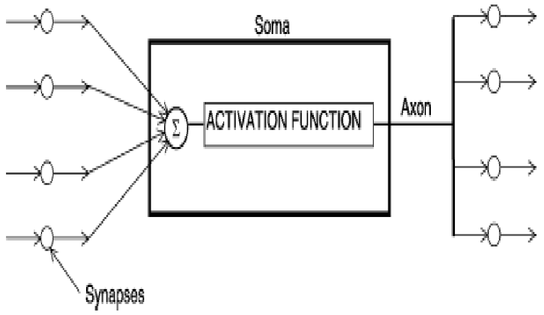

Fig 1.2 Simplified Structure of Artificial Neuron [1]

A learning algorithm is defined as a procedure that consists of adjusting the weights and biases of a network, to minimize an error function between the network outputs, for a given set of inputs, and the correct outputs. Basically, a biological neuron receives inputs from other sources, combines them in some way, performs generally a nonlinear operation on the result, and then outputs the final result. The network usually consists of an input layer, some hidden layers, and an output layer. Each input is multiplied by a connection weight. In the simplest case, products and biases are simply summed, then transformed through a transfer function to generate a result, and finally obtained output. Networks with biases can represent relationships between inputs and outputs more easily than networks without biases. A transfer function consisted generally of algebraic equations is linear or nonlinear. An important subject of a neural network is the training step. There are essentially two types of ANN learning models supervised learning and unsupervised learning [3]. Supervised training is the process of providing the network with a series of sample of inputs and comparing the outputs with the expected responses. The training continues until the network is able to provide the expected responses. The weights will be adjusted according to learning algorithm till it reaches the actual outputs. In the neural network if for the training input vectors, the target output is not known the training method adopted is called as unsupervised training. The net may modify the weight so that the most similar input vector is assigned to the same output unit. The net is found to form a exemplar or code book vector for each cluster formed. Various training functions can be used to train the networks reach from a particular input to a specific target output. The error between the network output and the actual output is minimized by modifying the network weights and biases [2].

Feasibility of ANN for CI engine optimization

From above mentioned techniques ANN is use to optimize the performance of CI engine for the following reasons:

- Learning capability non-linear relationships between input and output parameters through the 'training' phase.
- The ANN possess the capability to generalize, thus, they can predict new outcomes from past trends.
- The ANN is robust systems and is fault tolerant. They can, therefore, recall full patterns from incomplete, partial or noisy patterns.
- The ANN can process information in parallel, at high speed, and in a distributed manner.

There has been considerable interest in recent years in the use of neural networks for the modelling and controlling of IC engine because of their ability to represent non-linear systems and their self-learning capabilities. Most of the researchers use ANN technique for controlling and prediction of IC engine parameter [1].

Advanced engine control systems require accurate dynamic models of the combustion process, which are substantially non-linear. Then apply the fast neural network models for engine control design purpose. These neuro-models are then integrated into an upper-level emission optimization tool, which calculates a cost function for exhaust versus consumption/torque and determines optimal engine settings.

Since the introduction of microprocessor control, increase in number of sensors, actuators and digital control functions were introduced, replacing mechanical devices like ignition breaker and injection. Due to the use of such electromechanical configuration complex data is available. As the calibration and parameter tuning has become a crucial part in the timely development because of complex interactions and the many degrees of freedom, it is shown how by specially designed experiments for the identification of the engine a considerable improvement can be reached with the aid of local linear neural networks. The engine models are then used for the optimization of static and dynamic engine control, using a multi-objective performance criterion for fuel consumption and emissions.

Close control of combustion in these engines will be essential to achieve ever-increasing efficiency improvements while meeting increasingly stringent emissions standards. The engines of the future will require significantly more complex control than existing map-based control strategies, having many more degrees of freedom than those of today. Neural network-based engine modelling offers the potential for a multi-dimensional, adaptive, learning control system that does not require knowledge of the governing equations for engine performance or the combustion kinetics of emissions formation that a conventional map-based engine model requires. Applications of such a neural network model include emissions virtual sensing, on-board diagnostics and engine control strategy optimization [1]. Hence, from above discussion it is clear that an ANN technique is widely used for CI engine than other AI techniques.

1.2 Application of ANN for CI engine fuelled with cotton seed oil

Diesel engines are widely used for their low fuel consumption and better efficiency. In wake of the present energy environment crises it has become essential to identify renewable and alternative clean burning fuels. One of the significant routes to tackle the problem of increasing prices and the pollution problems of petroleum fuels is by the use of vegetable oil fuels known as biodiesels [5].

In recent years, efforts have been made by several researchers to use vegetable oils of Sunflower, Peanut, Soyabean, Rapeseed, Olive, Cottonseed, Jatropha, Pongomia, Rubber seed, Jajoba etc. as alternative fuel for diesel engine. Among those, cottonseed oil is used for study because cottonseed oil is non-edible oil, thus food versus fuel conflict will not arise if this is used for biodiesel production [5].

Performance of CI engine greatly depends upon the properties of fuel among which viscosity, density, cetane number, volatility, lubricity, calorific value etc are very important. Among those, viscosity of cotton seed oil creates major problems in pumping, atomization and fuel jet penetration. Transesterification process is use to reduce the viscosity. Also blending of cotton seed oil with diesel may reduce the viscosity and improve the volatility of oil, but its molecular structure remains unchanged. Then making of blends of cotton seed methyl ester and diesel in various concentrations [5].

An ANN model for the biodiesel engine is proposed to be developed by using the steady state experimental data. In this model, some of the experimental data will be used for the training set, some for the validation set while the remaining one will be used for the test purpose. The inputs to the ANN are cotton seed oil blend percentage (B), load percentage (W), mass flow rate of fuel (m_f) and mass flow rate of air (m_a) and the output parameters to the ANN are Brake power (BP), Brake thermal efficiency (BTE), Brake specific fuel consumption, (BSFC), Exhaust gas Temperature (T_{exh}). To ensure that each input provides an equal contribution in the ANN, we have to select proper hidden layer, activation function and learning algorithm will be selected. After development of ANN model the back propagation method to train ANN network will be applied. The output parameters can then be predicted and compared with experimental output parameters and minimize the error by giving epochs to ANN whereas optimum output parameter can be determine from those predicted output [6].

II. LITERATURE SURVEY

2.1 Soteris A. Kalogirou(2003): The major objective of this paper is to illustrate how AI techniques might play an important role in modelling and prediction of the performance and control of combustion process. The paper outlines an understanding of how AI systems operate by way of presenting a number of problems in the different disciplines of combustion engineering. The various applications of AI are presented in a thematic rather than a chronological or any other order.

From the description of the various applications presented in this paper, one can see that AI techniques have been applied in a wide range of fields for modeling, prediction and control in combustion processes. What is required for setting up such a system is data that represents the past history and performance of the real system and a selection of a suitable model. The selection of this model is done empirically and after testing various alternative solutions. The performance of the selected models is tested with the data of the past history of the real system.

Especially the ANN has wide application in IC engine combustion, monitoring and controlling. This system has ability to represent the non linear system and self learning capability advanced engine system required accurate dynamic models, which are substantially non linear and does not required knowledge of the governing equation of engine. These neuro-models are then integrated into an upper level emission optimization tool, which calculates a cost function for exhaust verses consumption/torque and determining optimal engine settings[1].

2.2Shivakumar, Srinivas Pai P., Shrinivasa Rao B. R.and Samaga B. S. (2010): In the present work biodiesel was prepared from Honge oil (Pongomia) and used as a fuel in C.I. engine. Experimental investigation of the Performance parameters and Exhaust emissions from the engine were done on a single cylinder four-stroke water-cooled compression ignition engine connected to an eddy current dynamometer. Experiments were conducted for different percentage of blends of Honge oil with diesel at various compression ratios.

Artificial Neural Networks (ANNs) were used to predict the Engine performance and emission characteristics of the engine. An ANN model for the biodiesel engine was developed by using the steady state experimental data. In the model 70% of the experimental data were used for the training set, 15% for the validation set, remaining 15% were employed for the test purpose. The inputs to the ANN are WCO blend percentage (B), load percentage (W), and the compression ratio (CR). The output parameters from the ANN are Brake thermal efficiency (BTE), Brake specific energy consumption, (BSEC), Exhaust gas Temperature (T_{exh}) and the emissions which include Oxides of nitrogen (NOx), Smoke (SN), Unburnt Hydrocarbon (UBHC), and Carbon Monoxide (CO). The computer codes for training the network using the back-propagation algorithm. Mean Relative error and the regression analysis was carried out for the trained as well as the test data are considered to be within the acceptable limits. The emission of smoke and CO shows slightly higher values. Hence ANN approach can be used for the prediction of engine performance and emission characteristics of I.C engines by performing a limited number of tests instead of detailed experimental study thus saving both engineering effort and funds [2].

2.3 Gholamhassan Najafi, Barat Ghobadian, Talal F. Yusaf and Hadi Rahimi(2007): The presented combustion analysis has been conducted to evaluate the performance of a commercial DI engine, water cooled two cylinders, in-line, naturally aspirated diesel engine using waste vegetable cooking oil as an alternative fuel. In order to compare the brake power and the torques values of the engine, it has been tested under same operating conditions with diesel fuel and waste cooking biodiesel fuel blends. The results were found to be very comparable. The total sulphur content of the produced biodiesel fuel was 18 ppm which is 28 times lesser than the existing diesel fuel sulphur content used in the diesel vehicles operating in Tehran city (500 ppm). By adding 20% of waste vegetable oil methyl ester, the maximum power and torque increased by 2.7 and 2.9% respectively, also the concentration of the CO and HC emissions have significantly decreased when biodiesel was used.

An artificial neural network (ANN) was developed based on the collected data of this work. The backpropagation algorithm was utilized in training of all ANN models. This algorithm uses the supervised training technique where the network weights and biases are initialized randomly at the beginning of the training phase. The error minimization process is achieved using gradient descent rule. To ensure that each input variable provides an equal contribution in the ANN, the inputs of the model were pre-processed and scaled into a common numeric range (-1,1). The activation function for hidden layer was selected to be logic. Linear function suited best for the output layer. This arrangement of functions in function approximation problems or modelling is common and yields to better results. The results showed that the training algorithm of Back Propagation was sufficient enough in predicting the engine torque, specific fuel consumption and exhaust gas components for different engine speeds and different fuel blends ratios. It was found that the R (the coefficient of correlaion) values are 0.99994, 1, 1 and 0.99998 for the engine torque, specific fuel consumption, CO and HC emissions, respectively [3].

2.4Sakir Tasdemir, Ismail Saritas, Murat Ciniviz, Novruz Allahverdi (2011): This study is deals with artificial neural network (ANN) and fuzzy expert system (FES) modelling of a gasoline engine to predict engine power, torque, specific fuel consumption and hydrocarbon emission. In this study, experimental data, which were obtained from experimental studies in a laboratory environment, have been used.

An ANN model can accommodate multiple input variables to predict multiple output variables. The available data set is partitioned into two parts, one corresponding to training and the other corresponding to validation of the model. The purpose of training is to determine the set of connection weights and nodal thresholds that cause the ANN to estimate outputs that are sufficiently close to target values. The system adjusts the weights of the internal connections to minimize errors between the network output and target output.

In FES model the input and output values of the system are crisp values. By fuzzification these crisp input values, its fuzzy membership values and degrees are obtained. In the inference mechanism fuzzy results are inferred from the memberships of fuzzy sets with the aid of knowledge base. In the inference sub process, the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. The knowledge base is built on a collection of fuzzy IF-THEN rules.

The biggest advantages of the ANN and FES compared to classical methods are speed of calculations, simplicity, and capacity to learn from examples and also do not require more experimental study [4].

2.5Md. Nurun Nabi, Md. Mustafizur Rahman, Md. Shamim Akhter (2009): Different parameters for the optimization of biodiesel production were investigated in the first phase of this study, while in the next phase of the study performance test of a diesel engine with neat diesel fuel and biodiesel mixtures were carried out. Biodiesel was made by the well known transesterification process. Cottonseed is non-edible oil, thus food versus fuel conflict will not arise if this is used for biodiesel production. However, the optimum conditions for biodiesel production are suggested in this paper.

A maximum of 77% biodiesel production was observed at 20% methanol and at a temperature of 55^0C. The crude CSO was used in the present investigation; therefore, biodiesel yield was less than 90%. A maximum of 77% biodiesel yield was found at 0.5 wt-% catalyst and at a reaction temperature of 55^0C. Thus 20% methanol and 0.5% NaOH were chosen as the optimum percentages for biodiesel production. Biodiesel mixtures showed less CO, PM, smoke emissions than those of neat diesel fuel. NOx emission with biodiesel mixtures showed higher values when compared with neat diesel fuel. Compared to the neat diesel fuel, 10% biodiesel mixtures reduced PM, smoke emissions by 24% and 14%, respectively. Biodiesel mixtures (30%) reduced CO emissions by 24%, while 10% increase in the NOx emission was experienced with the same blend[5].

2.6 C.V. Subba Reddy, C. Eswara Reddy & K. Hemachandra Reddy (2012): In the present work, experiments are conducted on 3.72 kW(5 BHP) single cylinder, four stroke, water-cooled diesel engine using cotton seed oil methyl esters blended with diesel in various proportions to study the engine performance and emissions at different injection pressures..

It could be concluded from the results that at the injection pressure of 200 bar, the performance and emission characteristics of 20BD are better as compared to180 bar for diesel fuel operation. The blends of biodiesel with diesel substantially reduced unburnt hydrocarbons, carbon monoxide and smoke opacity in exhaust gases, and slightly higher NOx due to higher combustion temperature than diesel fuel. Therefore, it is established that the blend 20BD is better alternative fuels for D.I. diesel engines at higher fuel injection pressure of 200 bar [6].

III. THE FUTURE SCOPE

Scope for future work as suggested in above review is to design ANN model by selecting proper hidden layer, activation function and learning algorithm and to determine the set of connection weight and nodal thresholds regarding given problem. Also there is a scope to optimize the performance and emission characteristics of CI engine by using ANN, so that the controlling of performance parameter of engine can be achieve in well manner.

IV. CONCLUSION

ANN is collection of small individually interconnected processing units. Information is passed between these units with the help of interconnection weights. ANN requires some past data to train with respect to that data set until the learning of network. Once ANN trained then it will predict new pattern of data. From this it is clear that ANN technique is very useful to predict and optimize the performance of CI engine.

The use of cotton seed oil as biodiesel reduces the CO, PM and smoke emission but there is slight increase in NO_X emission when compared to neat diesel fuel. Thermal efficiency with cotton seed oil was slightly lower than that of neat diesel fuel due to lower heating value of cotton seed oil.

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