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Performance and Emission analysis of Rapeseed Methyl Ester on DI diesel engine using Artificial Neural Network

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Abstract

In the present work, experiments were carried out on four stroke, single cylinder, water cooled, constant speed, variable compression ratio (VCR) diesel engine. Initially, experiments are done when the engine is fuelled with diesel fuel. After that the experimental tests are conducted by using fuel blends of RME20 (20% Rapeseed methyl ester and 80% diesel), RME40 (40% Rapeseed methyl ester and 60% diesel), RME100 (Pure Rapeseed Methyl Ester) on volume basis. Performance, emission characteristics of diesel and rapeseed methyl ester (RME) with diesel blends are examined. The engine speed is maintained constant at 1500 rpm at different loads and at compression ratios of 16:1, 17:1, 18:1. The performance parameters like brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperatures are measured and the results are recorded. The emission parameters like carbon monoxide (CO), carbon dioxide (CO_2), unburnt hydrocarbons (UHC), Nitrogen oxides (NO_x) and smoke are measured. In the present study, Artificial Neural Network (ANN) is used to model a diesel engine fuelled with the Rapeseed methyl ester and diesel blends. Artificial neural network is a tool to efficiently predict the combustion, performance and emission characteristics by using measured data. Artificial neural network toolbox in MATLAB software is used for simulation of engine parameters. Experimental results and artificial neural network predicted results which are in close agreement with each other.

***Keywords*:** Rapeseed Methyl Ester, Performance, Emissions, ANN

1. Introduction

In France, Rudolf Diesel used peanut oil as fuel in the diesel engine in the year 1910. When the cost of petroleum products increased, it is preferred to consider the usage of vegetable oils in the long run. The properties of diesel and vegetable oils are similar and are comparable with each other. Major problem is that the cost of vegetable oils is more than petroleum fuels. By developing agriculture sectors and production of vegetable oils from the plants, the cost of vegetable oils from the plants can be reduced. In agricultural country like India, several fuels like Pongamia pinnata, Mahua, Cashew, Rapeseed, Jatropha, Soybean can be made from plants for usage of fuel alternative to petroleum-based fuels. The main difference between vegetable oil and diesel is that vegetable oil has more viscosity and lower calorific value. The pollution levels in the environment are increasing day by day due to increase in vehicles running with petroleum-based fuels. Several rules and regulations are imposed to control the emissions by the emission regulatory boards every year worldwide.

For fresh experimental data, ANN has relearn capability for its performance improvement. Artificial neural network is very much useful for prediction of different output parameters by using various input variables. Artificial neural network has the learning ability, which is completely different from conventional modelling, which requires prior information regarding process relationships. In conventional mathematical simulations requires the large number of iterations and calculations to solve the differential equations, whereas, an ANN is faster for prediction of output variables, by using proper neural network topology (K. Prasada Rao et al., 2017).

2. Literature Survey

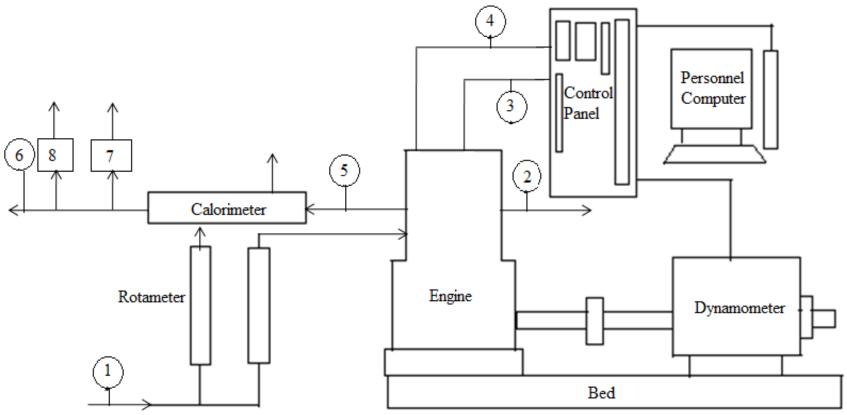
In recent years, ANN models are useful to model the internal combustions engines operation. An ANN approach is used to predict the performance and emission of the diesel engines (Canakci et al., 2006, Arcaklioglu et al., 2005), equivalence ratio and specific fuel consumption (Celik et al., 2005). The effect of turbulence of SI engines due to valve timing variations and fuel economy were studied by using ANN (Golcu et al., 2005). In ANN modelling the inputs from various sources are received by biological neurons and combines in one way or the other, and final output results are envisaged after performing a non linear operation. Artificial neural network consists of three layers such as input layer, hidden layer, and output layer (Haykin et al., 1994, Chouai et al., 2002). Back propagation algorithm is a well known algorithm, which has diverse options in the modelling. Due to small learning rates of steady learning, gradient descent, and gradient descent of back propagation algorithms are slow for the realistic problems. Parameters learning rate and momentum constant are the key parameters to know the success in the algorithms. Levenberg-Marquardt (LM), quasi-Newton and conjugate gradient algorithms are faster and standard operation techniques that are used by them. During the learning process of back propagation algorithm the weights are varied and these variations are stored as knowledge. One of the approximations of Newton’s method is in fact basically LM method (Marquardt et al., 1963). For obtaining the improved convergence the LM algorithm is used for second order derivatives of the constant function. The errors are indicated in terms of root mean square error (RMS), mean absolute percentage error (MAPE) and absolute fraction of variance (R^2).

3. Experimental setup

In this study, experiments were conducted on a single cylinder variable compression ratio 4 stroke diesel engine to determine the performance, emissions, and combustion characteristics at various loads and at different compression ratios. The inlet side of the engine is connected with biodiesel and diesel tanks separately and air box through the sensors. Similarly, the exhaust side of the engine was connected to INDUS smoke meter and INDUS 5 gas analyzer to measure the emissions from the engine. The exhaust temperature indicator is provided at the exhaust side of the engine to measure the exhaust gas temperature. The schematic diagram of the VCR diesel engine set up is shown in Fig 1. The detailed technical specification of the VCR diesel engine is shown in Table 1.

Table 1. Technical specification of the engine.

Make	Kirloskar
Number of cylinders	01
Number strikes	04
Power	5.20 kW
Bore X Stroke	87.5 mm X 110 mm
Swept volume	661 cc
Dynamometer	Mechanical loading
Orifice diameter	20 mm
Compression ratio	18:1
Rated speed	1500 rpm



1) Cooling water inlet 5) Exhaust gas inlet to the calorimeter
2) Cooling water outlet 6) Exhaust gas outlet
3) Airflow 7) Five gas analyzer
4) Fuel flow 8) INDUS smoke meter

Figure.1 Schematic diagram of VCR diesel engine

The RME blends were prepared with the proportions of 20%, 40%, and 100% biodiesel with standard diesel. The test fuels considered in this study were Diesel, RME20, RME40, and RME100 (pure biodiesel). The experiments are conducted at a constant speed of 1500 rpm. The engine is cooled using circulating water and then started at no load condition using decompression lever for sufficient warm-up and stabilization before taking the readings. The experiments were conducted at three different compression ratios of 16, 17, and 18. The fuel injector opening pressure is maintained at 220 bar. VCR diesel engine performance parameters like brake power, torque, brake specific fuel consumption, brake thermal efficiency, and exhaust gas temperature were calculated. Fuel flow is measured by using burette and stopwatch. The time required for 10 cubic centimetre of the fuel flow in the burette is measured by using stopwatch, which gives the flow rate of fuels like diesel, RME20, RME40, RME100. Exhaust gas temperatures were measured at each load by resistance temperature detectors, whose sensors are placed after the exhaust valve in exhaust pipe.

4. Results and Discussion

Root mean square error (RMSE) and regression analysis were calculated for all the ANN models. Statistical values for all the output data are shown in Table 2.

Table 2. R^2 and RSME values for ANN models.

ANN	Particulars	R^2	RSME
ANN1	BTE	0.990	0.441
ANN2	BSFC	0.974	0.031
ANN3	UHC	0.967	0.720
ANN4	CO	0.968	0.002
ANN5	CO_2	0.959	0.346
ANN6	NO_x	0.990	29.477
ANN7	Smoke	0.942	0.015

Absolute fraction of variance (R^2) values for BTE and BSFC are 0.990, and 0.974 respectively, which are near to unity represents the experimental results and ANN predicted results have correlated well with each other. Root mean square error values for performance parameters such as BTE and BSFC are 0.441 and 0.031 respectively.

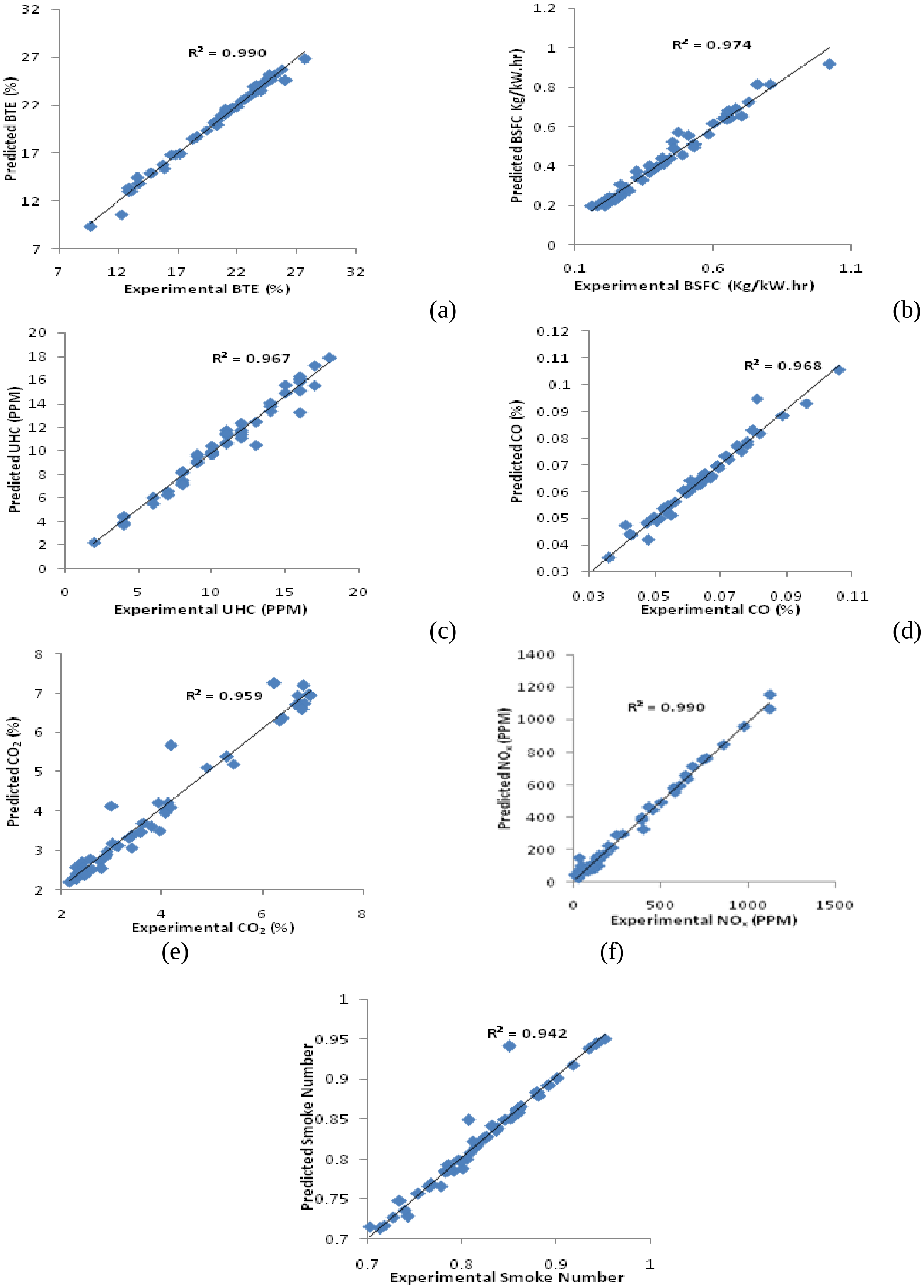


Fig 2. Relation between experimental and ANN predicted values for (a) BTE (b) BSFC (c) UHC (d)CO (e)CO_2 (f)NO_x (g) Smoke

The R^2 values for emission parameters such as UHC, CO, CO_2, NO_x, and INDUS Smoke number are 0.967, 0.968, 0.959, 0.990 and 0.942 respectively. Root mean square error values for emission parameters are 0.720, 0.002, 0.346, 29.477, 0.015 respectively, which are within acceptable limits. Regression plots of combustion, performance and emission characteristics for experimental results and ANN predicted results are shown in Figs. 2 (a) to (g). It is observed that the variations between them are very small. Experimental values are predicted by using ANN tool with minimum error and more precision.

5. Conclusion

It is concluded that experimental and ANN models predicted results are is good agreement with each other. The coefficient of determination R^2 values are in the range of 0.942 to 0.990, which represents that the ANN models predicted results are very near to experimental results. For nonlinear problems like IC engine performance applications, artificial neural network tool is an efficient tool for prediction of performance parameters with less cost, shorter duration, reliability, high accuracy, and precision.

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