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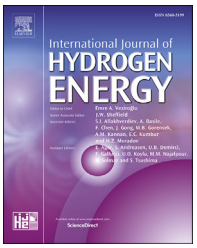

Artificial Neural Network modeling of a hydrogen dual fueled diesel engine characteristics: An experiment approach

Javed Syed [a,*], *Rahmath Ulla Baig* [b], *Salem Algarni* [a], *Y.V.V. Satyanarayana Murthy* [c], *Mohammad Masood* [d], *Mohammed Inamurrahman* [e]

[a] *Department of Mechanical Engineering, College of Engineering, King Khalid University, Abha, Saudi Arabia*
[b] *Department of Mechanical Engineering, P.E.S Institute of Technology-South Campus, Bangalore, India*
[c] *Department of Mechanical Engineering, GITAM Institute of Technology, GITAM University, Visakhapatnam, India*
[d] *Department of Mechanical Engineering, Lords Institute of Engineering and Technology, Hyderabad, India*
[e] *Department of Computer Science, College of Sciences and Arts, King Khalid University, Dhahran Al Janoub, Saudi Arabia*

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ABSTRACT

The rapid growth of vehicular pollution; mostly running on the diesel engine, emissions emerging are the concerns of the day. Owing to clean burn characteristics features, Hydrogen (H_2) as a fuel is the paradigm of the researcher. Extensive research presented in the literature on H_2 dual fueled diesel engine reveals, the significant role of H_2 in reducing emissions and enhancing the performance of a dual fueled diesel engine. With meager qualitative experiment data, the feasibility to develop an efficient Artificial Neural Network (ANN) model is investigated, the developed model can be utilized as a tool to investigate the H_2 dual fueled diesel engine further. In the process of developing an ANN model, engine load and H_2 flow rate are varied to register performance and emission characteristics. The creditability of the experiment is ascertained with uncertainty analysis of measurable and computed parameters. Leave-out-one method is adopted with 16 data sets; seven training algorithms are explored with eight transfer function combinations to evolve a competent ANN model. The efficacy of the developed model is adjudged with standard benchmark statistic indices. ANN model trained with Broyden, Fletcher, Goldfarb, & Shanno (BFGS) quasi-Newton backpropagation (trainbfg) stand out the best among other algorithms with regression coefficient ranging between 0.9869 and 0.9996.

* *Corresponding author.*
E-mail address: syedjavedme@gmail.com (J. Syed).

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Introduction

For decennaries, the dominant underpinning power source in industrial and transportation sector is diesel powered engines. With the rapid growth of transportation, emissions from the diesel-fueled engines are concerns of the day. Depletion of fossil fuel and an increase in emission made researchers endeavor for energy substitution with renewable and sustainable fuel in conjunction with a reduction in emissions. Literature divulges the cardinal role of hydrogen (H_2) as a dual fuel in diesel engines with enhanced performance and reduced emissions.

On the embarked prospect of performance enhancement and diminution in emission, the diesel engine was duel fueled with H_2. It was divulged that increase in H_2 energy substitution ratio increases thermal efficiency and NO_x emissions [1]. Mathur et al. [2] investigated utilization of H_2 fuel in dual fueled diesel engine on a commercial 4 kW diesel engine. The H_2 flow rate of 20–50 l/min were attempted, water is injected as a diluent to the cylinder to reduce knocking at higher H_2 energy substitution. The significant findings of experimentation reiterate the fact that, H_2 could be expediently used to enhance performance and alleviate emissions.

H_2 induction through intake port was inquisited on Kirloskar AV-1 single cylinder diesel engine and compared outcomes with computational fluid dynamics analysis [3]. An increase in peak pressure & NO_x emissions with advancement in ignition and increase in combustion velocity with the augmentation of H_2 substitution were reported. H_2 can be inducted into the cylinder by natural aspiration along with intake air or by injecting in the intake manifold. Lata et al. [4] inducted H_2 naturally through an intake manifold of a diesel engine running at 1500 rpm. At 80% engine load, H_2 dual fuel engine reported an increase in brake thermal efficiency (BTE) of 4.48% as compared to baseline diesel fuel, but H_2 flow rate beyond 45% energy substitution results in a decrease in BTE. In the presence of H_2 fuel, CO (carbon monoxide) emissions decrease as compared to baseline diesel fuel due to the absence of carbon particles.

An inquest into a variation of H_2 flow rate from 0 to 7.4% by energy was probed, H_2 substitution abates particulate matter emissions, and the effect of H_2 flow rate in reduction of NO_x (nitrogen oxide) is marginal [5]. Santoso et al. [6] investigated H_2 addition at low engine load conditions; the engine was run at the constant speed of 2000 rpm and 10 Nm load. Enrichment of fuel mixture with H_2 flow rate from 21.4 to 49.6 l/min results in a decrease in peak pressure and BTE.

The role of H_2 energy substitution on engine performance and emissions is espied by De Morais et al. [7]. H_2 energy substitution was varied from 0 to 20% while varying engine load from 0 to 40 kW. It was found that small H_2 energy substitution results in a decrease in specific fuel consumption. Also, carbon dioxide emissions decrease with a supplement of H_2 fuel. With the increase in engine load, the oxygen concentration in exhaust decreases, whereas EGT increase. Zhou et al. [8] effectuated experiments by increasing H_2 energy substitution from 0 to 40% at a constant engine speed of 1800 rev/min. H_2 was naturally aspirated into the intake manifold, and engine load is varied. The role of H_2 energy substitution with engine load was apparent. With 30% H_2 energy substitution at 90% load, a drastic increase in peak pressure, shorten ignition delay and combustion duration was recorded. Results show erratic combustion at higher H_2 energy substitution operating at higher loads.

Owing to carbon-free characteristics of H_2 fuel along with high calorific value, emanating lower emissions and exhibiting better performance behavior, endeavors confirm utilization of H_2 as energy substitution as a dual fueled mode in a diesel engine with minor modifications to the existing diesel engine. On the other hand, H_2 dual fueled engine experimentations are strenuous and arduous. It is noteworthy to mention that, with minimum significant qualitative experimentation data, an efficient Artificial Neural Network (ANN) model can be modeled to accurately predict the performance and emission characteristics of a diesel engine running on diesel fuel [9–12]. Parlak et al. [9] designed backpropagation neural model with three inputs, seven neurons and two outputs (specific fuel consumption and EGT). The mean absolute relative error was employed to judge the efficacy of the model for a diesel engine. Yusaf et al. [10] model to predict diesel engine torque and emissions accede to regression coefficients of 0.955.

Uzan [11] illustrated the development of ANN model for a turbocharged inter cooled diesel engine. Predictions obtained with the well-trained model were used to perform parametric studies. Bietresato et al. [12] model to predict torque and brake specific fuel consumption (BSFC) of a diesel engine, various transfer functions were tested, and maximal regression coefficient was observed for Gaussian transfer functions.

Literature review reveals, H_2 has notable engine performance & emission characteristics and is viable to be used as dual fuel in a diesel engine. Numerous network models were developed for diesel engine running on diesel fuel. However, sparse ANN models were reported in the literature to predict performance and emission characteristics of an H_2 dual fueled diesel engine.

Current research aims at developing robust ANN model with meager data generated from the experiment, which can efficiently predict the performance and emission characteristics of H_2 dual fueled diesel engine. The efficacy of the developed model is adjudged comparing with the current experimental results adapting standard benchmark statistics indices. The developed model can aid in the further investigation of H_2 as a dual fuel in a diesel engine.

Artificial Neural Network

Working model of ANN is quite close to the functioning of the human brain. When a set of input signal is received at a neuron, each input signal is weighted, sum together, and subjected to an activation (transfer) function. The neuron gets fired, i.e., transmit a signal to another neuron or environment when the resulted signal exceeds the threshold limit (bias) of the neuron. This configuration is known as a perceptron. The architecture of the perceptron is shown in Fig. 1.

The outcome of the perceptron is judged based upon the performance function such as Mean Squared Error (MSE). New weights and activation levels are redefined feeding the error.

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