INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 39 (2014) 12991–13001

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Mathematical modeling for the performance and emission parameters of dual fuel diesel engine using hydrogen as secondary fuel

A.E. Dhole [a,*], R.B. Yarasu [a], D.B. Lata [b], S.S. Baraskar [c]

[a] Department of Mechanical Engineering, Government College of Engineering, Amravati, Maharashtra 444603, India
[b] Department of Mechanical Engineering, G.H. Raisoni College of Engineering and Management, Amravati 444705, India
[c] Department of Mechanical Engineering, Government Polytechnic, Amravati, Maharashtra 444603, India

ARTICLE INFO

Article history:
Received 23 April 2014
Received in revised form
12 June 2014
Accepted 15 June 2014
Available online 11 July 2014

Keywords:
Dual fuel diesel engine
Hydrogen
Design of experiments
General factorial design
Mathematical model
Response surface methodology

ABSTRACT

In this work, mathematical models were developed to correlate the brake thermal efficiency, un-burnt hydrocarbons, carbon monoxides and oxides of nitrogen by varying engine parameters like Load and Gaseous (H_2) fuel substitution. The developed models can be used to predict the important performance and emission parameters for diesel-hydrogen operation in various combinations at different loads within the experimental domain. Response surface methodology (RSM) has been applied for developing the models using the techniques of design of experiments and multi linear regression analysis. General factorial design was used to plan the experiments. Second order response surface models were found to be the most suitable in the present work. Analysis of variance (ANOVA) of the experimental results at 95% confidence level revealed that the developed models are significant. Comparison of experimental output with those predicted by the developed models showed close proximity having high correlation coefficients R^2 for the various response variables.
Copyright © 2014, Hydrogen Energy Publications, LLC. Published by Elsevier Ltd. All rights reserved.

Introduction

Concern over current crude oil supplies in addition to varying oil prices has resulted in the wide evaluation of substitution of alternative sources of fuel. With the increasing need to conserve fossil fuel and minimize toxic emissions much effort is being focused on the advancement of present combustion technology. This has encouraged exploration and testing of several alternative fuels such as alcohol, gas viz. CNG, LPG, hydrogen and producer gas, which have been studied extensively [1–5]. The main exhaust emissions from diesel engine are smoke, NO_x. The only option to reduce these pollutants is to use alternative fuels which do not have sulfur dioxide, aldehydes and ketones [6]. Amongst these alternative fuels, hydrogen shows great potential. The advantage of using hydrogen as fuel for internal combustion engine in dual fuel mode is less polluting fuel, non-toxic, odorless, and has wide range of flammability [6,7].

* *Corresponding author*. Tel.: +91 9404242407.
E-mail addresses: ananta172002@yahoo.co.in, annt64@rediffmail.com (A.E. Dhole).
http://dx.doi.org/10.1016/j.ijhydene.2014.06.084
0360-3199/Copyright © 2014, Hydrogen Energy Publications, LLC. Published by Elsevier Ltd. All rights reserved.

Hydrogen dual fuel engines have many attractive features, but they tend to suffer from premature ignition called knocking, particularly under high load conditions because of hydrogen's lower ignition energy, wider flammability range and shorter quenching distance [6]. Hydrogen has auto-ignition temperatures of 858 K and requires an ignition source to be used in an I.C engine [8]. The diesel fuel which has an auto-ignition temperature of 525 K can be used as a pilot fuel to ignite hydrogen. Considerable research works have been done on hydrogen as an alternative fuel in the I.C. engine as it undergoes complete combustion [9]. Dual fuel engines have been a subject of high interest due to their potential to reduce emission with improved performances [10]. They exhibit good thermal efficiency and low smoke level at high power output [11]. The majority dual fuel engines use gaseous fuel mostly inducted with the air during induction process as secondary fuel. Therefore, hydrogen becomes a natural choice as secondary fuel since it exhibits wide flammability limits, high flame velocity and reduced pollution.

Several researchers have carried out works on hydrogen [6–17]. Saravanan et al. [6] worked with hydrogen as an air-enrichment medium while diesel as an ignition source and found increase in brake thermal efficiency (η_{BTH}) with reduction in emission of NO_x. Saravanan et al. [12] observed 15% rise in η_{BTH} at 75% load as compared to pure diesel operation by injecting hydrogen into the intake port of a single cylinder diesel engine while NO_x emission was raised by 1–2% at full load condition. Boretti [13] investigated that the dual fuel hydrogen-diesel engine had higher brake thermal efficiency nearer to 40% as compared to original diesel engine by introducing double injector one for hydrogen and other for diesel in an injector of a common rail diesel engine. Gomes Antunes et al. [14] obtained approximately 43% higher fuel efficiency in hydrogen-fueled engine in comparison with 28% for the conventional diesel engine in addition to 20% reduction in NO_x formation than diesel engine due to direct injection of hydrogen in a diesel engine.

Lata et al. [15] observed appreciable and eco-friendly performance of the engine using hydrogen, LPG and mixture combinations of hydrogen and LPG in different proportions as secondary fuels. Santoso et al. [16] identified slight increase in indicated efficiency with hydrogen enrichment at 15 Nm load and at lower load the efficiency decreases. Liu et al. [17] observed that an addition of a small amount of hydrogen significantly increased the emissions NO_2/NO_x ratio particularly at low load condition. Poor combustion results in high carbon monoxide and un-burnt emission [18]. Recently, authors have presented the effect on performance and emissions of a dual fuel diesel engine in which hydrogen, producer gas and mixture of hydrogen and producer gas were used as secondary fuels and the performances in these three distinct cases were compared [19]. Lata et al. [20] have reported theoretical and experimental studies on dual fuel diesel engine using hydrogen; LPG and a mixture of both were used as secondary fuels. Theoretical models were presented to predict brake thermal efficiency, pressure, and net heat release rate and compared with experimental results.

Baraskar et al. [21] applied response surface methodology for developing the models using the techniques of design of experiments and multi-linear regression analysis. Validation of the model was confirmed by conducting the confirmation experiments. Mu'azu et al. [22] developed a mathematical model for the esterification of *J. curcas* seed oil and studied effect of methanol to oil ratio, catalyst concentration and reaction time on free fatty acid (FFA).

Mu'azu et al. [23] developed mathematical model for the transestrification of jatropha curcas seed oil by factorial analysis of design of experiment. The factors which studied were methanol to oil molar ratio (6–10), catalyst concentration (4–8 wt %), reaction time (1–2 h) and stirrer speed (100–700 rpm). Analysis of variance (ANOVA) of the experimental results at 95% confidence level exposed that the developed model equation was significant and stirrer speed was the major parameter in the transestrification reaction followed by reaction time and methanol to oil ratio having effects of 24.59, 21.16 and 8.07% respectively. Comparison of experimentally obtained biodiesel yields with the predicted biodiesel yields by the developed model showed close proximity having high correlation coefficient ($R_2 = 0.995$). The developed mathematical model could be employed in simulation of biodiesel production under the reaction conditions studied.

Dhar et al. [24] presented work which evaluates the effect of current (c), pulse-on time (p) and air gap voltage (v) on metal removal rate (MRR), tool wear rate (TWR), radial over cut (ROC) on electric discharge machining of Al–4Cu–6Si alloy–10 wt % SiCP composites. Three factors, three level full factorial designs were adopted for analyzing the results. A second order, non-linear mathematical model had been developed for establishing the relationship among machining parameters. Analysis of variance (ANOVA) had been performed to verify the fit and adequacy of the developed mathematical models.

Karthikeyan et al. [25] developed mathematical models for optimizing electric discharge machining (EDM) characteristics such as the metal removal rate (MRR), the tool wear rate (TWR) and the surface roughness (CLA value). The process parameters had been taken in to consideration were the current (I), the pulse duration (T) and the percent volume fraction of SiC (25 m size) (V) present in LM25 aluminium matrix. A three level full factorial design was chosen for experimentation and mathematical models with linear, quadratic and interactive effects of the parameters chosen were developed. Finally the significance of the models was verified by using the analysis of variance technique (ANOVA).

Saidur et al. [26] investigated the effect of parameters like engine speed, throttle position, and operating time on engine emissions at different load conditions. The significance and adequacy of these parameters were evaluated using analysis of variance (ANOVA) and fisher's statistical test (F-test). From the analysis, it was concluded that emissions were more affected by engine speed and throttle position. Muhammad et al. [27] described the use of response surface methodology for the optimized biodiesel production using chemical and enzymatic transesterification of rice bran and sunflower oils. Based upon (ANOVA) and response Surface plots, significant impact of reaction parameters under study was ascertained. The monitoring of exhaust emission of synthesized biodiesels and their blends revealed a marked reduction in carbon monoxide (CO) and particulate matter (PM) levels, whereas an irregular trend was observed for NOx emissions.

Download English Version:

https://daneshyari.com/en/article/7718845

Download Persian Version:

https://daneshyari.com/article/7718845

Daneshyari.com