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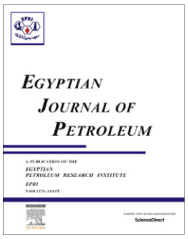

FULL LENGTH ARTICLE

Parametric optimization for performance and emissions of an IDI engine with Mahua biodiesel

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Abstract Experimental investigation was done on the IDI engine using Diesel, Mahua methyl ester (MME) and Methanol additive blends. The performance and emissions were carried out on the Indirect Injection diesel (IDI) engine with two input parameters like load and fuel and for nine response parameters like exhaust gas temperature (EGT), brake specific fuel consumption (BSFC), brake thermal efficiency (BTHE) and emissions like Hydro carbons (HC), Carbon monoxide (CO), Carbon dioxide (CO_2), Oxygen (O_2), Nitrogen oxides (NO_X), Smoke. In order to find out the optimal response the set of experiments were conducted using the design of experiments suggested by Taguchi for reducing time and cost. Then Grey Relational analysis was applied to the experimental data to find out the optimal combination of the load and fuel by converting the multi response problem into the single response problem with the help of Grey Relational Grade. Signal to noise ratio is calculated for the Grey Relational Grade (GRG) and optimal combination is found. The results after Grey Relational Analysis (GRA) were validated with the Response surface methodology (RSM) in which a desirability approach was used to find the optimal combination. It is found that the experimental results almost coincided with validation results. The optimal combination was found to be 20 kg of load and MME + 3% Methanol as the fuel.

1. Introduction

Now a days usage of biodiesel in diesel engine has increased rapidly. In this study we are validating to what extent the usage of biodiesel is useful in running the diesel engine. But running engine with different fuels with different targets is difficult and a lot of experimentation is needed. To reduce that effort we have used Taguchi design for design of a set of experiments, but Taguchi evaluation on multi response is not more effective when we are calculating responses with different objectives. So, this study used grey relational analysis for optimization and found the optimal combination of the load and fuel. However we cannot conclude the results obtained as suitable and there should be some validation done on the results. Hence for validation purposes we used the Response Surface Methodology.

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Ghaly et al. [1] reported that the research on the production of biodiesel has increased significantly in recent years because of the need for an alternative fuel which is endowed with biodegradability, low toxicity and renewability. Theansuwan et al. [2] concluded that the biodiesel produced by transesterification showed similar properties to the standard diesel. Agarwal et al. [3] investigated that the process of transesterification is found to be an effective method of reducing viscosity of vegetable oil. Prasada Rao et al. [4] in their study used modest amounts of methanol as an additive to Mahua methyl ester and used in an IDI engine. Methanol has a higher latent heat, lower viscosity and easy blending characteristics compared with biodiesel, which shows its advantage in combustion. The methanol presence slows down the combustion, similar to the EGR effect, and thereby reduces some of the pollutants. The performance and emissions have been evaluated to find a suitable methanol percentage that gives maximum benefits. It was observed that there is a maximum relief of exhaust temperature, which indicates that the ensuing combustion is a low temperature combustion in which methanol burned in the later stages because of the lower value of cetane number. The IDI engine indicates lower emissions in the exhaust. Additive mixing further reduced the HC and CO emissions to a large extent. NOx emission was also reduced at higher loads, especially with the additive. CO_2 emission increased because of combustion improvement. Thermal efficiency and specific fuel consumption improved with biodiesel.

Sahin et al. [5] examine experimentally the effects of gasoline fumigation (GF) on the performance and exhaust emissions of a turbocharged indirect injection diesel engine. The results showed that effective power was generally reduced and effective efficiency increased. Brake Specific Fuel Consumption (BSFC) was reduced and its decrement ratios are roughly at the levels of 5%. GF becomes economic for this engine and an average 5% reduction in fuel cost was attained. NO_x concentration decreased approximately at the levels of 5–10%. Smoke index was reduced for up to 8–12% GF and after this it started to increase. Its maximum reduction ratio was 20–8% GF at 2500 rpm. Singh et al. [6] said that transesterification is a process of converting vegetable oil into biodiesel fuel. This process supplies a fuel that can be operated in unmodified diesel engines. Numerous vegetable oil esters have been tried as alternative to diesel fuel. A lot of researchers have reported that with the use of vegetable oil ester as a fuel in diesel engines, a diminution in harmful exhaust emissions as well as equivalent engine performance with diesel fuel were achieved. Several studies have found that biodiesel seems to emit lower pollutants than standard diesel fuel. Decreasing of carbon dioxide (CO_2) using biodiesel contributes to reduce greenhouse effect. In other sense, diminishing of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x). Goutam Pohit and Misra [7] in their study optimized the engine responses comprising eight different parameters when three input parameters were varied simultaneously. Since the investigation clearly indicated possibility of a large number of test combinations, design of experiment was carried out using the Taguchi method to limit the number of experiments by the formation of orthogonal array. Complexity of the optimization problem was evident from the fact that the responses were not unidirectional. Subsequently, multi response problem was converted into a single one with the application of weighting factors of grey relational analysis and optimum solution was obtained from the test data. Finally finding of experimental study was validated with the result obtained through actual experimentation, and found the most suitable blend for diesel engine without significantly affecting the engine performance and emissions characteristics, corresponding compression ratio and engine load being 17% and 80% respectively. Sivaramakrishnan et al. [8] based on the results of their study said that the design of experiments was highly helpful to design the experiment and the statistical analysis helped to identify the significant parameters which are the most influencing on the performance emission characteristics. This experimental design considerably reduced the time required by minimizing the number of experiments to be performed and provided statistically proven models for all response. It is clear from this research that CO and HC emissions have been reduced when biodiesel is fuelled instead of diesel and also better BTHE with lesser BSFC with lower CO, HC and NO_x values. Desirability approach of the RSM was found to be the simplest and efficient optimization technique. A high desirability was obtained at the optimum engine parameters of CR, fuel blend, and power, where the values of the BTHE, BSFC, CO, HC, and NO_x were found to be 3.65%, 0.2718 kg/kW h, 0.109%, 158 and 938 ppm, respectively. Karnwal et al. [9] based on the results of their study concluded that the BSFC, BTE and EGT of diesel engine, are a function of biodiesel blend, compression ratio, injection pressure and injection timing. Results of the study have also revealed that almost same optimum combination of engine parameters for different engine loading conditions gives optimum multiple-performance. It emphasizes that Taguchi method coupled with grey relational analysis can be used effectively for investigation of multiple performance characteristics of diesel engine. It has given optimum engine performance which is defined by maximum thermal efficiency, minimum brake specific energy consumption, least exhaust gas temperature and lowest emissions. Hussain et al. [10] said that the Grey relational analysis based on an orthogonal array of the Taguchi method was a way of optimizing the process parameters in engine process. The optimum operating condition was obtained producing maximum performance of the engine. Sivaramakrishnan et al. [11] in their study used Taguchi's approach analysis for optimizing the performance of Karanja biodiesel on diesel engine. The various input parameters have been optimized using SNR. Based on this study, it can be concluded that BTHE, BSFC and Emissions of diesel engine depend upon biodiesel blend, compression ratio, nozzle pressure and injection timing. The results of this study revealed that almost identical combinations of engine parameters give optimum multiple performances for engine. It was found that a diesel engine fuelled with biodiesel has a better performance than fuelled with diesel. Wu et al. [12] concluded that the optimal operating factors of high BTHE and for low BSFC, NO_X, and smoke have been obtained for a diesel engine with diesel/biodiesel blend using H_2 and cooled EGR at the inlet port with Taguchi method. The combustion performance and emissions have also been compared between the optimized engine and baseline diesel engine. The Taguchi method was a good method to find out the optimum combinations. The predictions using Taguchi's parameter design technique are in adequate agreement with the confirmation results, with a confidence interval of 95%, and this technique saves 67% of the time taken to perform the experiment in this research. This combination improves combustion performance. At various

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