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OPTIMIZATION OF CI ENGINE PERFORMANCE FUELED WITH DIESEL-PPO BLENDS: A TAGUCHI'S APPROACH

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ABSTRACT

The automotive industry faces increasing pressure to mitigate environmental impacts while maintaining optimal engine performance. This study explores the potential of diesel-plastic blends as a sustainable solution to address both challenges. Using a Regression Analysis Approach, the research aims to optimize Compression Ignition (CI) engine performance and reduce emissions through systematic experimentation and statistical modeling.

The study begins with a comprehensive literature review, highlighting the urgent need for alternative fuels and the abundance of plastic waste. The rationale for investigating diesel-plastic blends is grounded in their potential to repurpose plastic waste while enhancing engine efficiency. The primary objectives include assessing blend feasibility, analyzing performance metrics, and identifying optimal blend ratios.

Methodologically, the study involves blend formulation, experimental testing, regression analysis, and optimization. Various diesel-plastic blends are formulated with different ratios of recycled plastic waste. Engine performance and emissions testing are conducted using a CI engine equipped with advanced instrumentation. Statistical regression models are then developed to analyze the relationships between fuel composition, engine behavior, and emissions characteristics. Finally, optimal blend ratios are determined to achieve maximum combustion efficiency and minimum emissions.

The significance of this research lies in its potential to offer a sustainable solution to plastic waste management and fossil fuel dependency. By leveraging recycled plastics as a fuel source, the automotive industry can reduce environmental impacts and pave the way for a greener transportation future.

In conclusion, the study underscores the importance of alternative fuels in achieving environmental sustainability and optimizing engine performance. Through rigorous experimentation and statistical modeling, diesel-plastic blends emerge as a promising avenue for enhancing CI engine efficiency while mitigating environmental harm.

Keywords: Parametric Optimization, Diesel-PPO, PPO, Pyrolysis, RSM, RSM CCD.

I. INTRODUCTION

The majority of diesel or CI engines are found in commercial and transport vehicles. Diesel engines are more durable than petrol engines. Moreover, their thermal efficiency are higher. When compared to the petrol version of the identical car, the diesel variation is typically more expensive. Fuel is injected when pressurised air is housed inside the cylinder of a diesel engine. After the diesel is injected, combustion begins because the air inside the cylinder is already compressed, hot, and under high pressure. As a result, diesel engines use less fuel than petrol engines. This is due to the fact that throttle response only controls the amount of air that enters the cylinder; fuel injection, which ignites the gasoline, is not as variable. Diesel fuel consumption has increased as a result of the increased demand for diesel vehicles brought about by these benefits. Crude oil, which is used to make diesel, is extracted from fossil fuels and takes millions of years to transform. As a result, alternative fuel for diesel engines becomes necessary. The proper disposal of plastic waste has become a global concern in recent years. Additionally, there is a greater amount of waste plastic as a result of rising plastic use rates. Usually, this waste plastic is burned in open fields or dumped into rivers and landfills. This is damaging the ecosystem and causing pollution to increase. Pyrolysis is one of the most widely used processes for turning plastic into oil. The heat breakdown of a material without the presence of oxygen is known as pyrolysis.

II. LITERATURE REVIEW

R. Karthikeyan et al [2010] said in their research paper about present global problem like increasing fuel price, continuous addition of on road vehicles, fast depleting petroleum resources and continuous accumulation green house gases and direct solution of above problem. This solution is alternative fuel. Many alternative fuels have been indentified and tested successfully in the existing engine with and without engine modification. However, still researches are continuing in this field to seek best alternatives which are offering best fuel characteristics.**1**

Devan.P.K. et al (2010) said in his research paper that Most of the alternative fuels suggested today are bio fuels and are proved to be a partial substitute for existing one. However, the various admission techniques experimented earlier are giving good solution to apply larger fraction of replacing fuel in the existing engine. The primary advantage of this kind of fuel is renewable and eco-friendly. These fuels are identified well before the exploration of the other promising alternatives fuels. **2**

T. Ganapathy et al [2009] proposed a methodology for thermodynamic model analysis of Jatropha biodiesel engine in combination with Taguchi's thermodynamic model based on two-zone Weibe's heat release function had been employed to simulate the Jatropha biodiesel engine performance. Among the important engine design and operating parameters **3**

Karthikeyan R. et al (2005) was done investigation & experiment on optimization of engine operating parameter for turpene mixed diesel fuel DI diesel engine. Turpentine is classified as biofuel because it is obtained from plant and animal. Of which plants contribute more by supply in large quantity of biofuels. A plant generally yields two types of oils namely triglyceride oil (TG oils) and turpene oil(light oil). The triglyceride oils are obtained from plant seeds but turpene oils are obtained from all parts of the plant. Also, this kind of oils are available in abundant in some plant species namely eucalyptus, pine tree etc.**4**

D.C. Rakopoulos et al were find possibility ethanol with diesel and problem related with it.they said in their investigation that while anhydrous ethanol is soluble in gasoline, additives must be used in order to ensure solubility of anhydrous ethanol (that is highly hygroscopic) in diesel fuel under a wide range of conditions. Especially at lower temperatures the miscibility is limited. Moreover, adding ethanol to diesel fuel can reduce lubricity and create potential wear problems in sensitive fuel pump designs. Ethanol possesses also lower viscosity and calorific value, with the latter imposing minor changes on the fuel delivery system for achieving the engine maximum power.**5**

M Nataraj et al [August 2005] has investigated that taguchi parameter design research methodology allow one to make product or processes robust to uncontrollable noise factor & Will also reduced the number of experiment to be carried out to arrive an optimized system.**6**

The literature review suggests –

- There has been a lot of research work carried out on the blend analysis of PPO-Diesel blends
- There has been some research done on the effect and optimization of certain parameters (Injection timing, injection pressure, EGR rates etc.) but little research has been done on the effect and optimization of parameters (CR, Load, %PPO) using Diesel-PPO blends CI engine.

The objectives of this research are –

- To develop an RSM model for the prediction of SFC.
- To optimize SFC for CI engine.

III. MATERIAL AND METHODS

The pyrolysis process has helped to transform waste plastic into plastic pyrolysis oil. One effective way to recover waste plastic is by pyrolysis. The heat breakdown of a material in the absence of oxygen is known as pyrolysis. A copper coil, a pyrolysis reactor, cold water storage, and a pipe to join the chamber's open end to the copper coil are the materials needed for pyrolysis.

- After being cleared of dust and other materials other than plastic, waste plastic is put into the pyrolysis chamber.
- Heat is supplied to the chamber.

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- When the gas first appears in the pipe, it is burned gas that has been liberated from combustion inside the chamber while all of the oxygen is still inside.
- The gas flow would halt and the chamber would begin to heat up once the combustion was finished.
- Since pyrolysis occurs at high temperatures, a significant quantity of heat is needed to convert it to PPO.
- Pyrolysis gas exits the chamber through the pipe that goes through the condenser after the chamber has reached a temperature.
- PPO is produced when the condenser converts the gas's phase from gas to liquid.

The pyrolysis process takes place as shown in Figure 1.

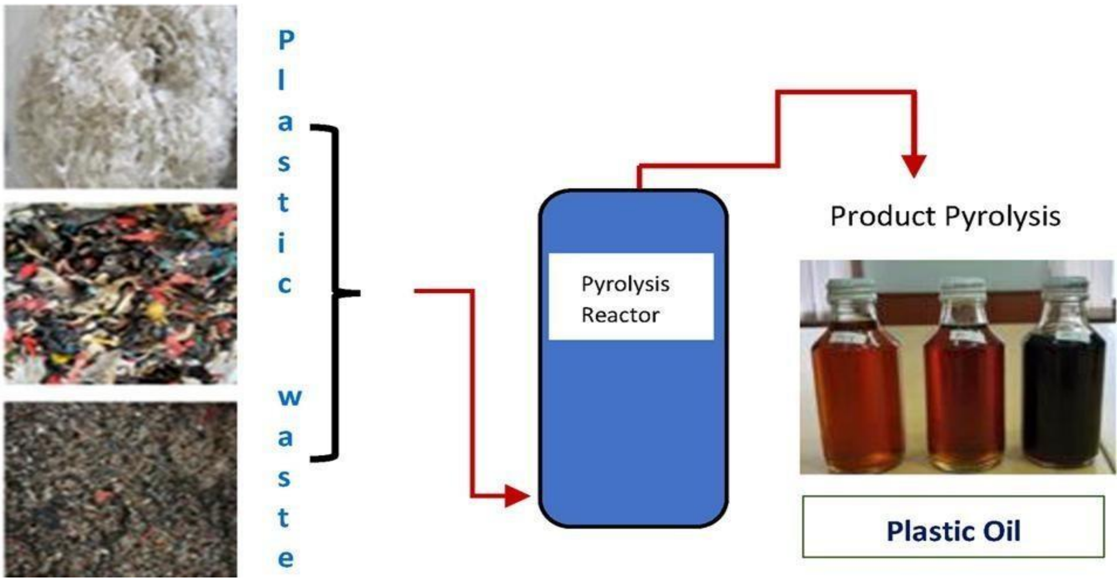

Figure 1: Pyrolysis of Plastic Waste [7].

Experimental Setup

A computerised research engine with four strokes, one cylinder, and water cooling is coupled to an engine test rig as part of the experimental setup seen in Figure 2. engine load as measured by an eddy current dynamometer. Numerous sensors help with parameter measurement (temperature, speed, air consumption, etc.).

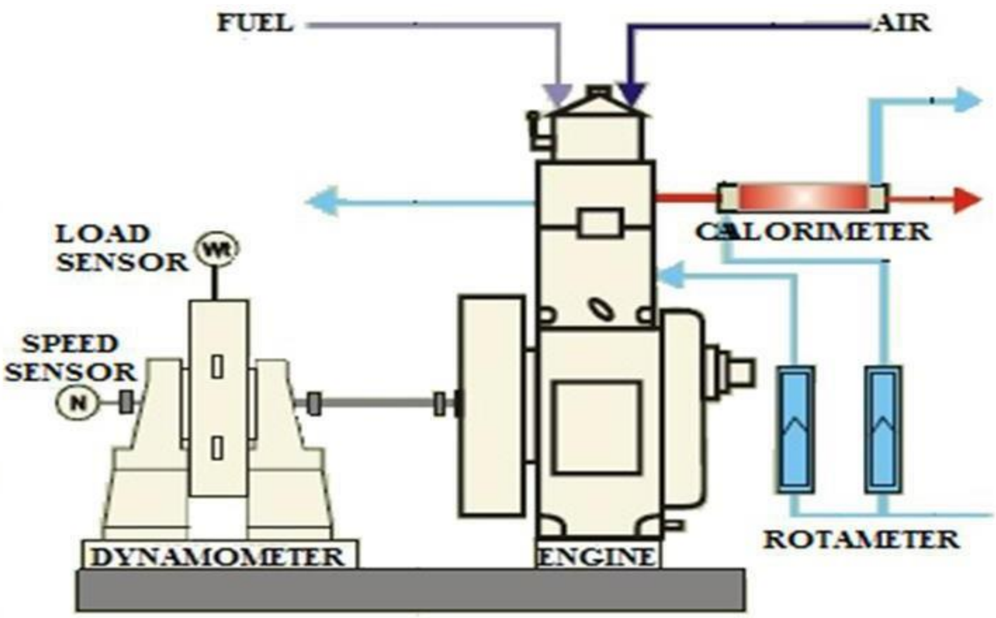

Figure 2: Schematic diagram of Experimental Setup.

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List of Instruments –

1. Single-cylinder four-stroke diesel engine (Power: 3.5 kW at 1500 rpm)
2. Hydraulic Dynamometer Load
3. Calorimeter and Tachometer
4. Temperature sensor
5. Speed sensor
6. Rotameter
7. Stopwatch

Procedure Methodology

Researchers can examine the link between numerous input variables, or factors, and their intended output variables, or responses, by using the methodical DOE technique. When important components have been found in the final rounds of experiments, response surface approach is usually employed. Usually, there are two to eight continuous elements. RSM finds the important parameters and illustrates the relationship between the input and output variables. The flowchart in Figure 3 illustrates the research technique.

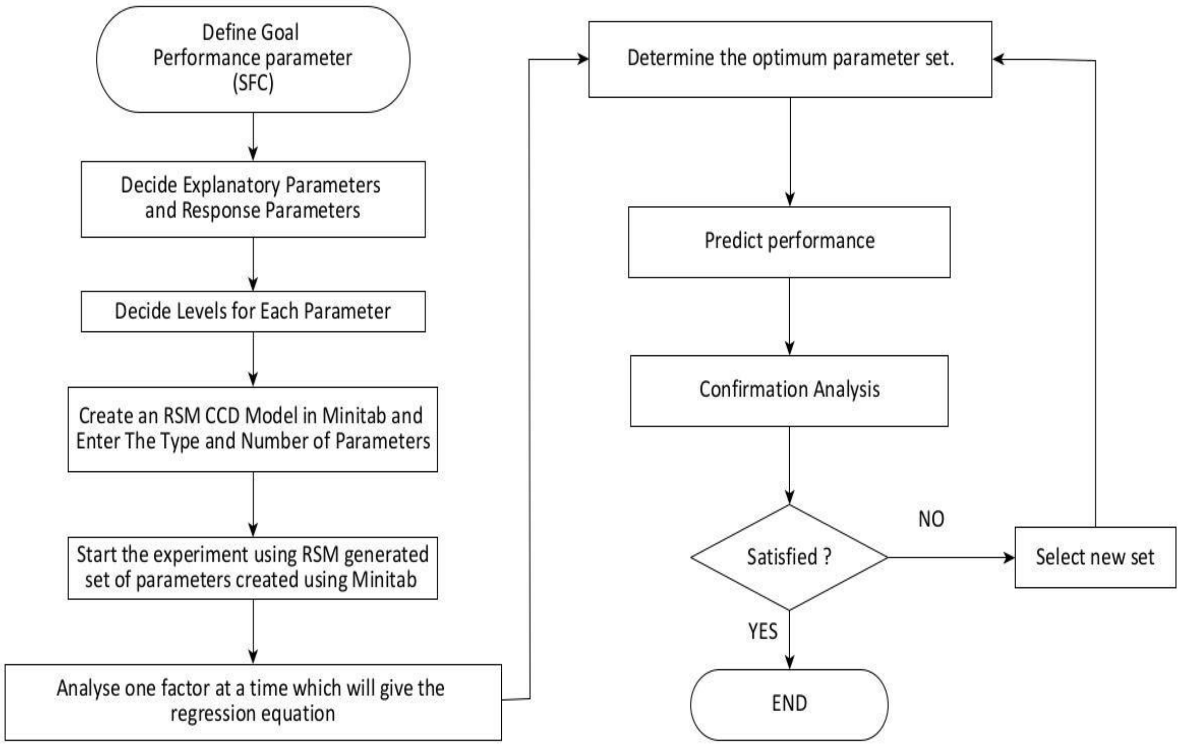

Figure 3: Methodology in RSM.

- Firstly, the goal needs to be defined (i.e. SFC in this case).
- Next, the explanatory parameters (input parameters) and response parameters (output parameters) need tobe decided.
- Later levels for each factor need to be decided.
- An RSM CCD model is then created using Minitab V18 and details like type and number of parameters are entered.
- The experiment is started using RSM generated set of parameters that are created using Minitab V18.
- The significant factors are then analyzed and several graphs are plotted.
- From the analysis of significant factors, a regression equation for each significant factor is generated.
- This equation is used to create an FFD, from which an optimum parameter set is to be selected.
- Later Depending on the goal, the optimum parameter set is identified from the FFD created using the regression equation.

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- Performance is predicted for the optimum set and is confirmed. If satisfied, the research is complete. If not satisfied, another optimum parameter set is identified and again performance is predicted for the optimum set and is confirmed.

The input elements for the experiments were established as levels, as indicated in the Table, and an analysis was carried out. For every factor, three levels were measured. In all, the response surface methodology was applied in nine different trials. Three independent variables were taken i.e. %PPO, CR & Load. These factors have three levels as shown in Table 1.

Table 1: Factors and Their Level

Factors	Level 1	Level 2	Level 3
Injection pressure (bar)	120	160	200
Engine load(kg)	0	5	10
Blend proportion(% by V/V)	0	50	100

IV. RESULTS AND DISCUSSION

Minitab designed a 9 experimental run table for 3 factors, to find the SFC for different sets of input factors as shown in Table 2.

All the values mentioned in Table 2 have been found by analyzing the model prepared in Minitab.

Table 2: Observation Table

Serial No	Blend Ratio(% Of Pyrolysis Oil In Diesel	Injection pressure	load	Fuel Consuption (cc/Min)	RPM	Friction
1	0	120	0.1	10	1713	2.24
2	0	120	5	16	1602	2.24
3	0	120	10	21	1559	2.24
4	50	160	5	15	1601	2.24
5	50	160	10	20	1561	2.24
6	50	160	0.1	10	1761	2.24
7	100	200	10	20	1574	2.24
8	100	200	0.1	7	1615	2.24
9	100	200	5	13	1597	2.24

Table 3: Validation Results for Specific Fuel Consumption

Experiment	Compression Ratio	Injection Pressure (bar)	Load (kg)	tf (sec)	FC (kg/hr)	BP (kw)	SFC(kg/kwh)
validation	100	160	10	0.33	1.11	2.28	0.49

V. CONCLUSION

- The Taguchi's approach has been carried out for optimizing the performance of diesel engine using pyrolysis and diesel blend. Three input parameters have been optimized using NR. The smaller-the-better quality characteristic have been used for minimize the Brake specific fuel consumption of the engine. An Li6 orthogonal array with three parameters and four levels has been used for predict set of parameter which gives value of predicated Brake specific fuel consumption. 9 numbers of experiments were done for those sets of parameters. Experimental values of performance were put in the Minitab software16 and software predicated Brake specific fuel consumption is 1.05 for set of 100% blend 120 bar injection pressure and 10 kg engine load and This suggested set of parameter which gives optimum performance of Brake specific fuel consumption. Validation experiment was done for that set of parameter and compared with predicated values. Validation experimental values for Brake specific fuel consumption is 0.49. This experimental values of Brake specific fuel consumption are very closer to the predicated values.

- Result obtained from validation experiments using optimum parameter combination gives excellent agreement with predicated results.
- The performance of the optimized engine is better than the baseline engine and also prove that Taguchi parameter design concept is more powerful and efficient tool for minimize Brake specific fuel consumption
- Pyrolysis oil can be successfully used in the diesel engine by changing parameters level.

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