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Parametric Optimization of Single Cylinder Diesel Engine for Specific Fuel Consumption Using Plastic Pyrolysis Oil as a Blend

KEYWORDS: Break specific fuel consumption, Plastic pyrolysis oil, Taguchi method, Diesel engine

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ABSTRACT *Due to the fossil fuel crisis in past decade, mankind has to focus on developing the alternate energy sources such as biomass, hydropower, wind energy, solar energy, and nuclear energy. The developing of alternative-fuel technologies are investigated to deliver the alternate of fossil fuel. In this context, waste plastics are currently receiving renewed interest. The objective of the study is to optimize the parameters such as plastic pyrolysis oil diesel Blend %, Injection pressure and Load of the single cylinder diesel engine through the Taguchi method. As the experiment required simultaneously optimization of three parameter with four levels used in this experiment. The taguchi experiment identifies that Injection pressure 200 bar, blend P30D70 and engine load 10 kg are optimum parameter setting for lowest break specific fuel consumption. Engine performance is mostly influenced by engine load and is least influenced by injection pressure.*

INTRODUCTION

Depleting fossil fuel reserves and increasing cost of the petroleum products are the big troubles of today's world. From past to present, tendency of oil price have increased consecutively. Researchers are continuously finding best alternative solution, which gives the best performance and fuel characteristics. Environmental pollution due to plastic wastes is a global phenomenon today. Recycling waste plastics into reusable plastic products is a conventional strategy followed to address this issue for years[1]. However this technique has not given impressive results as cleaning and segregation of waste plastics was found difficult but indispensible in this technique. It is estimated that approximate 10 thousand tons of plastics waste per day is generated in our country[2]. Today, refined technologies are available for plastic waste management.

PYROLYSIS PROCESS FOR CONVERSION OF WASTE PLASTIC INTO FUEL

Pyrolysis is the chemical decomposition of organic substances by heating at elevated temperature without the participation of oxygen. The word is originally coined from the Greek-derived elements pyro means "fire" and lysys means "decomposition". Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, cloth, like wood, and paper, and also of some kinds of plastic. Anhydrous Pyrolysis process can also be used to produce liquid fuel similar to diesel from plastic waste. Pyrolysis technology is thermal degradation process in the absence of oxygen. Plastic waste is treated in a cylindrical reactor at temperature of 300°C – 350°C[3].

EXPERIMENT SETUP

A single-cylinder, 4-Stroke, water-cooled diesel engine of 5 hp rated power is considered for the experimentation. The engine is coupled to a rope brake dynamometer through a load cell. It is included with a data acquisition system to store the data for the off-line analysis. The schematic layout of the experimental set up is shown in below Figure-1

Figure 1: experiment setup of diesel engine

A stationary, 5 hp direct injection diesel engine is used to conduct experiments. Its specifications are given in Table **TABLE – 1**

ENGINE SPECIFICATION

Parameter	Details
Engine	Single Cylinder High Speed Diesel Engine
Cooling	Water cooled
Bore × stoke	80 mm × 110 mm
Compression Ratio	16 : 1
Maximum Power	5 hp or 3.7 Kw
Rated speed	1500 rpm
Capacity	535 cc

1.The Rope brake dynamometer is attached to a brake drum or flywheel attached to moderate sized engine. A rope is wound around the brake wheel One end of rope is connected to the spring balance suspended from overhead and other end carries the load. Air suction rate and exhaust airflow rates are measured with the help of an air

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velocity meter. Automatically increases with increase of speed and vice versa so that steady speed conditions are more easily achieved.

EFFECT OF PARAMETER

Injection pressure

Injection pressure is a pressure which is required to inject the fuel into cylinder. For smooth function of injector, it is required that the injection pressure is higher than cylinder pressure. Higher the injection pressure gives better the dispersion and penetration of the fuel into all desired locations in combustion chamber.

Blend proportion

Blend ratio is percentage of alternate fuel or additive in the convention fuel by V/V ratio. When bland ratio increase or decrease, its changes the fuel consumption and consequently brake power and mechanical efficiency also change in brake thermal efficiency. When alcohol is a content of blend, it provides oxygen. So that, combustion becomes smooth and complete.

Engine Load

As engine speed increases, the loss of heat during compression decreases with the results that both temperature and pressure of the compressed air tends to rise, thus the increase in turbulence, however may tend to increase the heat loss in some cases.

OPTIMIZATION METHOD

The blends are in 10%, 20% & 30% plastic pyrolysis oil with standard diesel fuel. A method called "Taguchi" was used in the experiment for simultaneous optimization of engine such as injection pressure and load condition.

Taguchi Method of Optimization

Taguchi method is a simplest method of optimizing experimental parameters in less number of trials. The number of parameters involved in the experiment determines the number of trials required for the experiment. Hence, this was tried in the experiment to optimize the levels of the parameter involved in the experiment. This method uses an orthogonal array to study the entire parameter space with only a small number of experiments. The present study uses three factors at four levels and hence, an L16 orthogonal array was used for the construction of experimental layout (Table-2,column-1,2,3&4).The L16 has the parameters such as blend, injection pressure and load arranged in column 1, 2 and 3[4].

According to this layout, sixteen (16) experiments were designed and trials were selected at random, to avoid systematic error creeping into the experimental procedure. For each trial the brake specific fuel consumption was calculated and used as a response parameter.

Taguchi method uses a parameter called signal to noise ratio (S/N) for measuring the quality characteristics. There are three kinds of signal to noise ratios are in practice. Of which, the smaller-the-better S/N ratio was used in this experiment because this optimization is based on lower SFC. The taguchi method used in the investigation was designed by statistical software called "Minitab 16" to simplify the taguchi procedure and results.

RESULT AND DISCUSSION

Experiment was done for selection sets of parameters by Minitab software and find brake specific fuel consumption (BSFC) for those sets of parameters.

TABLE – 2
L16 Orthogonal array

Sr. No	Blend	Injection pressure	Load	BSFC
1	B0D100	160	1	1.402434
2	B0D100	180	4	0.459815
3	B0D100	200	7	0.312017
4	B0D100	220	10	0.258646
5	B10D90	160	4	0.442768
6	B10D90	180	1	1.428285
7	B10D90	200	10	0.251378
8	B10D90	220	7	0.305245
9	B20D80	160	7	0.294022
10	B20D80	180	10	0.244477
11	B20D80	200	1	1.330409
12	B20D80	220	4	0.415042
13	B30D70	160	10	0.238791
14	B30D70	180	7	0.292398
15	B30D70	200	4	0.412199
16	B30D70	220	1	1.364522

In this experiment, three parameters for four levels were considered. L16 single orthogonal array shown in table-2(column-1,2 & 3) was selected for the experimental investigation. "smaller-the-better" is being taken as quality characteristics, since the objective function is to maximize performance. brake specific fuel consumption(BSFC) for those sets are given in table-2.

Response curve analysis

Response curve analysis is aimed at determining influential parameters and their optimum levels. It is graphical representations of change in performance characteristics with the variation in process parameter. The curve give a pictorial view of variation of each factor and describe what the effect on the system performance would be when a parameter shifts from one level to another. The S/N ratio for the performance curve were calculated at each factor level and average effects were determined by taking the total of each factor level and dividing by the number of data points in the total. The greater difference between levels, the parametric level having the lowest S/N ratio corresponds to the parameters setting indicates highest performance[5]. From fig.5, mean is average value for reading taken for particular parameter. From graph, mean value is maximum (0.628228) for P0D100 blend and minimum (0.570987) for P20D80 blend. Mean value is maximum (0.606244) for 180 bar injection pressure and minimum (0.576501) for 200 bar injection pressure. Mean value is maximum (1.38141) for 1kg load and minimum (0.248323) for 10kg load.

Volume : 5 | Issue : 4 | April 2015 | ISSN - 2249-555X

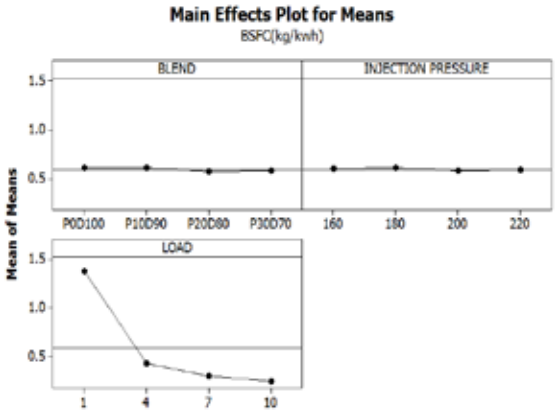

Figure 2: Main effect of parameter

Delta is difference of maximum value and minimum value. Delta value is maximum for load (1.1331) and minimum (0.0372) for blend parameter. injection pressure Delta value is between other two parameter. So that effect of load is maximum and effect of blend is minimum on Specific fuel consumption (SFC).

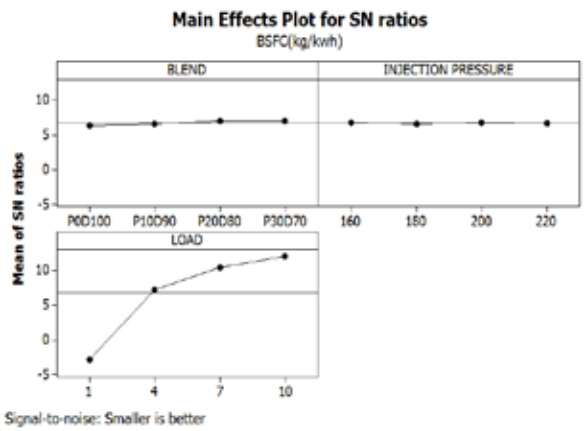

Figure 3: Main effect for S/N ratio

Referring (Fig.3) the response curve for S/N ratio, the lowest S/N ratio was observed at blend(P0D100), injection pressure(180 bar) and load(1 kg), which are optimum parameter setting for lowest Break specific fuel consumption(BSFC).From delta values as mention above maximum (14.907) for engine load and minimum (0.190) for injection pressure. Parameter engine load is most significant parameter and injection pressure is least significant for Break specific fuel consumption (BSFC).

Choosing optimum combination of parameters level

The term optimum set of parameters is reflects only optimal combination of the parameters defined by this experiment for lowest Break specific fuel consumption (BSFC). The optimum setting is determined by choosing the level with the highest S/N ratio.

TABLE – 3
Response Table for Signal to Noise Ratios

Level	Blend	Injection pressure	LOAD
1	6.418	6.803	-2.803
2	6.57	6.642	7.29
3	7.007	6.832	10.434
4	7.03	6.748	12.104
Delta	0.611	0.19	14.907
Rank	2	3	1

Referring fig.3 and Table.3, the response curve for S/N ratio, the highest performance at set P30D70 blend, Injection pressure 200 bar and engine load 10 kg which is optimum parameter setting for lowest Break specific fuel consumption(BSFC).

CONCLUSIONS

The results of the taguchi experiment identifies that Injection pressure 200 bar, blend P30D70 and engine load 10 kg are optimum parameter setting for lowest break specific fuel consumption. Engine performance is mostly influenced by engine load and is least influenced by injection pressure.

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