Experimental Study of Specific Fuel Consumption on Single Cylinder Diesel Engine Fuelled With Water-In-Diesel Emulsion Using Taguchi Method

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Abstract

An experimental work has been carried out for Emulsion of water-in-diesel used in single cylinder water cooled four stroke direct injection diesel engine. Stable emulsion was produced with 5% and 10% water by volume in diesel with the help of Span 20 used as surfactant. Emulsions were prepared by using mechanical homogenizer at speed of 2500rpm for 20 minutes of duration. In this work, the effect of parameters i.e. compression ratio, percentage water contents, injection pressure and load were taken as variable for optimization with three levels. Taguchi method used for optimization of diesel engine. The results of the taguchi experiments identifies that 10% water content in diesel, 17 compression ratio, 180 injection pressure and 12 load were optimum parameter setting for lowest specific fuel consumption. Confirmation experiment was done using optimum parameter set showed that specific fuel consumption was found by experiment is closer to the predicated value.

Keywords: water-in-diesel emulsion, diesel engine, parametric optimization, Specific fuel consumption (SFC), Taguchi method.

1. Introduction

Compression Ignition (CI) engines have a significant role in transportation, agriculture, heavy industries and power generation due to their high power to weight ratio, better fuel economy and low breakdown rate[1]. A transport sector contributes a major share to environmental pollution (around 70%). A among these pollutants CO is the major pollutant coming from the transport sector, contributing 90% of total emission. Diesel exhaust may cause lung cancer and other respiratory diseases[2]. The different kinds of fuels that have been considered as alternative fuels for petroleum based fuel are classified as solid, liquid and gas. The liquid fuels are alcohols (ethanol, methanol) and vegetable oils (edible and non-edible) and also emulsified fuel. Emulsified fuel is most favorable fuel due to easily availability of water and it is free of cost.

2. Literatures survey

Suresh V. et al. (2015) were conducted experimental work for study of combustion and performance characteristics of water-in-diesel emulsion fuel (0, 5, and 10% of water-in-diesel) are studied in variable compression ratio (15 to 18), single-cylinder four-stroke diesel engine. Brake Specific Fuel Consumption reduced and Brake Thermal Efficiency increase with increase water concentration.

BSFC also improved by using WD fuel. BTE of 10% WD emulsion fuel at full load is approximately 9.3%[3].

Narindar Singh et al. (2015) were conducted experiments to the investigate the effect of emulsified Fuel on Single-cylinder Direct Injection (DI) water-cooled diesel engine. BSFC at full load is minimum for 20% water diesel emulsion. Water diesel emulsion (up to 20% water by volume in diesel) can be used as a fuel in diesel engine with no engine modification[4].

Ali alahmer (2013) studied on the effect of emulsified diesel fuel on the engine performance and on the main pollutant emissions on water-cooled, four stroke, four cylinders, and direct injection diesel engine. It concludes that BSFC is minimum value at 5% water content[5].

M. P. Ashok et al (2012) studied on the effect of best emulsified fuel: with and without water addition for the reduction of automobile CO and NO*x* emissions in human life on diesel engine. Higher BTE values achieved by H2O2 added emulsified fuel with and without water addition are 34.87% and 33%. Lower SFC values for H2O2 added emulsified fuel with and without water addition are 0.259 and 0.246 kg/kWh[6].

Pradeep Kumar A R et al. (2015) studied on Effect of emulsified fuel on performance and emission characteristics on a single cylinder direct injection diesel engine. It concludes that Increase in break thermal efficiency and also the increase in the SEC was found after experiment[7].

3. Experimental Setup

The setup consists of single cylinder, four stroke, multi-fuel, research engine connected to eddy type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratios can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The diagram illustrated in figure indicates setup in laboratory. The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The setup has stand-alone panel box consisting of airflow, two fuel flow measurements, process indicator and hardware interface. Rotameters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement.

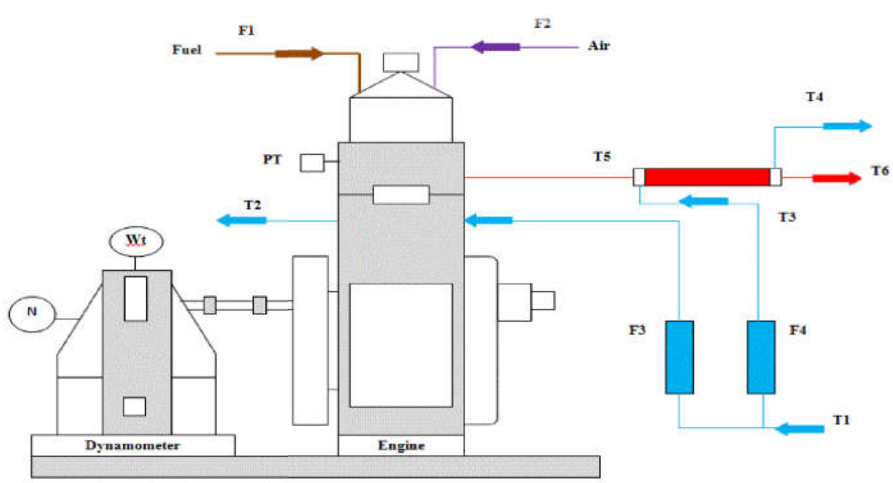

Figure: 1 Schematic Diagram of Experimental Setup

Symbol	Sensor Name
F1,F2	Fuel flow sensors
F2	Air flow sensor
F3	Engine water flow
F4	Calorimeter water flow
W	Load sensor
N	Engine speed sensor
PT	Cylinder pressure and Injection pressure sensor
T1	Jacket water inlet temperature ^{o}C
T2	Jacket water outlet temperature ^{o}C
T3	Calorimeter water inlet temperature ^{o}C
T4	Calorimeter water outlet temperature ^{o}C
T5	Exhaust gas to calorimeter inlet temperature ^{o}C
T6	Exhaust gas from calorimeter outlet temperature ^{o}C

Table: 1 Description of Symbols Used in Schematic Diagram

Figure: 2 Experimental Setup

Product	Research Engine test setup 1 cylinder, 4 stroke, Multifuel Computerized
No. of cylinder	1
Type of cooling	Water cooled
Rated power	3.5 kW @ 1500 rpm
Cylinder diameter	87.5 mm
Orifice diameter	20 mm
Stroke length	110 mm
CR Range	12:1-18:1
Connecting rod length	234 mm
Dynamometer	Type eddy current, water cooled, with loading unit
Injection variation	0- 25 Deg BTDC

Table: 2 Engine Specifications

4. Methodology

In this study, the effects of parameters` i.e. percentage water contents, injection pressure, compression ratio, and load are taken as variable for optimization. A method called 'taguchi' was used in the experiment [8].

Design factors	Levels		
	1	2	3
%water	0%	5%	10%
Compression ratios	16	17	18
Injection pressure	L	M	H
load	2	7	12

Table: 3 Design factors and their levels

5. Design of Experiments

Based on the taguchi method, an orthogonal array is being employed to reduce the number of experiments for determining the optimal test parameter for better engine performance. An orthogonal array provides the shortest possible matrix of combination in which all the parameters are varied to consider their direct effect on output responses. In the present work an L27 orthogonal array was used. The 2nd column represents the water contained in diesel, 3rd column represents compression ratios, 4th column represents the injection pressure and 5th column represents the loads, 6th column represents the SFC.

6. Observation and Results Table

Trail no.	%water	CR	IP	Load	SFC
1	0	16	L	2	0.40
2	0	16	M	7	0.17
3	0	16	H	12	0.15
4	0	17	L	7	0.18
5	0	17	M	12	0.15
6	0	17	H	2	0.36
7	0	18	L	12	0.13
8	0	18	M	2	0.30
9	0	18	H	7	0.17
10	5	16	L	2	0.44
11	5	16	M	7	0.18
12	5	16	H	12	0.15
13	5	17	L	7	0.15
14	5	17	M	12	0.13
15	5	17	H	2	0.33
16	5	18	L	12	0.13
17	5	18	M	2	0.32
18	5	18	H	7	0.18
19	10	16	L	2	0.38
20	10	16	M	7	0.17
21	10	16	H	12	0.15
22	10	17	L	7	0.15
23	10	17	M	12	0.11
24	10	17	H	2	0.22
25	10	18	L	12	0.15
26	10	18	M	2	0.31
27	10	18	H	7	0.17

Table: 4 Results Table for SFC

7. Response Curve Analysis

Response curve analysis is used for the evaluating effective variable and their optimum levels. Now for the final optimisation from the performance curves by ‘Minitab software.’ Minitab offers four types of designed experiments: factorial, response surface, mixture, and Taguchi. After conducting the analysis and entering the results, Minitab provides several analytical and graphing tools to help understand the results. The S/N ratio for optimal SFC is coming under “Smaller-is-better” characteristic, which can be calculated as logarithmic transformation of the loss function.

Level	% Water	CR	IP	Load
1	13.738	13.178	13.696	9.520
2	13.872	14.531	14.165	15.467
3	14.336	14.236	14.085	16.959
Delta	0.598	1.353	0.468	7.439
Rank	3	2	4	1

Table: 5 Response Table for Signal to Noise Ratios

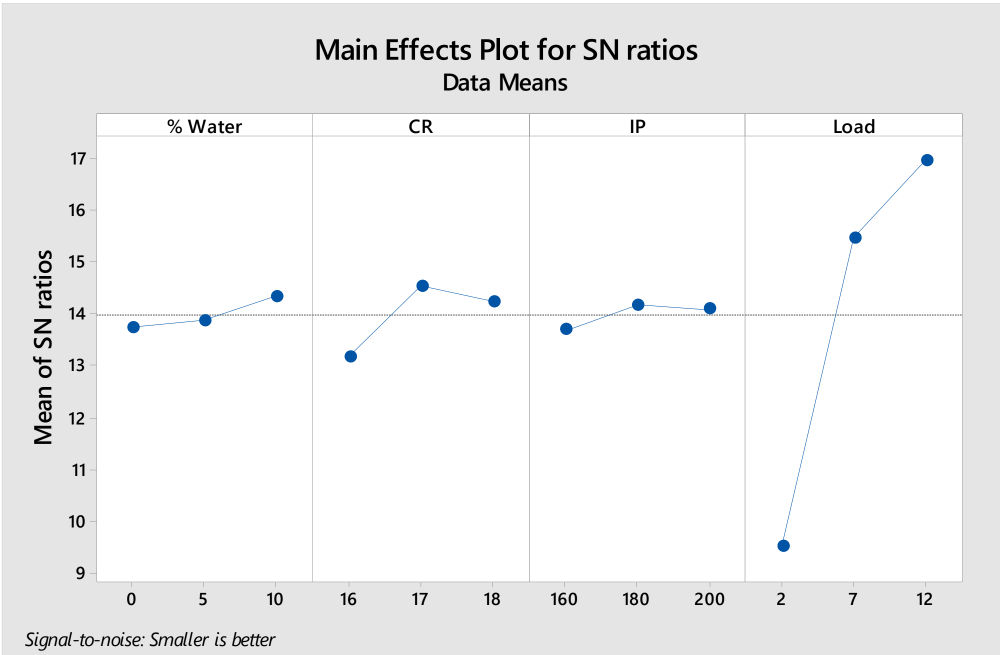

Figure: 3 SN ratios for BSFC

In the experiment, four parameters are considered such as percentage water contents, injection pressure, compression ratio, and load etc. Main Effects Plot for S/N ratio data and Mean data are shown in Fig. 3 and 4 that shows optimal results of SFC. From above fig. 6 the highest SN ratio was observed at 10% water-diesel emulsion (14.336), compression ratio 17 (14.531), injection pressure 180bar (14.165) and 12kg load (16.959), which are the optimum parameter setting for the lowest SFC. Delta value as mention above maximum (7.439) for engine load and minimum (0.468) for injection pressure. Parameter engine load is most significant parameter and the injection pressure is least significant for SFC.

Level	% Water	CR	IP	Load
1	0.2233	0.2433	0.2344	0.3400
2	0.2233	0.2011	0.2078	0.1689
3	0.2044	0.2067	0.2089	0.1422
Delta	0.0189	0.0422	0.0267	0.1978
Rank	4	2	3	1

Table: 6 Response Table for Means

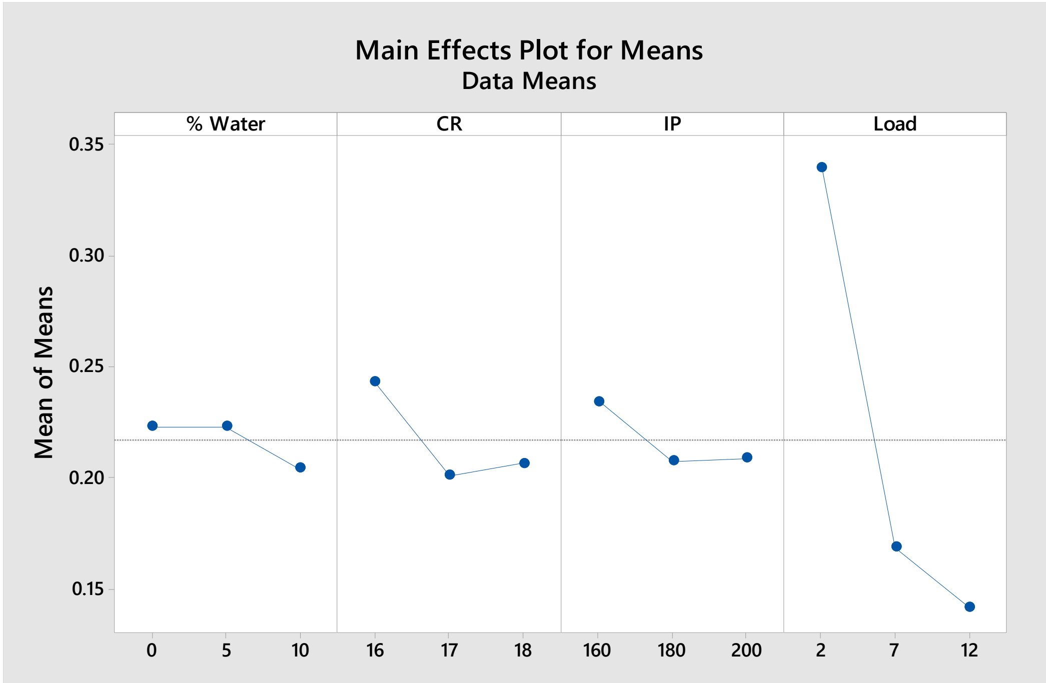

Figure: 4 Mean data for SFC

From above figure 4, mean is average value for reading taken for particular parameter. For % water parameter, mean value is maximum (0.2233) for 0% blend and minimum (0.2044) for 10% water. For compression ratio, mean value is maximum (0.2433) for 16 CR. And minimum (0.2011) for CR 17. For injection pressure parameter, mean value is maximum (0.2344) for 160IP and minimum (0.2078) for 180IP. And load parameters, mean value is maximum (0.3400) for 1kg of engine load and minimum (0.1422) for 12kg of engine load. Delta value as mention above maximum (0.1978) for engine load and minimum (0.0189) for %water. Parameter engine load is most significant parameter and the %water is least significant for SFC.

Predict performance at optimum setting:

% Water	CR	P	Load	S/N Ratio	SFC
10	17	180	12	18.0451	0.10444

Table: 7 Predicted Value for SFC

Comparison table:

Specific Fuel Consumption	
Predicted Value	Experimental Value
0.1044	0.114

Table: 8 Validation of experiment

8. Conclusion

The feasibility of using taguchi method to optimize selected diesel engine parameter for highest performance was investigated using single cylinder, 4-stroke diesel engine. The conclusions from this work are summarized as follow:

- The Taguchi method was found to be an efficient technique for quantifying the effect of control parameters.
- From experiment observed that at 10% water-diesel emulsion, compression ratio 17, injection pressure 180bar and 12 kg load, which are the optimum parameter setting for the lowest BSFC. Delta value as mention above maximum for engine load and minimum for injection pressure.
- Parameter engine load is most significant parameter and the injection pressure is least significant for BSFC.
- This experimental value 0.114 kg/kWh was nearer our predicted value 0.1044 kg/kWh.

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