International Journal of Mechanical Engineering and Technology (IJMET)
Volume 8, Issue 1, January 2017, pp. 62–69, Article ID: IJMET_08_01_007
Available online at http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=8&IType=1
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

OPTIMIZATION OF A SINGLE CYLINDER, 4-STROKE DIESEL ENGINE PERFORMANCE PARAMETERS USING DIESEL/COTTON SEED OIL BLEND WITH HYDROGEN INDUCTION BY TAGUCHI METHOD

Naseeb Khan
Mechanical Engineering Department,
Shadan College of Engineeing & Technology, Hyderabad, India

B. BaluNaik
Professor, Mechanical Engineering Department, Director, UGC-HRDC,
JNT University Hyderabad, Kukatpally, Hyderabad, India

Syed Yousufuddin
Mechanical Engineering Department,
Jubail University College, Jubail Industrial City, Kingdom of Saudi Arabia

V. V. Satyanarayana
Professor, Mechanical Engineering Department
Vidya Jyothi Institute of Technology, Hyderabad, India

ABSTRACT

The performance of a diesel engine by blending cottonseed oil with the diesel and suction is enriched with hydrogen inducting through port in the suction stroke. The process parameters identified are injection operating pressure (IOP), compression ratio (CR) and amount of hydrogen each at three levels. Taguchi L_9 OA is chosen for the experimentation and two responses have been recorded namely brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC). The contribution of these parameters on these parameters on those responses has computed by signal to noise (S/N) analysis.

Key words: Injection Operating Pressure, Compression Ratio, Hydrogen, Taguchi, Parameters, Optimized Condition.

Cite this Article: Naseeb Khan, B. BaluNaik, Syed Yousufuddin and V. V. Satyanarayana, Optimization of a Single Cylinder, 4-Stroke Diesel Engine Performance Parameters Using Diesel/Cotton Seed Oil Blend with Hydrogen Induction by Taguchi Method. *International Journal of Mechanical Engineering and Technology*, 8(1), 2017, pp. 62–69.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=8&IType=1

1. INTRODUCTION

Bio-diesel is produced from various sources like plants, animals and is used by blending with diesel. Bio-diesel, which can be used as an alternative diesel fuel, is made from renewable biological sources such as vegetable oil and animal fats. It is biodegradable, non-toxic and possesses low emission profiles. Also, the uses of bio-fuels are environmentally beneficial. The name bio-diesel was introduced in the United States during 1992 by the National Soy Diesel Development Board (presently National Bio-diesel Board) which has pioneered the commercialization of biodiesel in the US [1]. The limited (and fast diminishing) resources of fossil fuels, increasing prices of crude oil, and environmental concerns have been the diverse reasons for exploring the use of vegetable oils as alternative to diesel oil [2-5]. Vegetable oils offer almost the same output with slightly lower thermal efficiency when used in diesel engines [6-8]. Reduction of engine emissions is a major research aspect in engine development with the increasing concern over environmental protection and the stringent exhaust gas regulation [9-14].Among the various possible alternative fuels, hydrogen is found to be most promising due to its clean burning and better combustion properties. There are several reasons for applying hydrogen as an additional fuel to accompany diesel fuel in the internal combustion (IC) compression ignition (CI) engine. Primary; it increases the H/C ratio of the entire fuel. Secondly, injecting small amounts of hydrogen to a diesel engine could decrease heterogeneity of a diesel fuel spray due to the high diffusivity of hydrogen which makes the combustible mixture better premixed with air and more uniform. It could also reduce the combustion duration due to hydrogen’s high speed of flame propagation in relation to other fuels [15]. Diesel blended with methanol has been investigated for its performance and emission in the diesel engine by employing Derringers desirability approach [16]. The problem of increasing demand for high brake power and the fast depletion of the fuels demand severe controls on power and a high level of fuel economy. Many innovative technologies are developed to tackle these problems. As far as the internal combustion engines are concerned the thermal efficiency and emission is the important parameters for which the other design and operating parameters have to be optimized. The most common optimization techniques used for engine analysis includes Taguchi method [17]. Taguchi technique has been popular for parameter optimization in design of experiments. Design of Experiments (DOE) has introduced the loss function concept which combines cost, target and variations into one metric. Orthogonal arrays are significant parts of Taguchi methods. Instead of one factor at a time variation all factors are varied simultaneously as per the design array and the response values are observed. It has the ability to evaluate several factors in a minimum number of tests. DOE approach is used to find the effect of design and operating parameters on brake power and specific fuel consumption [17]. Taguchi method was applied by taking the parameters injection operating pressure and compression ratio to find the impact on engine performance and heat released and consequently optimal parameters are identified [18].An experimental study has been carried out for palm seed oil blended with diesel used in a single cylinder diesel engine by varying parameters the load, compression ratio and injection pressure. It is found that the engine performance is mostly influenced by engine load and is least influenced by compression ratio [19]. In this investigation, diesel blended with cottonseed oil and inducting the hydrogen during suction stroke, is proposed to be carried out by employing Taguchi methods.

2. EXPERIMENTAL DESIGN

2.1. Engine Employed

The experiment was conducted on fully computer interface, single cylinder, four stroke, variable compression ratio, multi fuel, water cooled engine with eddy current loading and whose specifications are given in Table 2, while a test rig setup is shown in Fig. 1.

Figure 1 Experimental set-up.

Table 1 Engine specifications.

PARTICULARS	SPECIFICATIONS
Make	Kirloskar Oil Engines
Model	TV-1
Type Of Ignition	Compression Ignition
Fuel Injection	Direct Injection
Dynamometer	Eddy Current Type
Piston Bowl	Hemispherical
Starting	Auto Start
Rated Power (kW)	3.5
Speed (rpm)	1500
Bore (meter)	0.0875
Stroke (meter)	0.110
Connecting Rod Length (meter)	0.234
Cylinder Capacity (cc)	661
Injection Timing (degree BTDC)	23
Injection operating timing (bar)	220
Compression Ratio	17.5

2.2. Fuels Employed

In this investigation cottonseed oil is blended with diesel in the ratio 20:80 more popularly called B20 and is supplemented with hydrogen fuel in the suction stroke.

2.3. Factors Chosen

Three parameters namely IOP, CR and hydrogen are chosen for conducting the experiments by considering each parameter at three levels. The parameters and their levels are given in Table 2.

Table 2 Process parameters with their different levels

S.No	Factors	Units	Notation	Level 1	Level 2	Level 3
1.	Injection Operating Pressure	bar	A	200	220	240
2.	Compression Ratio	---	B	16.5	17.5	18.5
3.	Hydrogen	litres per minute(lpm)	C	10	15	20

2.4. Taguchi Experimental Matrix

Taguchi method is the most powerful investigating technique available to reduce product cost, improve quality, and simultaneously reduce development interval by changing many different parameters and observing the performance characteristic in a condensed set of experiments. It can be examined by using the orthogonal array experimental design proposed by Taguchi. The experiments are conducted and analyzed using MINITAB-17 software. All the experiments were carried out at full load with a constant speed of 1500 rpm. The engine had a provision to vary the compression ratio from 14.5 to 18.5. These experiments are conducted randomly to avoid bias and error. In this investigation L_9 orthogonal array has been chosen and is given in Table 3.

Table 3 L9 orthogonal array of the experiments

Runs	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

3. RESULTS

In this experimental study two responses namely BTE and BSFC are recorded and is presented in Table 4.

Table 4 Response given for BTE and BSFC.

↓	C1	C2	C3	C4	C5
	IOP (bar)	C R	Hydrogen (lpm)	BTE (%)	BSFC (kg/kW hr)
1	200	16.5	10	28.5113	0.215928
2	200	17.5	15	32.6296	0.230330
3	200	18.5	20	30.2760	0.234194
4	220	16.5	15	30.2476	0.213516
5	220	17.5	20	33.5200	0.251450
6	220	18.5	10	30.9981	0.234762
7	240	16.5	20	28.9694	0.224087
8	240	17.5	10	31.9568	0.244720
9	240	18.5	15	31.3081	0.221002

4. ANALYSIS AND DISCUSSION

It is recorded that minimum BTE has obtained when all the parameters are at lower level i.e injection operating pressure at 200 bars, compression ratio at 16.5 and hydrogen induction at 10 lpm respectively. While the maximum BTE of about 33.52% when the parameters are at injection operating pressure at 220 bars, compression ratio at 17.5 and hydrogen induction at 15lpm respectively. Larger BSFC obtained when the process parameters in A and B are at middle level (220 bar, 17.5) while C is at higher level (20 lpm). Similarly minimum BSFC has obtained when the process parameters A and C are at middle level (220 bar, 15 lpm) while the parameter B is at lower level (17.5). Taguchi recommends the loss function in the form of signal to noise (S/N) ratio. The response BTE is analyzed according to the higher the better characteristics while BSFC belongs to smaller the better quality characteristic, hence computed accordingly. The S/N ratio graphs for BTE and BSFC are presented in figure 3 and 4 respectively.

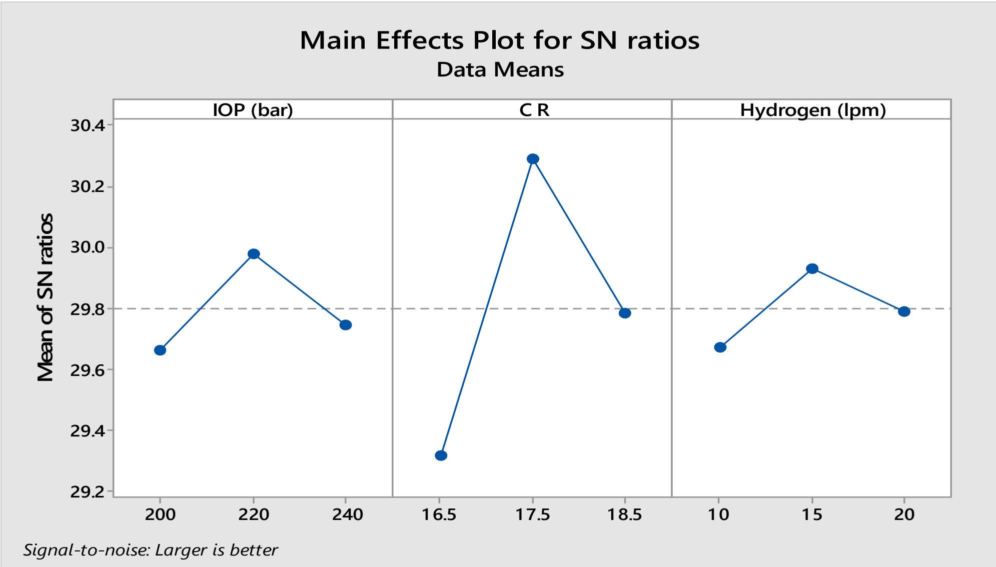

Figure 3 S/N ratio graph for Brake Thermal Efficiency.

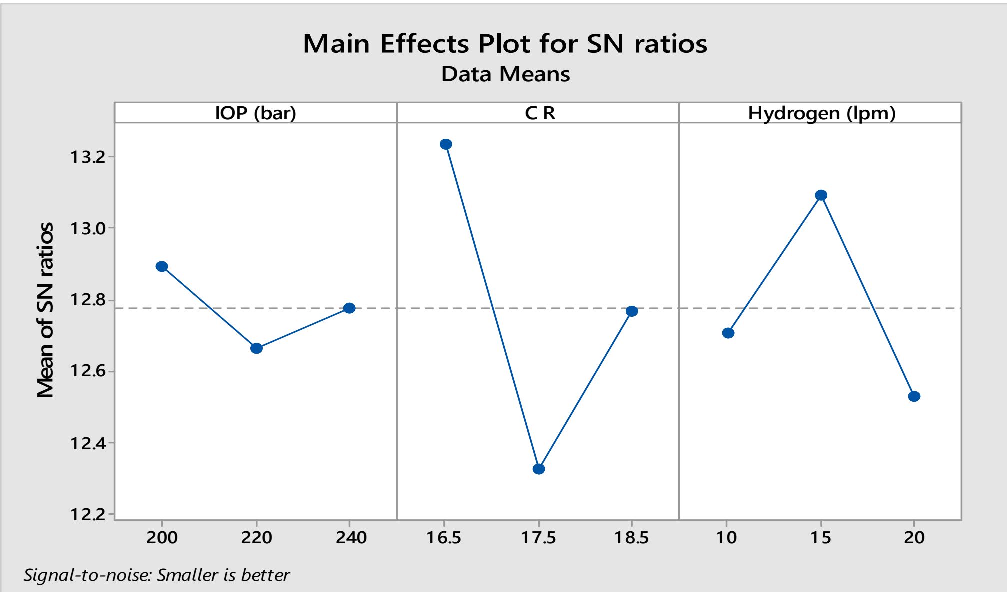

Figure 4 S/N ratio graph for Brake Specific Fuel Consumption.

From the response graph Figure 3, the optimal condition for higher BTE is obtained with the combination of parameters injection operating pressure at 220 bars, compression ratio at 17.5 and hydrogen induction at 15 lpm. Similarly from the response graph Figure 4 the optimal condition is found to be at injection operating pressure of 220 bars, compression ratio at 17.5 and hydrogen with 15 lpm.

The data has been subjected to standard analysis of variance applying the Yates's algorithm and the corresponding ANOVA computations for BTE and BSFC are given in Table 6 and Table 7 respectively. The F-values are higher than the critical value at 95% confidence level and 5% error. The contribution of each factors are also enlisted in the ANOVA tables. The parameter compression ratio is contributing to a larger extent in the achievement of BTE and BSFC. While IOP is playing major role for BTE and hydrogen content is affecting to a larger extent in the attainment of BSFC.

Table 6 ANOVA computation for variance for BTE

Source	DF	SS	MS	F-value	% contribution
IOP (bar)	2	2.0323	1.01617	14.04	9.5
C R	2	17.9758	8.98790	124.22	84.05
Hydrogen(lpm)	2	1.2331	0.61653	8.52	5.76
Error	2	0.1447	0.07235		
Total	2	21.3859			

Table 7 ANOVA computation for variance for BSFC

Source	DF	SS	MS	F-value	% contribution
IOP (bar)	2	0.000062	0.000031	20.19	4.75%
C R	2	0.000887	0.000444	289.22	68.07%
Hydrogen(lpm)	2	0.000350	0.000175	114.20	26.86%
Error	2	0.000003	0.000002		
Total	2	0.001303			

The optimal conditions for both the responses are compiled in Table 8. It depicts IOP and CR are at medium level for both the responses while the hydrogen is at medium level for BTE and at high level for the BSFC.

Table 8 Optimal condition

S.No	Responses			
		A (IOP)	B (CR)	C (Hydrogen)
1.	BTE	Medium	Medium	Medium
2.	BSFC	Medium	Medium	High

5. CONFIRMATION TEST

The engine so employed is required to deliver low BSFC from the economic point of view and hence hydrogen is taken at high level and the remaining two factors are chosen at medium level as optimal condition and a confirmation test is conducted. The result obtained at these conditions for both the responses are given in Table 9. It shows a higher BTE and lower BSFC as optimal condition which are in tandem with the experimental results domain obtained.

Table 9 Results for confirmation experiments

1.	Input Parameters			BTE(%)	BSFC(kg/kW hr)
2.	Medium	Medium	High	33.6	0.219

6. CONCLUSION

- Brake Thermal Efficiency and Brake specific fuel consumption are affected to a larger extent by Compression Ratio.
- Brake Specific Fuel Consumption is affected by hydrogen with a contribution of 26.86%.
- As the hydrogen content is at higher level of 15 lpm yielding lower BSFC indicates that the parameters are working for the economic conditions.

7. ACKNOWLEDGEMENT

The authors express their sense of gratitude to Lord’s Institute of Engineering & Technology, Hyderabad for the support extended in the utilization of the engine for conducting the experiments.

Nomenclature

DOE	Design of Experiments
S/N	Signal to Noise Ratio
A(IOP)	Injection Operating Pressure
B(CR)	Compression Ratio
C(Hydrogen)	Hydrogen (lpm)
BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
ANOVA	Analysis of Variance
DF	Degree of Freedom
SS	Sum of Squares
MS	Mean Square
F-value	Fisher Ratio

REFERENCES

[1] J. Xue, T. E. Grift, and H. C. Alan, “Effect of biodiesel on engine performances and emissions,” Renewable and Sustainable Energy, 2011.

[2] Ramadhas A.S., Jayaraj S. and C. Muraleedharan. 2004. Use of vegetable oils as I.C. engine fuels- A review. Journal of Renewable Energy. 29: 727-742.

[3] Muralidharan M., Thariyan M.P., Roy S., Subrahmanyam J.P. and P.M.V. Subbarao. 2004. Use of pongamia bio-diesel in CI engines for rural application. SAE Paper No. 28-0030.

[4] RecepSelim C. and S.Y. Huseyin. 2000. The potential of using vegetable oil fuels as fuel for diesel engines. International Journal of Energy Conversion Management. 42: 529-538.

[5] Vellguth G. 1983. Performance of vegetable oils and their monoesters as fuels for diesel engines. SAE Paper No. 831358.

[6] Agarwal D. and A.K. Agarwal. 2007. Performance and emission characteristics of a Jatropha oil (preheated and blends) in a direct injection compression ignition engine. Journal of Applied Thermal Engineering. 27: 2314-2323.

[7] Barsic N.J. and A.C. Humke. 1981. Performance and emission characteristics of a naturally aspirated diesel engine with vegetable oil fuels. SAE Paper No. 810262.

[8] Moneym A and J.H. Gerpen. 2001. The effect of bio-diesel production on engine performance and emissions. Journal of Biomass and Bio energy. 20: 317-325.

[9] Lee Pedkey R and C.H. Hobbs. 1998. Fuel quality impact on heavy duty diesel emissions- A literature review. SAE Paper No. 982649.

[10] Akasaka Y., Suzuki T. and Y. Sakurai. 1997. Exhaust emissions of a DI diesel engine fueled with blends of bio-diesel and low sulphur diesel fuel. SAE Paper No. 972998.

[11] Owen K. and T. Coley. 1995. Automotive fuels reference book. Society of Automotive Engineers, USA.

[12] Szybist J. 2003. Potential methods for NOx reduction from bio-diesel. SAE Paper No. 01-3205.

[13] NabiMdN, AkhterMdS, MhiaMd and S. Zaglul. 2006. Improvement of engine emissions with conventional diesel-bio-diesel blends. Journal of Bioresource Technology. 97: 372-378.

[14] Sarath M., Ravi Kumar P., and Prashanth Reddy K. 2009. Performance characteristics of a diesel engine operating with animal tallow oil blended with diesel.

[15] Quadri S. A. P., Masood M., and Ravi Kumar P., 2015. Effect of pilot fuel injection operating pressure in hydrogen blended compression ignition en-gine : An experimental analysis, Fuel; V 157, pp-279-284

[16] Y. D. Bharadwaz, B. G. Rao, V. D. Rao and C. Anusha, Improvement of biodiesel methanol blends performance in a variable compression ratio engine using response surface methodology, Alexandria Engineering Journal,55, 2016, pp. 1201-1209.

[17] K. Sivaramakrishnan and P. Ravikumar, “Performance Optimization of karanja bio-diesel engine using Taguchi approach and multiple regressions,” ARPN J., vol. 4, pp. 506–516, April 2012.

[18] Quadri S.A.P, M. Masood, T. Wahidi, M. S. Ghouse, M. Wajid, “Doe applied to multi response optimization study on performance, combustion and emission characteristics of a VCR diesel engine,” Int. J. of Ambient Energy, Taylor & Francis, July 2016.

[19] M. A. Modi, T. M. Patel, G. P. Rathod., “Parametric Optimization Of Single Cylinder Diesel Engine For Palm Seed Oil & Diesel Blend For Brake Thermal Efficiency Using Taguchi Method”. IOSR Journal of Engineering., Vol.5, pp.49-54, 2014.

[20] Datta S, Bandyopadhyay A, Pal PK, “Grey based Taguchi method for optimization of bead geometry in submerged arc bead-on-plate welding,” Int. J. Adv. Manuf. Tech, vol. 11, December 2008.

[21] Taguchi G. “Taguchi on Robust Technology Development: Bringing Quality Upstream by Genichi Taguchi”. ASME, New York, 1993.

[22] G.O.Verran, R.P.K. Mendes, L.V.O. DallaValentina, “DOE applied to optimization of aluminum alloy die castings. Journal of materials processing technology,” Journal of materials processing technology, vol. 200, pp. 120–125, 2008.

[23] Philip Ross J. “Taguchi techniques For Quality Engineering,” McGraw-Hill 2nd edition.

[24] U.S. J yothi and K. Vijaya Kumar Reddy, Effect on Performance and Combustion Characteristics of Diesel Engine Enriched with Hydrogen with Varied Piston Bowl Geometry, *International Journal of Mechanical Engineering and Technology (IJMET)*, 6(10), 2015, pp. 39-47.

[25] Shivakumar Vasmate, Sreenuraju. M, Shashikant Kushnoore and Prasad Biradar, Experiment on Multi Blend Biodiesel Using Jatropha and Pongamia Biodiesel on Single Cylinder Diesel Engine with Base Line of Diesel Fuel. *International Journal of Mechanical Engineering and Technology (IJMET),* 7(2), 2016, pp. 273–281.