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COMBINE EFFECT OF INJECTION PRESSURE AND COMPRESSION RATIO ON PERFORMANCE OF SINGLE CYLINDER CI ENGINE USING DIESEL-WPO BLEND BY TAGUCHI'S DESIGN OF EXPERIMENT APPROACH

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Abstract: *Environmental concern and availability of petroleum fuels have caused interest in the search for alternative fuels for internal combustion engine. Many alternate fuels are tried by various researches. It is found that for diesel engine, Bio Diesel is most promising fuel. As per the literature survey 20% Waste Plastic pyrolysis oil and 80% Diesel blend is best in performance compare to other blends. In this project works prospects and opportunities of utilizing 100% Waste Plastic Pyrolysis oil and increasing Waste Plastic Pyrolysis oil-diesel blend ratio as fuel in diesel engine is going to be studied by varying engine loads. Also based on experimentation an optimum blend and engine parameters are to be suggested for obtaining better performance. Waste Plastic Pyrolysis oil presents a very promising scenario of functioning as alternative fuels to fossil diesel fuel. The properties of these have been compared favorably with the characteristics required for internal combustion engine fuels specially diesel engine. Experiments was performed for three engine loads i.e. 2 kg, 7 kg and 12 kg and fuel injection pressure 160 bar, 180 bar and 200 bar using Waste plastic Pyrolysis oil diesel different blends and pure Waste Plastic Pyrolysis oil with constant speed of diesel engine. Analysis of brake thermal efficiency, specific fuel consumption, fuel consumption and mechanical efficiency was done and Found best combination set of optimum parameter for them for maximum performance.*

Keywords: *Waste plastic oil; Taguchi's method; Pyrolysis process; Diesel engine; Engine Performance;*

Nomenclature:

WPO	*: Waste Plastic Oil*
CR	*: Compression Ratio*
BTHE	*: Brake Thermal Efficiency*
BMEP	*: Brake Mean Effective Pressure*
FC	*: Fuel Consumption*
SFC	*: Specific Fuel Consumption*
MEEF	*: Mechanical Efficiency*
S/N Ratio	*: Signal to Noise Ratio*

I. INTRODUCTION

Environmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. Conversion of waste to energy is one of the recent trends in minimizing not only the waste disposal but also could be used as an alternate fuel for internal combustion engines. Waste plastics are indispensable materials in the modern world and application in the industrial field is continually increasing. The explosive growth in the production and everyday use of plastics over the past decades has made plastic waste disposal a serious environmental challenge. Plastics have become an indispensable part in today's world, due to their lightweight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, these plastics are employed in entire gamut of industrial and domestic areas hence plastics have become essential materials and their applications in the industrial field are continually increasing.

Recycling of plastics is found to be the optimal solution to manage the plastic waste. Chemical recycling conforms to the principles of sustainable development and energy crisis, which has gained great attention by researchers. The challenges of waste management and increasing fuel energy crisis can be addressed simultaneously with the production of fuel from plastics. Some researchers showed that the fuel produced from plastics have properties similar to that of petroleum fuels [1].

II. LITERATURE SURVEY

Many researchers have been carried out many analyses to find best alternative for diesel fuel for diesel engine. **Vignesh et al**. **(2015)** have concluded that blend represents a good alternative fuel which gives good performance and better emission characteristics. The Waste Plastic Pyrolysis Oil 5%, Methanol 5% and diesel 90% blends with Cetane Improver gives good performance when comparing to the other blends [2]. **Mukherjee et al. (2014)** have analyzed that it is concluded that B20 has characteristics as near to diesel. The emissions are very near to that of Diesel. It indicates that WPO oil is not at all hazardous to environment. It can be considered as neat as gasoline and diesel [3]. **Yasin et al. [2013]** studied on fuel properties for biodiesel and its B20-alcohol blend fuels when being compared as an increase in biodiesel concentration is greatly increased the density and viscosity of the biodiesel blend fuel, B20.A small concentration of alcohol, 5% and 10% by volume diluted in B20 blend fuel significantly reduced viscosity and density of the B20 blend fuel. However, as a result, flash point and Cetane number are increased [6]. **Ioannis Kalargaris et al. [2017]** have investigated that the combustion performance and emission characteristics of a diesel engine gen-set running on oils derived from the pyrolysis of plastics at 700 ○C and 900.. The engine was able to operate stably on PPO700 and PPO900 blends at 75%, 85% and 100% load. PPO900 had a significantly longer ignition delay period, higher peak heat release rate and shorter combustion period compared to PPO700.The engine brake thermal efficiency was 3-4% lower for PPO900 and 2-3% lower for PPO700 in comparison to diesel. All measured emissions (NO_X, UHC, CO and CO_2) were higher for PPO700 and PPO900 compared to diesel, however the highest emissions were produced by PPO900 [7]. Many literatures have been done till now for various biodiesel oil and found that waste plastic oil is best among them. properties of waste plastic oil has been found near to diesel.

III. WASTE PLASTIC PYROLYSIS OIL

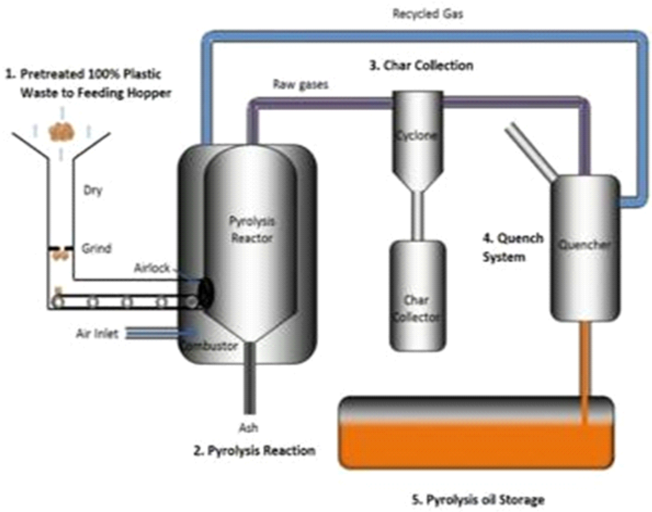

Figure 1. Process of pyrolysis of waste plastic.

Pyrolysis is the chemical decomposition of organic substances by heating the word is originally coined from the Greek derived elements pyro "fire" and lysys "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 300ºC – 350ºC. The plastic waste is gently cracked by adding catalyst and the gases are condensed in a series of condensers to give a low sulphur content distillate. All this happens continuously to convert the waste plastics into fuel that can be used for generators. The catalyst used in this system will prevent formation of all the dioxins and Furans (Benzene ring). All the gases from this process are treated before it is let out in atmosphere. The flue gas is treated through scrubbers and water/ chemical treatment for neutralization. The non-condensable gas goes through water before it is used for burning. Since the Plastics waste is processed about 300ºC - 350ºC and there is no oxygen in the processing reactor, most of the toxics are burnt. However, the gas can be used in dual fuel diesel-generator set for generation of electricity.

IV. 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 of from Petrol to Diesel with some

necessary changes. In both modes the compression ration can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement.
Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle 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 set up has stand-alone panel box consisting of air box, two fuel flow measurements, process indicator and hardware interface. A battery, starter and battery charger is provided for engine electric start arrangement.

Figure 2. Side view of experimental setup

Table 1. Engine technical specifications

Model	TV1
Make	Kirlosker Oil Engines
Type	Four stroke, Water cooled, Diesel
No. of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Combustion principle	Compression ignition
Cubic capacity	0.661 litres
Compression ratio 3 port	18:1

The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio etc. Lab view based Engine Performance Analysis software package “Engine soft” is provided for on line performance evaluation. Table.1 shows Technical specification of C.I Engine.

V. OBSERVATIONS AND CALCULATIONS

Table 1. Observation table for engine normal condition.

Ex. no.	C.R.	Blend Ratio	Injection Pressure	Load(kg)	Torque (Nm)	IP (kW)	BP (kW)	FP (kW)	BTHE (%)	Mech eff. (%)	SFC (kg/kWh)
1	18	100D0B	L	1.98	3.60	4.37	0.60	3.77	25.69	13.74	0.36
2	18	50D50B	M	7.19	13.05	5.72	2.14	3.59	52.24	37.31	0.18
3	18	0D100B	H	12.12	22.00	7.07	3.53	3.54	67.15	49.92	0.14
4	16	100D0B	M	11.93	21.64	6.65	3.42	3.23	65.08	51.46	0.14
5	16	50D50B	H	1.88	3.42	3.95	0.56	3.39	24.14	14.28	0.38
6	16	0D100B	L	7.18	13.03	5.49	2.13	3.36	52.09	38.78	0.18
7	14	100D0B	H	7.04	12.77	5.63	2.09	3.53	51.22	37.21	0.18
8	14	50D50B	L	12.1	22.02	7.12	3.58	3.54	68.19	50.33	0.14
9	14	0D100B	M	2.29	4.15	3.99	0.69	3.30	23.49	17.21	0.39

Observations are done by taking readings for various combination of blend by Taguchi's experiment method. First of all the readings were taken for conventional diesel fuel. Than Waste plastic oil was blended with diesel in different concentration and readings were taken. And then the result data is found out.

VI. RESULT AND DISCUSSION

Factor and Levels

Experiments are designed according to Taguchi's orthogonal array as shown in table. Here number of experiment carried out are 9 with 4 factors and 3 levels as show in table. After doing experiments it will be transferred in to S/N ratio. Taguchi method Orthogonal array two levels, three levels and mixed level fractional factorial design. The unique aspects of this approach are the use of signal and noise factors, inner and outer arrays, and signal to noise ratio. The Taguchi method defines two types of factors: control factors and noise factors.

Table 2. Factors effecting and level set

Control factor	Level1	Lever2	Level3
Compression ratio	18	16	14
Blend ratio	0B100D	50B50D	100B0D
Injection pressure	L	M	H
Load	2	7	12

Taguchi Analysis for Brake Thermal Efficiency with Different Compression Ratio, Blend Ratio, Injection Pressure and Load

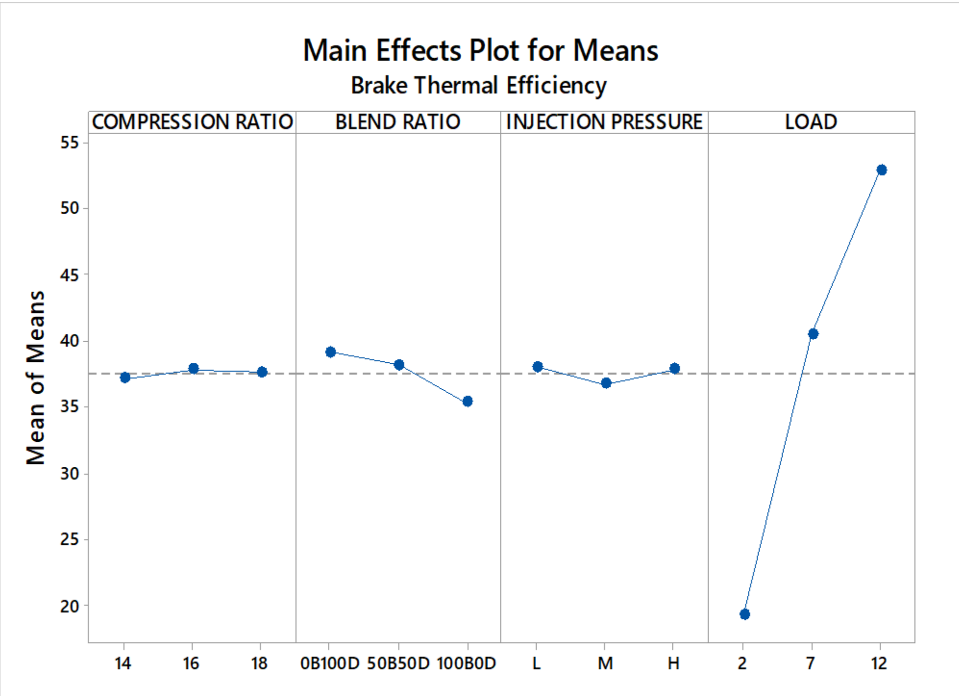

Figure. 3. Main effect plot for means brake thermal efficiency

From given response Table 3 values of S/N ratio is taken for brake thermal efficiency. From Fig 4 curve analysis S/N ratio is maximum (30.96) for compression ratio 14 and minimum value (30.33) for compression ratio 18. S/N ratio is maximum (31.24) for diesel and minimum value (29.98) for WPO. S/N ratio is maximum (31.00) for low injection pressure and minimum value (30.24) for high injection pressure. S/N ratio is maximum (34.46) for engine load of 12 kg and minimum value (25.58) for engine load of 2 kg.

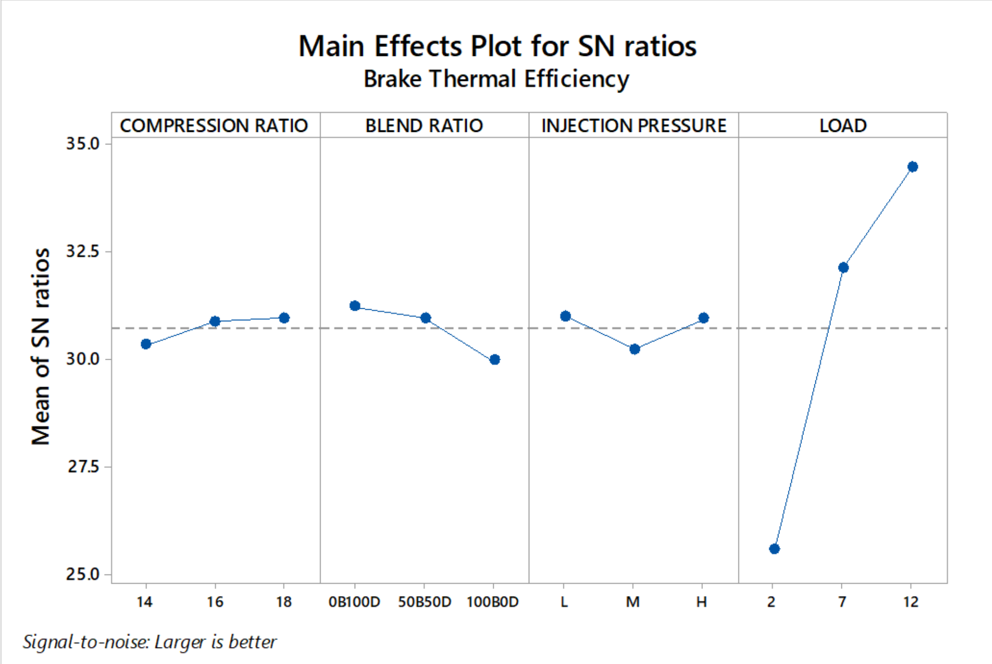

Figure 4. Main effect plot for S/N ratio brake thermal efficiency

Table 3. Response table for signal to noise ratio for brake thermal efficiency

Level	Compression Ratio	Blend Ratio	Injection Pressure	Load
1	30.33	31.24	31.00	25.58
2	30.88	30.96	30.24	32.14
3	30.96	29.98	30.94	34.46
Delta	0.62	1.25	0.75	8.89
Rank	4	2	3	1

Here, delta is Error between maximum value and minimum value. Shown in Fig 4, S/N ratio curve and Table 3 analysis most effecting parameter is load on brake thermal efficiency because it has maximum value of delta 8.89 and least effecting parameter is compression ratio because it has minimum value of delta 0.62.
So optimum set of parameter for maximum brake thermal efficiency,

Table 4. Optimum set of parameter for maximum brake thermal efficiency

Compression Ratio	Blend Ratio	Injection Pressure	Load	Predict Value	Experiment Value	Error (%)
18	0B100D	L	12	55.0624	54.050	1.873

Experiment was performed using optimum set of parameter. Experimental brake thermal efficiency for optimum set of parameter is 54.050%. This experimental value is much more nearer to predicted value 55.050% as shown in Table 7.

Taguchi analysis for mechanical efficiency with different compression ratio, blend Ratio, injection pressure and load

From given response Table 4 values of S/N ratio is taken for Mechanical Efficiency. From Fig 6 curve analysis S/N ratio is maximum (29.82) for compression ratio 16 and minimum value (29.31) for compression ratio 14. S/N ratio is maximum (29.67) for WPO and minimum value (29.50) for Diesel. S/N ratio is maximum (29.69) for medium injection pressure and minimum value (29.45) for high injection pressure. S/N ratio is maximum (34.04) for engine load of 12 kg and minimum value (23.34) for engine load of 2 kg.

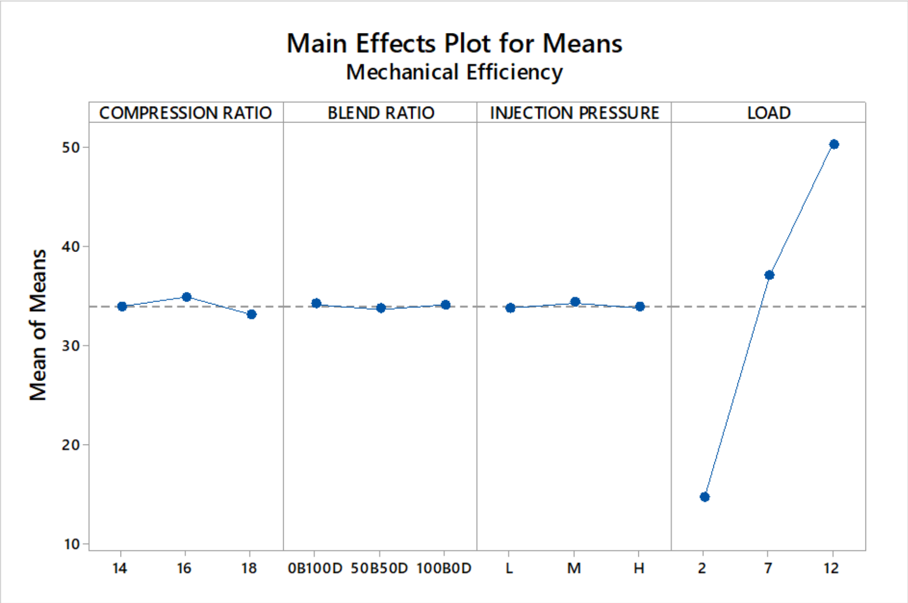

Figure 5. Main effect plots for means mechanical efficiency

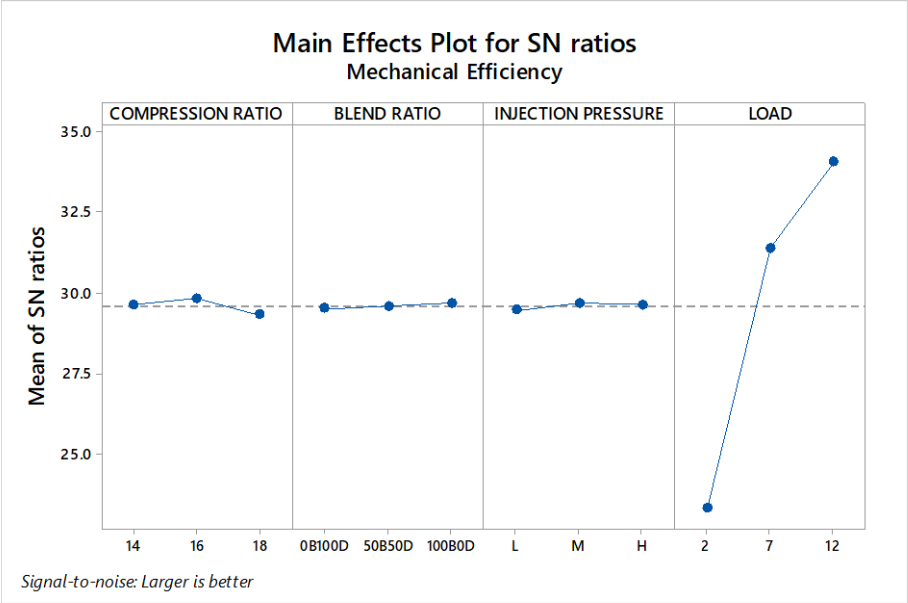

Figure 6. Main effect plot for S/N ratio mechanical efficiency

Here, delta is Error between maximum value and minimum value. Shown in Fig 6, S/N ratio curve and Table 4 analysis most effecting parameter is load on mechanical efficiency because it has maximum value of delta 10.70 and least effecting parameter is blend ratio because it has minimum value of delta 017

Table 4. Response table of signal to noise ratios for mechanical efficiency

Level	Compression Ratio	Blend Ratio	Injection Pressure	Load
1	29.63	29.50	29.45	23.34
2	29.82	29.59	29.69	31.38
3	29.31	29.67	29.63	34.04
Delta	0.52	0.17	0.24	10.70
Rank	2	4	3	1

Here, delta is Error between maximum value and minimum value. Shown in Fig 6, S/N ratio curve and Table 4 analysis most effecting parameter is load on mechanical efficiency because it has maximum value of delta 10.70 and least effecting parameter is blend ratio because it has minimum value of delta 017.
So optimum set of parameter for maximum Mechanical Efficiency,

Table 6. Optimum set of parameter maximum mechanical efficiency

Compression Ratio	Blend Ratio	Injection Pressure	Load	Predict Value	Experiment Value	Error (%)
16	100B0D	M	12	51.7182	50.1342	3.16

Experiment was performed using optimum set of parameter. Experimental mechanical efficiency for optimum set of parameter is 50.1342. This experimental value is much more nearer to predicted value 51.7182 as shown in Table 6.

VII. CONCLUSION

After conducting the experiment on Waste Plastic Oil with diesel by Taguchi method, it is concluded that the WPO blends represent a fairly good alternative fuel for diesel. From experiment found that for Maximum brake thermal efficiency is compression ratio 18, blend ratio 0B100D, injection pressure L, engine load 12. For maximum mechanical efficiency is compression ratio 16, blend ratio 100B0D, injection pressure M, engine load 12. Engine performance is mostly influenced by engine load and is least influenced by Compression ratio.

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