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Analysis of Influencing Parameters on CI Engine Performance Fuelled by Waste Plastic Oil and Ethanol Blends Using Taguchi Method

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Abstract:
Waste plastics take more than four hundred years to degrade and it is not biodegradable. Only less than 10% are mechanically reprocessed and around 12% are destroyable and remaining 75% occupy the land and oceans. One of the methods of disposal is to utilize its energy by converting into fuel. The enable energy to be derived from the disposal used plastics by the catalytic pyrolysis. In this paper, plastic oil performance has been examined on a single-cylinder diesel engine. The influencing parameters like engine load, injection pressure, plastic oil and ethanol blend ratio are optimized and identified by the Taguchi method. The L9 orthogonal array was created with the incremental ratio of Waste Plastic oil (WPO) was blended with the ratio of ethanol. Taguchi method was analysed with engine efficiency, fuel consumption and emission characteristics through S/N ratio.

Keywords:*Waste Plastic oil, Diesel Engine, Emission Characteristics, Ethanol, Engine performance, Taguchi Method.*

I. INTRODUCTION

Themotivationofourresearchisinthestratagem of energyretrievalfromusedplastics.Thewasteplasticto energydevelopmenttransformation resultsinnetenergy savings. V L Mangesh et al (2017) attempted an exhaustive review on waste plastic oil conversion methodology and testing and properties characteristics which leads to a better understanding of WPO fuel conversion as an alternative fuel.PappulaBridjesh et al (2018) an attempt made to supplant diesel with half quantity of Waste plastic oil (WPO) along with diethyl ether and methoxyethyl acetate as additives. Researcher looking for a decent alternative source for diesel from the non-biodegradable waste plastics, which will address the increasing fuel crunch for current conditions. V L Mangsh et al (2020) have made an exhaustive investigation on various types of waste plastic oils can be converted into an alternate fuel for diesel.

Damodharan et al (2019) have investigated in a water ventilated diesel engine with catalytic pyrolysis WPO. WPO was blended with lignocellulosic biomass which is high carbon content *and* the test was carried out under the impact of EGR and injection timing with varying load condition. Sachuthananthan et al (2019) have blended anaddition of various ratio of nano additive magnesium oxide with plastic pyrolysis oil. An investigation was made to evaluate the change in physicochemical properties in compression ignition engine. Hariram V et al (2019) have tested a pyrolysis plastic oil under the ASTM standards and performed GC-MS and

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Fourier Transform Infrared Analysis studies and presented the presence of several different mixtures in Plastic oil. Venkatesh A P et al (2018) have examined the engine performance and emission norms of the waste used oil with nanoemulsions. Prasanna Raj Yadav and Saravanan (2016) have explored the engine analysis and emission parameters of altered transformer oil as fuel in a single-cylinder diesel engine. Ganesan et al (2019) and Padmanabhan et al (2018) have observed the influence of oxygenated nano additive of Cerium oxide with the bio seeded diesel by the experimental investigation of engine analysis and emission norms of different proportions.

MohanrajChandran et al (2019) have evaluated diesel engine exploration and the exhaust emissions with 100% WPO and distilled WPO. The investigation was recorded and results not promising because of higher sulfur content, density and viscosity, and worse cetane number. V L Mangsh et al (2019) have examined the hydrogenated waste plastic oils on the diesel engine and its influence to be a substitute fuel for diesel.

Ganesan et al (2020) have optimized the diesel engine parameters for the lemongrass oil blends by forming orthogonal array by Taguchi method. Karnwal et al (2011) have examined multi-response optimization of diesel engine performance parameters using thumba biodiesel-diesel blends by applying the Taguchi method and grey relational analysis. MohdMuqeem et al (2018) have optimized the four input parameters like fuel injection timing, compression ratio, air temperature and pressure of diesel engine were varied at five levels. The emission of hydrocarbon and smoke under no load, half load, and full load conditions were experimented and analysed by Taguchi approach. Horng-Wen Wu et al (2013) have used the Taguchi method toregulate the optimal blends of concentrations biodiesel using hydrogen and cooled exhaust gas recirculation at the inlet port.

Karmakar et al (2018) have employed L16 Taguchi orthogonal array and identified theimportant parameters in the molar ratio of oil to methanol, agitation speed, reaction temperature and catalyst concentration.Dhawane et al (2016) have examined the four factors reaction time, reaction temperature, methanol to oil ratio and catalyst loading to influence the transesterification process which affecting the biodiesel yield.Sathish Kumar et al (2015) have optimized transesterification method parameters for the making ofManilkarazapota methyl ester has been studied using Taguchi design. In this paper, plastic oil performance has been examined on a single-cylinder diesel engine. The influencing parameters like engine load, injection pressure, plastic oil and ethanol blend ratio are optimized and identified by the Taguchi method.

II. WASTE PLASTIC OIL AND ETHANOL

The waste plastics can be transmuted into alternate energy fuel for the diesel engine by the catalytic pyrolysis. The Plastic Pyrolysis fuel differs on its chemical properties dependents on the different grades of used plastics and pyrolysis method. Ethanol is high octane energy that empowers very effective and dominant engine performance. Engines enhanced for Ethanol could deliver an energy-based efficacy gain of 50% over a typical engine in a light-duty automobile. Ethanol is added to improve the diesel engine efficiency and to reduce the exhaust emissions of Plastic Pyrolysis oil. Poor calorific value and high viscosity of the Plastic Pyrolysis oil are the foremost complications of Plastic oil for a diesel engine substitute. Paul Daniel et al (2017) blended the diesel fuel with different ratios of plastic oil viz, 10%, 20%, 30% and 50% of WPO. In this research, Plastic Pyrolysis oil prepared from waste plastics and experimental sample were blended with diesel at different ratios of 10%, 20% and 30% WPO in addition of 5 to 15 % of ethanol by sonication process. Padmanabhan et al (2017) have evaluated the Plastic Pyrolysis oil properties

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compared with diesel and also tabulated the blended fuel properties with cetane additive and ethanol. The properties of Waste Plastic Pyrolysis oil were tabulated in Table 1.

Table 1. Properties of Waste Plastic Oil

Sl.No	Properties	WPO
1	Calorific value (kJ/kg)	41919
2	Kinematic viscosity @ 40 ^{o}C (cst)	3.8
3	Flashpoint ^{o}C	62
4	Fire point ^{o}C	69
5	Density kg/m^3	800
6	Cetane number	38

III. EXPERIMENTAL SETUP AND TAGUCHI ANALYSIS

A constant speed single-cylinder, the air-cooled direct injection diesel engine was used to evaluate the engine investigation and emission norms of plastic pyrolysis oil. The specification of the diesel engine is tabulated in Table 2. The test engine was started by hand cranking method and the diesel engine was coupled with eddy current dynamometer. A dynamometer can be used for loading the engine manually from zero to full load and can be varied in the incremental of 0%, 25%, 50%, 75% and 100% based on the engine power produced. The test set up was attached with essential computational instruments for combustion pressure, diesel line pressure and crank angle measurement. The exhaust emission characteristics were observed by AVL gas analyser.

Table 2. Test Engine specifications

Parameter	Description
Make and Model	Kirloskar Engine
Type	4-S, Single Cylinder, Vertical Air Cooled Diesel Engine
Bore and Stroke length	87.5mm and 110mm
Compression ratio	17.5:1
Engine Power and Speed	4.4 kW @ 1500 rpm

The Taguchi method was developed by Dr Taguchi and itelaborated theminimizing of variation in test methods through the robust design of experiments. A standard L9 orthogonal array (Table 4) was selected for designing the experimental plan based on the total number of degree of freedom, number of factors, and level of each factor. Consequently, Taguchi's factor design method was implemented to recognize the result of different input constraints on output response. Table 3 deliver experimental levels and factors. Though, conventional Taguchi method might efficiently establish an optimum constraint setting for single performance features.

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Table 3.Experimental levels and factors

No.	Factors	Notation	Levels		
			-1	0	1
1	Engine Load (%)	A	25	50	100
2	Waste Plastic Oil (%)	B	10	20	30
3	Ethanol (%)	C	5	10	15
4	Injection Pressure (bar)	D	200	220	240

Table 4.Experimental Results

Ex. No	Load (kW)	WPO (%)	Ethanol (%)	Injection Pressure (bar)	Brake Thermal efficiency (%)	SFC (kg/kW-hr)	HC (ppm)	CO (%)	NOx (ppm)
1	25	10	5	200	27.06	0.422	36	0.072	201
2	50	10	10	220	23.26	0.404	47	0.074	224
3	100	10	15	240	25.58	0.368	30	0.085	230
4	50	20	5	240	33.56	0.265	28	0.042	225
5	100	20	10	200	27.1	0.344	38	0.079	264
6	25	20	15	220	31.06	0.301	40	0.083	275
7	100	30	5	220	28.72	0.381	26	0.0818	385
8	25	30	10	240	30.42	0.339	29	0.064	325
9	50	30	15	200	28.84	0.375	27	0.0648	309

IV. RESULTS AND DISCUSSION

4.1 Analysis of Engine performance:

Response analysis through SN ratios was used to know about the most significant engine parameters on this experiment and their levels. It designates the variation in performance and emission characteristics with the change in each engine parameters graphically. It also shows the pictorial Representation (Fig 1 and Fig 2) of engine performance, when the engine parameters change from one level to another level. The projected optimized engine parameters for brake thermal efficiency was at A1B2C1and D3 from Figure 1. The highest efficiency can be obtained from 25% of load, 20% and 5% of WPO, Ethanol blend with diesel at 240 bar injection pressure.

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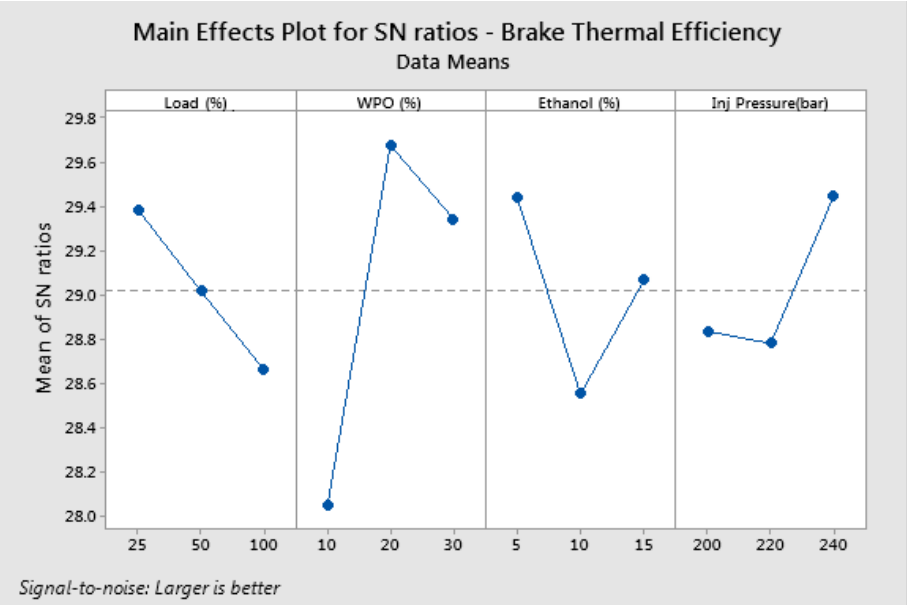

Fig. 1.Analysis of Brake Thermal Efficiency

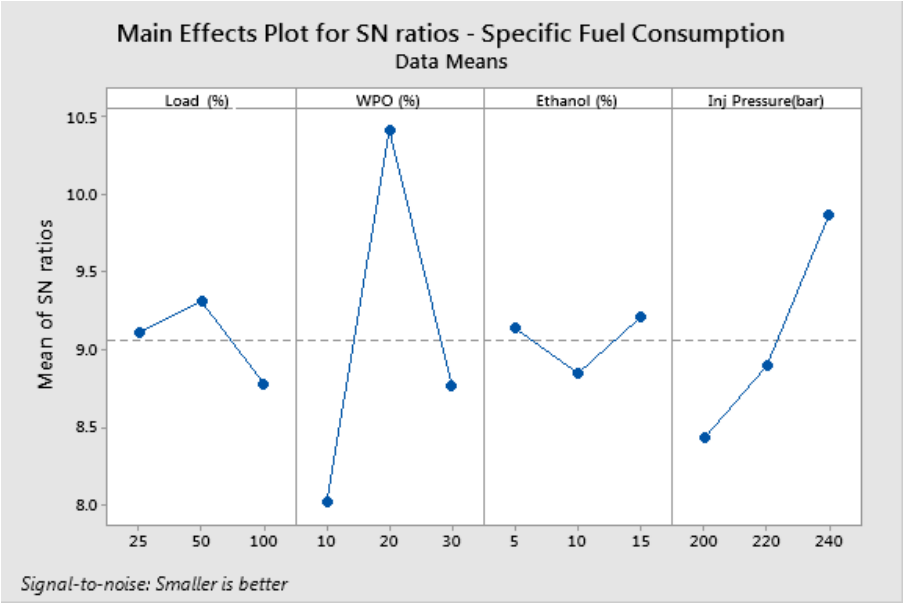

Fig.2.Analysis of Specific Fuel Consumption

Similarly, the optimized engine parameters for specific fuel consumption was at A3B1C2and D1 from Figure 2. The minimum fuel consumption can be obtained at 50% of engine load, 10% and 10% of WPO, Ethanol blend with diesel at 200 bar injection pressure [1-9].

4.2. Analysis of Emission characteristics:

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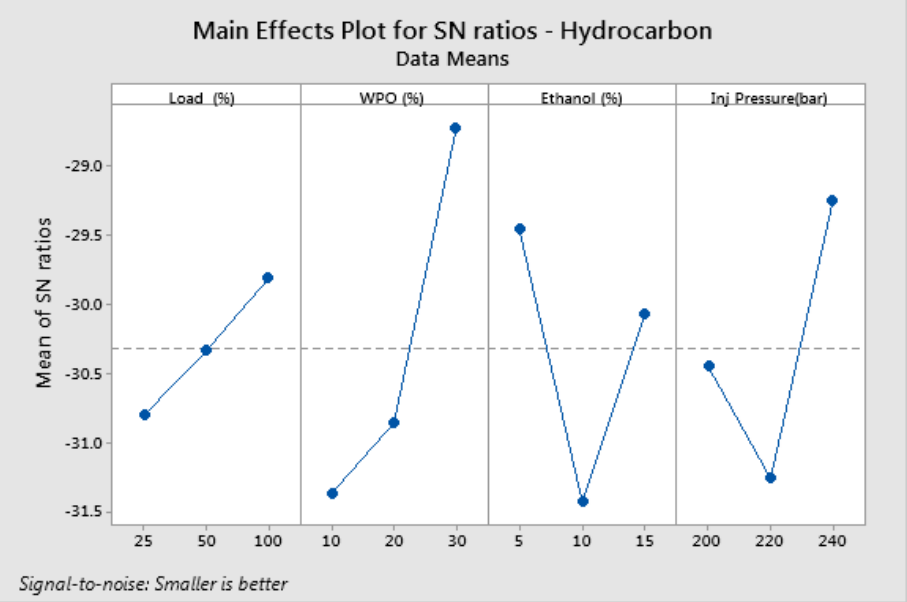

Fig. 3. Response of Hydrocarbon

Figure 3 shows the response of the test CI engine parameters for hydrocarbon emission was at A1B1C2and D2 from the response plot. The minimum hydrocarbon emission can be obtained at 25% of engine load, 10% and 10% of WPO, Ethanol blend with diesel at 220 bar injection pressure.

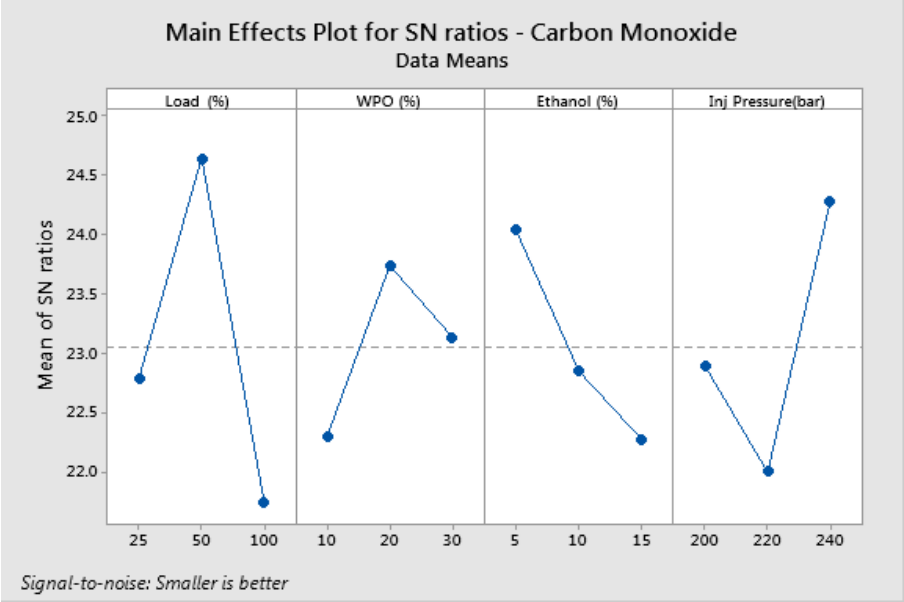

Fig.4. Response of Carbonmonoxide

The carbon monoxide emission response was plotted in figure 4. The predicted CI engine parameters for CO emission was at A3B1C3and D2 from the plot. The minimum carbon monoxideemission can be obtained at full load condition, 10% and 15% of WPO, Ethanol blend with diesel at 220 bar injection pressure [10-24].

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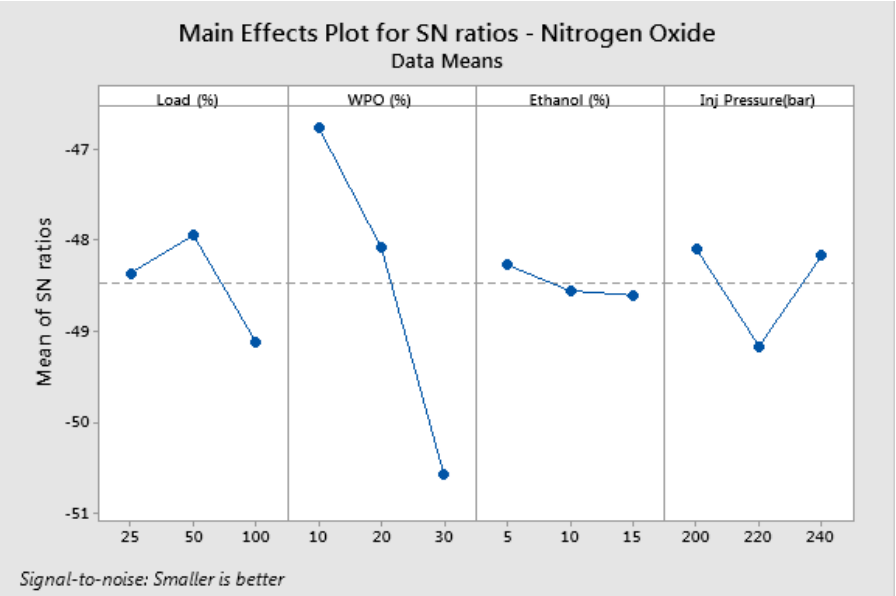

Fig 4: Response of Nitrogen Oxide

NOx emission response was plotted in figure 5. The expected diesel engine parameters for nitrogen oxide emission was at A3B3C3and D2 from the plot. The lowest nitrogen oxide emission can be attained at full load condition, 30% and 15% of WPO, Ethanol blend with diesel at 220 bar injection pressure [25-28].

V. CONCLUSION

The abandoning the used plastic products was a significant challenge for the ecologist. This paper tried the waste plastic oil and ethanol blends with dieselin a constant speed single cylinder, the air-cooled direct injection diesel engine. The engine influencing parameters were identified as engine load, plastic and ethanol blend ratio and injection pressure on the response of diesel engine performance and emission characteristics. The L9 orthogonal array was created by Taguchi method and analysed with SN ratio. The results show plastic oil blend was the most influencing factor through its ranking at 10% blends. The nominal factors can be listed as full load condition, 10% and 10% of WPO, Ethanol blend with diesel at 220 bar injection pressure as optimum engine parameters.

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