

## Optimization of Diesel Engine for Tyre Pyrolysis Oil & Diesel Blend



### Engineering

**KEYWORDS :** Pyrolysis oil, CI engine, Diesel, Blended fuel, Engine performance

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### ABSTRACT

*Reduction of biological fuel resources and stringent environmental laws have forced researchers to develop methods to sustainably manage resources. The focus has been shifting towards energy recovery from waste materials which can solve the problems. One of the biggest wastes in the automobile sector is automobile tires. These have an unfavorable impact on the atmosphere if they are not disposed properly. Further, tires are a source of energy so it's not suitable disposal means wastage of energy. Some methods have been developed to extract energy from waste tires. One of them is pyrolysis of tires which produces Tyre Pyrolysis Oil (TPO) by thermal decomposition of tires. The properties of TPO with diesel were analyzed and compared with diesel and found that it is also used as a fuel in diesel engines. Tests are carried out on a diesel engine running with dissimilar blends of TPO 15% on a volume basis. The value of the Taguchi identifies that compression ratio 18, injection pressure 160 bar and engine load 9 kg are optimum parameters for lowest specific fuel consumption. Engine performance is mostly influenced by engine load and is least influenced by pressure injection.*

### INTRODUCTION

In the current situation of the world, energy crisis due to fast depletion of fossil fuel is the main problem. Increase in fuel price day by day, continuing development of automobile industry, rapid growth in individual mobility and improved living standard, a continuous gathering of greenhouse effects are the main causes for development of alternative fuels. In current conditions, there is more chance of more in the research on biodiesel, vegetable oils and other alternate fuels. Taking everything in mind bio fuels as a diesel, Researchers are finding best alternative fuel, which gives the better efficiency and fuel properties. Best of alternative fuels used today are biodiesel or bio ethanol, which can be utilized in existing engines. The basic advantage of this kind of fuel is that they are renewable and eco-friendly. The different techniques for fuel and combine of alternate fuel with diesel. Recently in this field, the researcher work has been going on to add a maximum share of equivalent fuel in blend with diesel. With the utilization of alternate fuels, main issue is the qualification required in IC engines. To lower the cost of conversion some optimization techniques must be utilized. So performance and efficiency may not be lower. In such problem, utilization of non-linear methods like Design of Experiments, fuzzy logic and neural network is suitable to explore the linked effects of input parameters. The optimum performing parameters for a given system can be determined using experimental techniques, but experimental procedure will be slow and costly when the parameters are in the order of 30, 40 etc., in IC engines. In specific conditions mathematical will be a very useful tool for optimizing the parameters.

### Pyrolysis Oil

Pyrolysis oil is produced from waste tire by a process which is called pyrolysis process. It is a decomposition of chemical, biological matter in the absence of oxygen. Pyrolysis of tires with the meaning of the production of fuel for the regulation as a fuel in a diesel engine can be seen as environmentally pollution free and efficient way of preparing them. In study, it was found that, samples of 3-4 cm wide, whole tire, have been paralysis at 700 °C. At over 500 °C no result of temperature on gas and liquid which were about 18% and 37%, respectively. Tire pyrolysis oil

derived from waste tires of automobiles were compared with the petroleum brand and was found that it is utilized as a fuel for diesel engine. It was noticed that waste tires pyrolysis produced oil in properties to a light fuel oil, with same calorific value, and sulfur and nitrogen constituents. The oil is found to contain 1.5% sulfur and 0.46% nitrogen by mass, and had similar properties to diesel fuel. A single oil drop combustion studied and also the oil is evaluated in detail for its content of polycyclic hydrocarbons. The oil is combusted in 18.4 kW oil-fired, spray warmer furnace, 1.5 m length and 0.6 m diameter. The emissions of NO<sub>x</sub>, CO<sub>2</sub>, grainy and unburned hydrocarbons were found in excess oxygen levels. Throughout the combustion method, the similarity of the emissions is made to the combustion of diesel. The oil is found to contain 1.5% sulfur and 0.46% nitrogen and have comparable fuel properties to those of DF.

**Table - 1**

**The fuel Properties of Tire Pyrolysis Oil and Diesel**

Property	Tire Pyrolysis Oil	Diesel
Density at (gm/ml)	0.950	0.833
Kinematic viscosity at 40°C (cSt)	6.52	3.0
Flash point (°C)	28°	74°
Calorific value (KJ/kg)	47362.88	42850

### EXPERIMENTAL SETUP

The setup subsists of one cylinder, 4-stroke and research engine with dynamometer for loading. The operating mode of the engine is from Petrol to Diesel from Diesel to Petrol with some changes. In dual modes the compression ratio is diverse when stopping the engine and altering the combustion designed with cylinder block tilting arrangement. The injection point and spark point are to be changed for research tests. Setup is arranged with some instruments for combustion pressure, Diesel line pressure and crank-angle measurements. That indicator is

interfaced with CPU for pressure crank-angle diagrams. The instrument is organized to interface fuel flow, temperatures, and airflow and load measurements. The setup has panel box consisting of air box, two fuel flow measurements, method hardware and indicator interface. Rota meter is provided for cooling water flow measurement. A battery, starter and battery charger are arranged for engine electric start arrangement. The setup study of Variable Compression Ratio engine performance for indicating power, brake power, BMEP, frictional power, IMEP, Brake thermal efficiency, Mechanical efficiency, indicated thermal efficiency, volumetric efficiency, A/F ratio, specific fuel consumption, combustion analysis and heat balance. Lab based Engine Performance Analysis software package “Engine soft” is given for performance evaluation. Table.1 shows Technical specification of C. I Engine.

**Table - 2**  
**Engine Specifications**

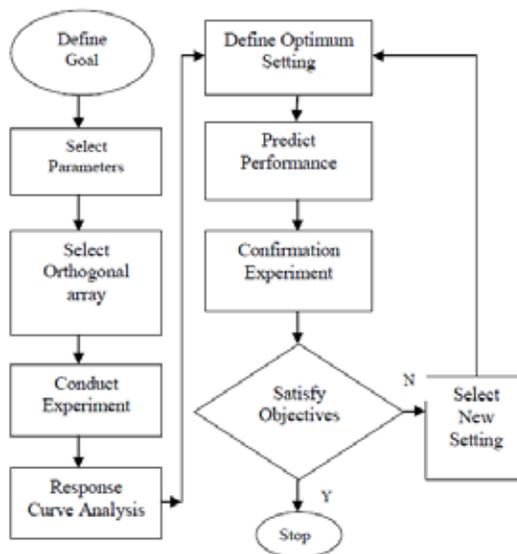
Item	Specification
Model	TV1
Make	Kirlosker Oil Engines
Type	Four stroke, Water cooled, Diesel
No. of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	12 to 18
Power rating	7.5 HP
Injection timing	≤ 25° BTDC

**METHODOLOGY**

Bi-fuelling or blending is the easiest technique to low cetane fuels in high compression ratio engines. According Mitesh Parmar et.al, 15% blend of pyrolysis oil in diesel gives best performance in the mech. Efficiency. In this practical the pyrolysis oil was blend with regular diesel in 15% and its properties such as viscosity and calorific value were calculated before an experiment. The effects parameters, i.e. load, injection pressure and compression ratio are variable for optimization. A method named “Taguchi” is used in the practical for optimization of parameters of engine such as load, injection pressure and compression ratio.

Taguchi method is the easiest method of optimizing the parameters in a small number of tests. The parameters included in the practical determines the number of tests required for the experiment. Many NUM. Of parameters led to a number of tests and use up more time to complete the practical. So a method called “Taguchi” was selected to optimize the levels of parameter contained in the practical. The Taguchi method utilized an orthogonal array to finish a small number of practical. The study uses three components at five levels and hence, an L25 orthogonal array with twenty five rows were used for the construction of experimental design. According to taguchi, twenty five practicals are carry out and tests were selected at random, to avoid systematic error creeping into the experimental procedure. For each test the SFC (specific fuel consumption) was calculated and used as a response parameter. Taguchi procedure utilized a parameter named S/N ratio (signal to noise ratio) for measuring the quality property. There are three types of S/N ratios is in the method. Of which, the smaller-is-better S/N ratio was utilized in this practical as a result of this optimization is placed on lower SFC. The Taguchi procedure used in the analysis was designed by software called “Minitab 17” to facilitate the Taguchi procedure and results. A full area of practical for the selected blend is also conducted after modifying the engine operating parameters. This is generally to optimize the performance characteris-

tics of pyrolysis oil-diesel blend.



**Figure 1: Flow chart (Taguchi Method)**

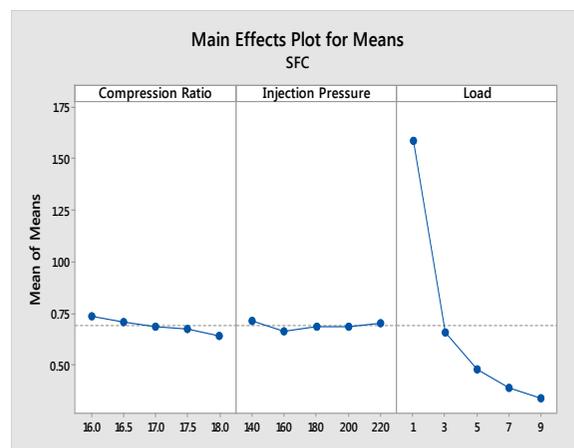
**RESULTS AND DISCUSSION**

Practical is done for choosing sets of parameters by Minitab application and find SFC (Specific Fuel Consumption) for those sets of parameters.

**Response Curve analysis**

An analysis of the result is created with the help of Minitab software. As the dissimilarity between two levels is more, the parametric level, having the highest S/N ratio coincides to the parameters signify highest performance.

Load, Compression ratio and injection pressure is being plotted against the Mean of Means of the specific fuel consumption utilizing the Minitab Software as well as the effect of all these parameters were also planned using the same software for the S/N ratio. Then the results are equal for the optimization of Specific fuel consumption.



**Figure 2: Means of Specific Fuel Consumption (Main effects Plot)**

From above Fig 2, the mean is an average value for reading taken for a particular parameter.

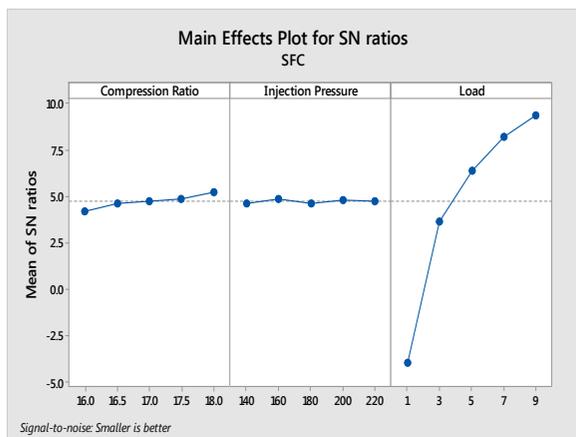
From the graph, the mean value is the maximum (0.7391) for 18 compression ratio and minimum (0.6434) for 18 compression ra-

tio. Similarly, mean value is maximum (0.7157) for 160 bar injection pressure and mean value is minimum (0.7042) for 160 bar injection pressure, the mean value is the maximum (1.5842) for 9 kg load and a minimum (0.3418) for 9 kg engine load.

**Table - 3**  
**Response Table for Mean of means of specific fuel consumption**

Level	Compression Ratio	Injection Pressure	Load
1	0.7391	0.7157	1.5842
2	0.7088	0.6635	0.6589
3	0.6874	0.6887	0.4809
4	0.6769	0.6835	0.3898
5	0.6434	0.7042	0.3418
Delta	0.0956	0.0522	1.2424
Rank	2	3	1

Table-3 shows the value of mean of means of specific fuel consumption. Three parameters are considered hereby namely compression ratio, injection pressure and Load. Delta is the difference from maximum value and minimum value of means of means for a singular parameter. The highest difference suggests that singular parameter has a greater effect. From the table it can be seen that Load has a maximum reaction after that compression ratio and lastly injection pressure of specific fuel consumption. Similarly, main reaction plots for SN ratio is generated using Minitab software as shown below.



**Figure 3: Main effects Plot for Means of SN Ratio**

Above Fig 3 shows the response curve for S/N ratio, the lowest S/N ratio was observed at 18 compression ratio, 160 bar injection pressure and 9 kg load.

**Selecting an optimum set of parameter level**

**Table - 4**  
**Response Table**

Level	Compression Ratio	Injection Pressure	Load
1	4.185	4.606	-3.979
2	4.617	4.862	3.631
3	4.721	4.601	6.379
4	4.832	4.769	8.186

5	5.189	4.704	9.327
Delta	1.003	0.261	13.306
Rank	2	3	1

As per Table-4, Delta is the difference between the maximum value and minimum value. Rank denotes the maximum and minimum effect of the parameters. It shows that the effect of load is maximum whereas the effect of Injection Pressure is minimum on Specific Fuel consumption.

**Predict performance at the optimum setting**

**Table 5: Predicted Values for Minimum Specific Fuel consumption**

Compression ratio	Injection pressure	Load (kg)	Specific Fuel Consumption (kg/kWh)
18	160	9	0.3199

In Table-5 an optimum set of parameters has been achieved by response curve analysis generated with the help of Minitab software. Minitab software for Taguchi method of optimization suggested Signal to Noise (S/N) ratio to be maximized for minimum specific fuel consumption. The result suggests that minimum specific fuel consumption is obtained when the engine is operated at 18 compression ratio, 160 bar injection pressure at 9 kg Load.

**CONCLUSION**

The value of the Taguchi identifies that compression ratio 18, injection pressure 160 bar and engine load 9 kg are optimum parameters for lowest specific fuel consumption. Engine performance is mostly influenced by engine load and is least influenced by injection pressure.

**References**

- [1] Murugan, S., Ramaswamy, M. C., &Nagarajan, G. (2008). The use of tyre pyrolysis oil in diesel engines. Waste Management, 28(12), 2743-2749.
- [2] Sharma, A., &Murugan, S. (2013). Investigation on the behaviour of a DI diesel engine fueled with Jatropa Methyl Ester (JME) and Tyre Pyrolysis Oil (TPO) blends. Fuel, 108, 699-708.
- [3] Williams, P. T., Bottrill, R. P., &Cunliffe, A. M. (1998). Combustion of tyre pyrolysis oil. Process safety and environmental protection, 76(4), 291-301.
- [4] Roy, C., &Chaala, A. (2001). Vacuum pyrolysis of automobile shredder residues. Resources, Conservation and Recycling, 32(1), 1-27.
- [5] Wang, S., Fang, M., Yu, C., Luo, Z., & Cen, K. (2005). Flash pyrolysis of biomass particles in fluidized bed for bio-oil production. China Particuology,3(01n02), 136-140.
- [6] Karaosmano lu, F., Tetik, E., &Göllü, E. (1999). Biofuel production using slow pyrolysis of the straw and stalk of the rapeseed plant. Fuel processing technology, 59(1), 1-12.
- [7] Bridgwater, A. V. (2012). Review of fast pyrolysis of biomass and product upgrading. Biomass and bioenergy, 38, 68-94.
- [8] de Marco Rodriguez, L., Laresgoiti, M. F., Cabrero, M. A., Torres, A., Chomon, M. J., & Caballero, B. (2001). Pyrolysis of scrap tyres. Fuel processing technology, 72(1), 9-22.
- [9] Aydın, H., & Iklıç, C. (2012). Optimization of fuel production from waste vehicle tires by pyrolysis and resembling to diesel fuel by various desulfurization methods. Fuel, 102, 605-612.
- [10] Authayanun, S., Pothong, W., Saebea, D., Patcharavorachot, Y., &Arpornwichanop, A. (2008). Modeling of an industrial fixed bed reactor based on lumped kinetic models for hydrogenation of pyrolysis gasoline. Journal of Industrial and Engineering Chemistry, 14(6), 771-778.
- [11] Ringer, M., Putsche, V., &Scahill, J. (2006). Large-Scale Pyrolysis Oil.Assessment.
- [12] Do an. O., Çelik, M. B., &Özdalyan, B. (2012). The effect of tire derived fuel/diesel fuel blends utilization on diesel engine performance and emissions. Fuel, 95, 340-346.
- [13] Murugan, S., Ramaswamy, M. C., &Nagarajan, G. (2009). Assessment of pyrolysis

- oil as an energy source for diesel engines. *Fuel processing technology*, 90(1), 67-74.
- [14] Murugan, S., & Ramaswamy, M. C. (2008). Running a Diesel Engine with Tyre Pyrolysis Oil Diesel Blends at Different Injection Pressures. *Thammasat Int. J. Sc. Tech*, 13(1).
- [15] Bhatt, P. M., & Patel, P. D. (2012). Suitability of tyre pyrolysis oil (TPO) as an alternative fuel for internal combustion engine. *International Journal of Advanced Engineering Research and Studies*, 4, 61-65.
- [16] Murugan, S., Ramaswamy, M. C., & Nagarajan, G. (2008). The use of tyre pyrolysis oil in diesel engines. *Waste Management*, 28(12), 2743-2749.
- [17] Peláez, W. J., Szakonyi, Z., Fülöp, F., & Yranzo, G. I. (2008). Flash vacuum pyrolysis (fvp) of some hexahydroquinazolin-4 (1H)-ones. *Tetrahedron*, 64(6), 1049-1057.
- [18] Williams, P. T., & Brindle, A. J. (2002). Fluidised bed catalytic pyrolysis of scrap tyres: influence of catalyst: tyre ratio and catalyst temperature. *Waste management & research*, 20(6), 546-555.