Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7750859

# INVESTIGATE THE EFFECT OF DME FUMIGATION AT 250GM/HR BY USING TYRE PYROLYSIS OIL AS FUEL IN CI ENGINE

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**Abstract**:

In the current energy situation of quick reduction of fossil fuels, there will be a multifold boost in research on biodiesel and pyrolysis oil as alternative fuels for use in CI engines. This research starts by describing the problems related to global fossil fuel scarcity and alternative sources. Clean burning and efficient fuel use will address the issue of public health and safety for many people. There is a massive conversion of fuel into motive energy as well as electrical energy, and this is typically a significant cost to each economy. This cost will be measured in terms of both economic and environmental impacts. Due to these costs, the world will be pushed towards a more efficient use of energy.

The study's main goal is to assess the credibility of tyre pyrolysis oil as an alternative fuel and to determine the minimum specific fuel consumption for the various parameters in an internal combustion engine in order to save millions of tonnes of fuel. ns of fuel. The literature survey reveals that a little research has been conduct to obtain the optimal levels of variable parameters that yield the optimum SFC in Compression Ignition (CI) engine. A diesel engine is used as a prime mover for power generation in agriculture, personal and public transportation, industrial processes, and marine propulsion. Industries and marine propulsion are significant consumers of fuel; hence, there are economic and environmental costs involved.

The present study was conducted with the main objective of improving the performance, emission, and combustion characteristics of a direct injection diesel engine fuelled with methyl ester biodiesel by DME fumigates at 250gm/hr flow rates. The effects of DME fumigation (the addition of DME to the intake air manifold) and tyre pyrolysis oil biofuel blends on the performance and emissions of a single-cylinder diesel engine were compared in a study. An attempt was made to determine the optimum percentage of DME that gives lower emissions and better performance

***Keyword: DME, tyre pyrolysis oil, Biofuel, CI Engine***

## 1. INTRODUCTION:

The energy crisis and environmental degradation are the main problems in the present days due to growing population and rapid industrialization. Around the world, there are initiatives to replace gasoline and diesel fuel due to the impact of fossil fuel crisis and hike in oil price. Millions of dollars are being invested in the search for alternative fuels. The scrap tire is one by which alternative fuel can be produced and also can be tested the properties of the fuel as well as the performance of the diesel engine by using the tire pyrolytic oil.

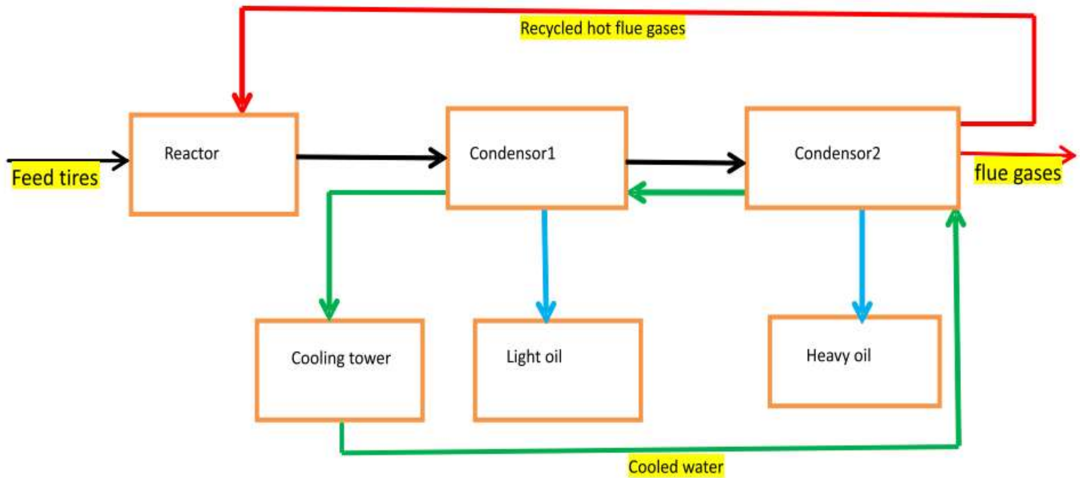



**Figure 1.1 Process flow diagram of tire pyrolysis**

Pyrolysis is the process of chemical decomposition of organic materials by heating in the absence of oxygen or any other reagents. Pyrolysis process can be used to re-cycle the waste tyres and produce carbon black, solid residue (steel wire), fuel gas and fuel oil. The word is coined from the Greek-derived elements pyro "fire" and lysis "se-parating". The waste tyres are reduced primarily into three products, i.e. Carbon black, fuel oil, steel (the steel belt in the tyre) and other hydrocarbon gases. The tyre pyrolysis oil can be used in boilers, chemical industries and in a furnace as a fuel. The pyrolysis process is mostly used in chemical industry, i.e. to produce charcoal, activated carbon, methanol and other chemicals. It is used to convert

ethylene dichloride into vinyl chlo-ride, to produce coke from coal, to convert biomass into synthesis gas and biochar, to turn waste into safely disposable substances, and for transforming medium-weight hydrocarbons from oil into lighter ones like gasoline. These specific uses of pyrolysis may be a dry distillation, distractive distillation.

## 1.1 SIGNIFICANCE OF WASTE TYRE PYROLYSIS OIL

Pyrolysis plants provide an alternate petroleum product, which can be used as a substitute to conventional industrial fuel. Thus, waste tyre recycling plants are very effective &appropriate approach to recycle waste tyres & extract valuable streams of industrial fuel, which has a great demand in the market. To understand tyre pyrolysis as a new business opportunity & its scope in India one needs to analyse the growth of modern Automobile Industry in India & Tyre Manufacturing Industry in India. These give a clear idea regarding raw material availability in India. The pyrolysis oil is used as a burning fuel by the number of industries, so the demand is increased greatly. The cost of pyrolysis oil is cheaper than diesel, hence can be used as a substitute for diesel.

## 1.2 PYROLYSIS PROCESS

The Pyrolysis gas, Pyrolysis oils, Carbon black and Steel wire is obtained from pyrolysis process of waste tyres. Production of the first three products is highly depending on process temperature. The pyrolysis process is a technique, which heats whole or shredded tyres in a reactor vessel containing an oxygen-free atmosphere and a heat source. In the reactor, the rubber is softened after which the rubber polymers continuously break down into smaller molecules. These smaller molecules are finally vaporized and exit from the reactor. These vapours can be used to produce power or condensed to produce oil type liquid. The oil is generally used as a fuel. Some molecules are too small to condense. They remain as a gas, which can be burned as fuel. From the waste tyre, about 40 to 45 % by weight is removed as a solid. The properties of the gas, liquid and solids are highly depended on the type of feedstock and the process conditions. For instance, whole tyres contain fibres and steel. Shredded tyres have most of the steel and sometimes most of the fibres are removed. The steel can be removed from the solid stream by using magnets. The remaining solid material often referred to as "charcoal"

**Table 1.1 Waste tyre outputs**

| Type of Material | Total Quantity | Finish quantity |
|---|---|---|
| Nylon scrap tyres | 1000 kg | 1. 550 to 600 litre of Pyrolysis oil<br>2. 50 to 80 kg of Hydrocarbon Gas<br>3. 300 to 350 kg of Carbon Black |
| Radial scrap tyres | 1000 kg | 1. 400 to 450 of Pyrolysis oil<br>2. 50 to 80 kg of Hydrocarbon Gas<br>3. 300 to 350 kg of Carbon Black<br>4. 150 to 200 kg of Mild steel tyre scrap |

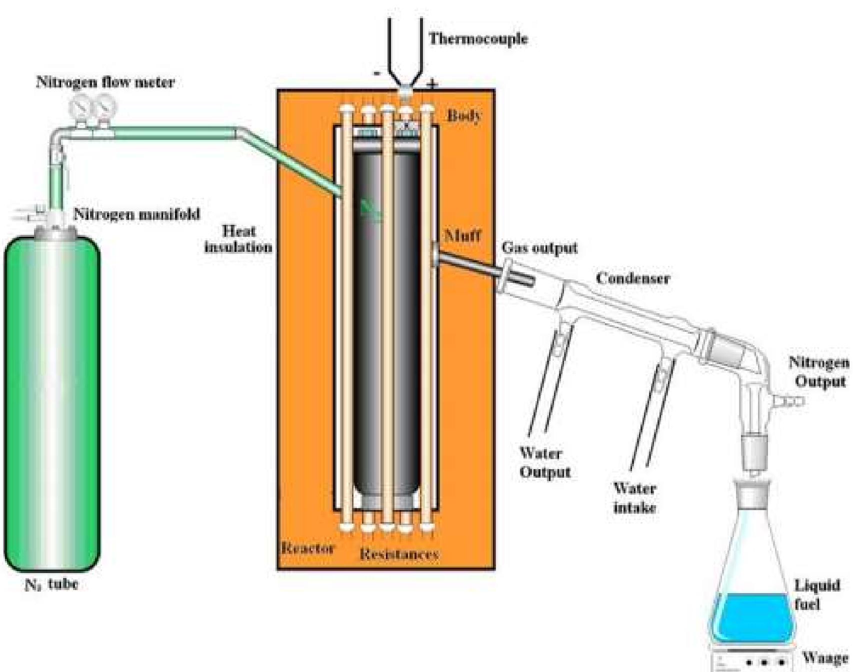



**Figure 1.2 Schematic diagram of the pyrolysis unit**

### 1.3 WASTE TYRE PYROLYSIS ADVANTAGES

- The raw materials are cheaper and easily available in any part of the world for the waste tyre recycling pyrolysis plant
- The waste tyres management problems of any country can be easily overcome by using pyrolysis plant.
- The waste tyres can give a valuable output product like Fuel (Pyrolysis Oil), Carbon black powder, Steel wires and Gas. Fuel oil (Pyrolysis oil), Carbon Black Powder and Steel Wires have great demand in the market nowadays.
- The execution of pyrolysis plant technology can be easily feasible with smaller investment cost, high availability of raw materials, short recovery period and with bright future.
- No catalyst is used in pyrolysis plant during execution of tyre pyrolysis process.

**Table 1.2 Properties of diesel and tyre pyrolysis oil**

| Property | Diesel | Tyre Pyrolysis Oil |
|---|---|---|
| Density (kg/m$^3$) | 830 | 923.9 |
| Kinematic viscosity (cSt) | 2.58 | 3.77 |
| Net calorific value (MJ/kg) | 43.8 | 38 |
| Flashpoint, °C | 50 | 43 |
| Fire point, °C | 56 | 50 |

## 2. METHODOLOGY AND EXPERIMENTAL SETUP

### 2.1 Materials and Methods:

Experimental tests have been carried out to evaluate the performance, emission and combustion characteristics of a diesel engine when fuelled TPO (Tyre pyrolysis oil) and its blends of 20%, 40%, 60% 80% and 100% with Diesel and DME fumigation at 250gm/hr flow rate with intake air inside the engine cylinder. The DME injection system consists of an electric pump which supplies DME at a maximum pressure of about 6 bar, a pressure control valve to maintain the fuel supply pressure (not more than 3 bar), desired quantity of DME as a fine spray was injected into the intake port during suction stroke. The excess DME was diverted back into the DME tank. The gasoline injector was fitted in the inlet manifold and very near to

inlet valve. The injector position is shown in Figure, the start of injection and duration of the injector opening were controlled by using an electronic control unit (ECU). An electronically controlled DME injection system was developed to inject a known quantity of well-atomized spray of DME into the inlet port of the engine. The pump was housed in a 10-liter tank, which was perfectly sealed to avoid DME evaporation. The emission like HC, CO, and NOx, $CO_2$ were measured in the exhaust gas analyzer and smoke density was measured in the smoke meter.

**Table 2.1 properties of fuels and additives.**

| Properties | Diesel | Bio Diesel | DME |
|---|---|---|---|
| **Chemical Structure** | $C_{12}H_{26}$ | | $C_2H_5$-O- $C_2H_5$ |
| **Density- Kg/m$^3$** | 833 | 772 | 713.4 |
| **Specific gravity** | 0.831 | 0.769 | 0.712 |
| **Kinematic Viscosity (mm$^2$/s) @ 40°C** | 3.0 | 9.2 | 0.23 |
| **Cetane number** | 49 | 42-48 | 127 |
| **Flash point °C** | 64 | 140 | -40 |
| **Auto ignition temperature °C** | 315 | 235 | 160 |
| **Low calorific value(kj/kg)** | 42500 | 40800 | 33890 |
| **Oxygen content – wt%** | 0 | 11 | 21.6 |
| **Carbon content – wt%** | 87 | 52.18 | 64.9 |
| **Hydrogen content – wt%** | 13 | 13.04 | 13.5 |

**2.2 Experimental Setup:**

The experiment was conducted on Kirlosker engine. Technical specifications of the Kirlosker engine are tabulated in Tab. 4.2. The engine ran at constant speed at 1500 rpm for different load conditions. The BENZ eddy current dynamometer was used for applying loads to the engine. The smoke density was measured using an AVL smoke meter. Combustion parameters like pressure in cylinder, net heat release rate and maximum pressure were measured by AVL combustion analyser. The AVL combustion analyser placed with experimental setup was capable to measure the pressure up to 250 bar and capable to capture the heat release rate and cylinder pressure for each crank angle.

**Table 2.2: Specifications of test engine**

| | |
|---|---|
| **Engine type** | Single cylinder,4 stroke, DI |
| **Bore Diameter** | 87.5 mm |
| **Stroke length** | 110 mm |
| **Comp. ratio** | 17.5:1 |
| **Power output** | 3.7 KW |
| **Cylinder Volume** | 553 CC |
| **Speed** | 1500 rpm |
| **Fuel type** | Diesel |
| **Cooling System** | Water |
| **Injection pressure** | 220 kg/cm$^2$ |
| **Ignition Timing** | $23^0$ Before TDC (rated) |

**2.3 DME fumigation arrangement:**

The engine used for the experimental investigation was a Kirloskar AV1, single cylinder, four strokes, cooled water, direct injection diesel engine, developing a rated power of 3.7 KW at a rated speed of 1500 rpm. The engine is coupled to an electrical dynamometer with resistance loading. The engine is mounted on an engine test bed with suitable connections for lubrication and for the supply of cool water. The electronic control unit (ECU) controls the operation of DME fuel injector. The one end of the positive power supply from the 12 V battery is connected to the injector; the other negative terminal of the injector is connected to the ECU, which is having the control of injector opening timing and duration. The electronic control unit is also having the input from the infrared detector. The IR Detector is used to give the signal to the ECU for the injector opening timing. The negative terminal of the injector is connected to the ECU. Based on the pre-set timing, the duration the injector will be opened for injection and closed after injection. The injection timing and injection duration will vary within the specified range by using the knob control. The power supply for the injector opening is 4A and for holding the injector to inject the fuel 1A will be the power supply. Based on the pre-setting, the DME will flow and the flow of DME can be controlled either by using the pressure regulator or by using the digital mass flow controller. DME injector was fixed in the intake manifold for DME injection and the electronic fuel pump was fixed for the purpose of DME supply. In neat form DME is injected into the intake manifold.

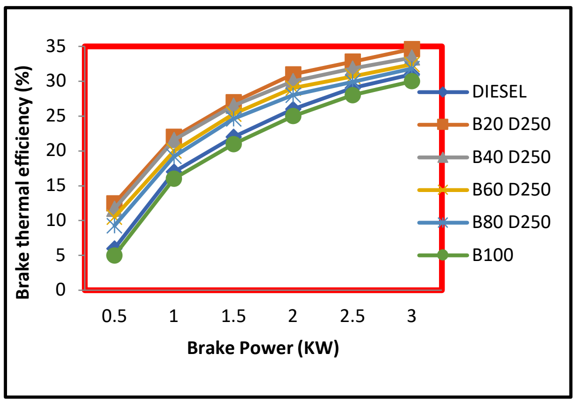
**Figure 2.1 DME injection arrangements**

**2.4 Data Acquisition System**

AVL indicom acquisition provides 6 inputs for cylinder pressure sensor as well as to multipurpose inputs for piezo resistive sensors, strain gauges, needle valve lift signal etc.8 digital and 2 Delta T input complement the input facilities. The Indi smart supports and automated cold start measurement sequence with concurrent time based and crank angle based data acquisition. An integrated Gigabit Ethernet interface supports real time raw data transfer to a connected laptop automotive PC utilising AVL indicom mobile software package. Flexible measurement modes support automatic event catching and event for data storage to the hard disk of the personal computer. The data acquisition system is able to measure and store up to 1000 cycle of engine pressure histories with an accuracy of 0.5 degree of crank rotation.

**Figure 2.2 AVL data acquisition system**

## 3. RESULT AND DISCUSSION



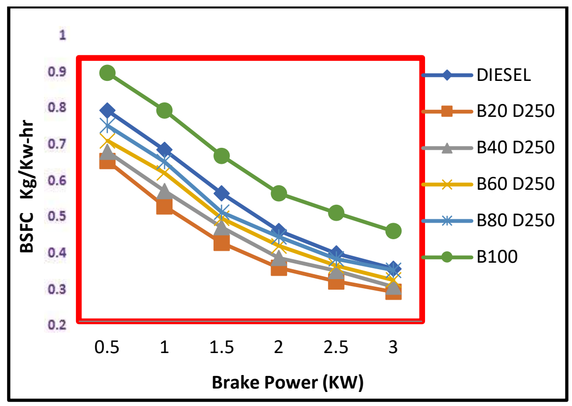
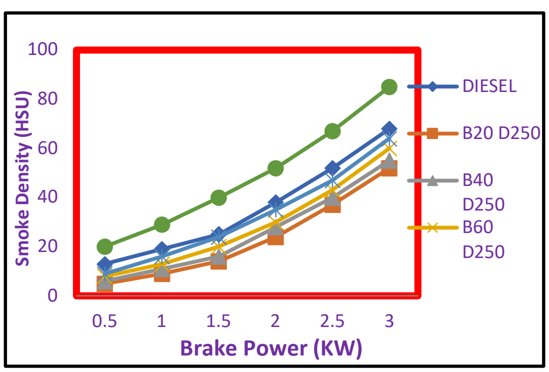




**Figure 3.1 Variation of Brake thermal efficiency with Brake** **Figure 3.2**
**Variation of BSFC with Brake power for D250 power**



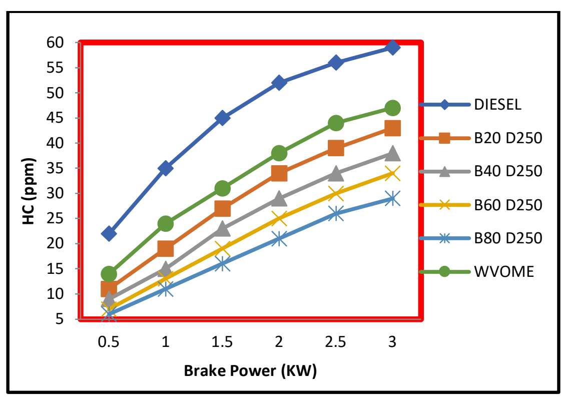
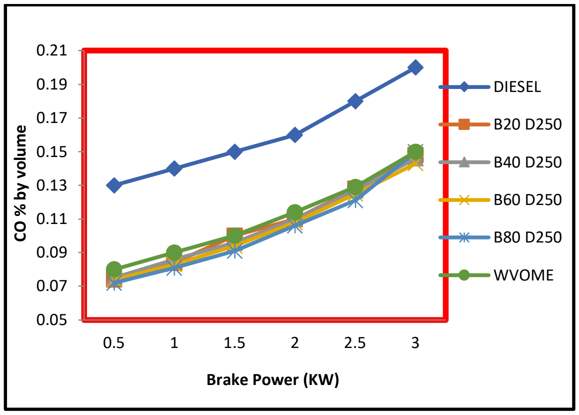




**Figure 3.3 Variation of smoke emission with Brake power** **Figure 3.4**
**Variation of hydrocarbon emission with BP**



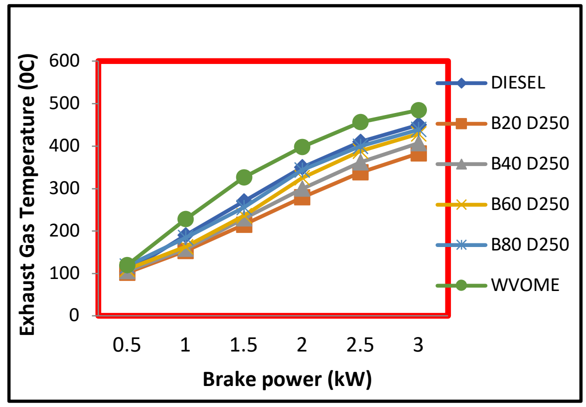




**Figure 3.5 Variation carbon monoxide emissions with BP Emission with BP**

**Figure 3.6 Variation EGT**

As indicated in **figure 3.1** the maximum flow rate of DME (250g/hr) was injected in intake port and blended fuel burnt which gave maximum BTE for engine, BTE higher than diesel fuel because of more oxygen supply to the engine which causes complete combustion of fuel. The complete combustion is possible when maximum amount of DME be injected in the engine with blended fuel supply.

As may be seen in **figure 3.2** brake specific fuel consumption values for B20, B40, B60 and B80 are lower SFC than that of diesel while B80 shows a slightly higher value than diesel but close to 250g/hr. This may be due to the fact that mass flow rate of DME 250 g/hr gives better combustion rate which give lower fuel consumption.

In **figures 3.3** 250g/hr mass flow rate of DME give better smoke density than diesel. Flow rate of 200g/hr gives better smoke density with 20% blend, but other blends like B40, B60, and B80 are much closer to each other because of DME property which gives better combustion inside the engine cylinder.B20, B40, B60 and B80 have lower smoke density. DME has been identified as a supplementary oxygenated additive to improve fuel properties and combustion characteristics of biodiesel.

**Figure 3.4** Shows the variation of HC emission with brake power with different blends of WVOME and TPO used along fixed 250 g/hr mass flow rate of DME. It may be seen that the HC emission is the highest in case of diesel fuel followed by B20, B40, B60, B80 and WVOME and TPO in that order. the mass flow rate of 250 g/hr DME give lower HC emission.

**Figures 3.5** Show the effect of BP on CO emission when operated with diesel and all WVOME and TPO blends used with 250g/hr mass flow rate of DME respectively. Here results show the percentage of CO emission increased with load on the engine in all the cases.

**Figure 3.6** Shows the variation of the exhaust gas temperature with brake power for different blending of WVOME and TPO with DME flow rate of 250 g/hr. its seems that the EGT is much lower for D250 at different blending.

## 4. CONCLUSION

- **Brake thermal efficiency: -** The B20D250 has highest BTE (about 33.8%) than neat diesel (about 31%) at maximum load.
- **Brake Specific Fuel Consumption: -** The B20D250 has minimum BSFC (about 3.9 kg/kw-hr) as compared to neat diesel (about 7 kg/kw-hr) at maximum load.
- **Smoke Emission: -** The smoke emission is found minimum in B20D250 (about 52 HSU) than neat diesel (about 68 HSU) at maximum load.
- **Hydrocarbon Emission (HC): -** The hydrocarbon emission is found minimum in B80D250 (about 29 HSU) than neat diesel (about 59 HSU) at maximum load.
- **Carbon monoxide Emission (CO): -** The Carbon monoxide Emission minimum in case of B80D250 (about 0.143%) by volume than neat diesel (about 0.21%) by volume at maximum load.
- **EGT** found much lower for B20D250 mass flow rate is about $330^0$C.

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