Experimental study of VCR engine performance analysis using python module

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Abstract. Petroleum is non-renewable supply of energy and also the diminution of natural fuel resources, leads to explore for various fuels for cars. The critical search for various fuels for compression ignition engines has been paying interest on fuels obtained from hydrogen and linseed oil plays a significant role in alternate fuel for C.I Engines. The aim of this research effort is to appraise the property of Linseed oil and Hydrogen as dual blend recital on a variable Compression ratio diesel engine. This really provides the discharge individualism of linseed oil amalgamated with gas and its blends with diesel and are taken up for study. Vertical, 4-stroke, water cooled VCR engine with Linseed oil blends for an extensive series of engine load conditions such as Diesel, B10, B20, B40 along with 5lpm, 10lpm and 15lpm of hydrogen were performed. The brake thermal competence of B20 is found nearly closer to diesel fuel with minimum vibrations and less emissions of CO, hydro carbons HC and slight increase in NOx when compared to fossil fuels. During the experiments, vibrations, performance uniqueness of the test engine was analysed and compared with the precise VCR diesel vibrations, fuel performance. The results obtained by using Python module and the best suited code is derived and found that the combined increase of compression ratio and injecting timing increases the brake thermal efficiency and reduces specific fuel consumption. This module helps and reduces each load variations and performances compared tp experimental. Diesel (25%) saved, will greatly meet the demand of fuel in automobiles.

Keywords: Biofuel, Biodiesel, VCR, Optimization, Linseed oil, Hydrogen, Compression ratio.

1. Introduction
Petroleum is the largest contributing energy source to mankind, surpassing all other resources like- Coal, Nuclear, Hydro, Natural gas and Wind [1]. Diesel engines approved over spark ignition engines in most significant heavy duty applications due to accuracy and persistence. Therefore, the world’s demand for diesel oil will increase each year. Since previous few decades, researchers world over are attempting to seek out new various fuels that technically possible, economically and environmentally viable and environmentally acceptable [2-4]. Biodiesel as another fuel is one amongst the simplest alternatives among more sources overdue to its high potential to weaken levels of emissions like Hydrocarbons (HC), Carbon monoxide (CO), Nitrogen oxides (NOx) and Smoke once employed in engines, additionally to being renewable and perishable.
1.1 Literature Review:

Vegetable oils are found to be a possible substitute to diesel. They acquire properties similar to diesel and may be run a compression ignition engine with minor modification [5, 6]. The use of edible fat fuel also scale down carbon monoxide emissions [7]. Because of its advanced structure and composition, the gas emissions area higher, combustion period and ignition delay augmented [8]. The results of biodiesel sorts and biodiesel fraction on the emission characteristics of a CI engine were studied. The results additionally clearly indicate that the engine running with biodiesel and blends have higher NOx emission by up to twenty percent [9]. The temperature of intake air rises, the brake thermal efficiency (BTE) will increase by one percent from 30ºC to 60ºC, correspondingly brake specific fuel consumption (BSFC) decreases [10-14]. Among emissions, it’s detected that, the oxides of nitrogen will increase by ten percent emission of HC and smoke decreases by thirty five and fifteen percent each the variations have shown through mathematical modelled adopting fitting of curves technique by applying Python module and also the best suited equations. In current work, experiments were conducted to check the performance characteristics by derived linseed oil and H blends as an alternate fuel in an exceedingly direct injection diesel engine.

| Property                      | B10   | B20   | B40   |
|-------------------------------|-------|-------|-------|
| Density at 20°C (gm/ml)       | 0.878 | 0.834 | 0.829 |
| Viscosity mm²/sec             | 2.6   | 3.1   | 3.6   |
| Flash point °C                | 35    | 46    | 52    |
| Boiling point °C              | 180   | 200   | 230   |
| Net heating Value MJ/kg       | 31.16 | 37.12 | 35.12 |

2. Experimental Procedure

A single cylinder 4-stroke, direct injection, variable compression ratio computerised diesel motor test Rig of 3.5 kilowatt rated power 5lpm, 10lpm and 15lpm was used. It’s coupled on to eddy current sort of measuring instrument called dynamometer [15-20].The experiments were conducted at a rated engine speed of 1500 rpm with before injecting time TDC (top dead centre). The engine was allowed to run until the steady state is reached. Then it absolutely was loaded by 6(D+15), 6(B10+10), 6(B20+10), 6(B40+10) with different mass flow rates 5lpm, 10lpm and 15lpm.

Fig 1: Layout of experimental setup.
1 Hydrogen cylinder, 2 Hydrogen regulator, 3 Flash back arrestor, 4 Flame arrestor, 5 Hydrogen flow meter, 6 Engine, 7 Clinker pressure sensor, 8 Mixing chamber, 9 Exhaust flow pipe, 10 Calorimeter,
11 Exhaust gas, 12 Exhaust gas analyzer probe, 13 Exhaust gas analyzer, 14 Power supply, 15 Eddy current dynamometer, 16 Engine water inlet pipe line, 17 Flywheel, 18 Fuel tank, 19 U-tube manometer, 20 Loading unit, 21 Rotameter, 22 Computer, 23 Hydrogen gas flow pipe, 24 Exhaust gas, 25 Air supply, 26 Calorimeter water inlet, 27 NI-6210 USB multifunction line, 28 Control panel, 29 Burette.

**Table 2:** Engine Specification and setup

| Make and Model | Rocket Engineering Model VRC |
|----------------|-------------------------------|
| Type           | 4-Stroke single cylinder, water Cooled, VC ratio from 15.5-17.5 |
| Standard Dimensions of Cylinder | 75mm bore diameter and 110mm length of stroke |
| Speed          | 1500 rpm constant, governor controlled |
| Exhaust Gas Analyser Make | Indus Scientific Pvt. Ltd. |
| Measurable Gases | CO, NOx and HC |

### 3. RESULTS AND DISCUSSIONS

#### 3.1 Performance Parameters:

Experimentally observed data are used for the evaluation of performance characteristics and correlated with Python programming each discussed below.

**CR Performances:**

**Table 3:** Optimum CR Performances

| Diesel | H2 | CR | CR(D,B10,B20,B30,B40) | Ampli | BP   | BSFC | BTE   | ME    | VE   |
|--------|----|----|------------------------|-------|------|------|-------|-------|------|
| D      | 15 | 15 | 15(D+15)               | 0.5587| 1.7700| 0.4082| 15.9600| 60.1800| 71.6500|
| B10    | 15 | 15 | 15B(10+15)             | 0.6878| 1.7700| 0.3140| 22.6700| 49.5700| 71.7800|
| B20    | 15 | 15 | 15B(20+15)             | 0.5780| 1.7900| 0.4107| 16.0500| 35.9800| 71.8900|
| B30    | 10 | 10 | (B30+10)               | 0.693 | 1.775 | 0.441 | 16.425 | 44.12 | 72.54 |
| B40    | 5  | 15 | 15(B40+5)              | 0.8883| 1.7800| 0.7244| 11.2000| 41.1800| 72.6800|

**Fig 2:** Graph showing Optimum CR-DB10B20B40-performances

**Python Code:**

```python
# OPTIMUM-CR-DB10B20B40-Performances
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```
import matplotlib.gridspec as gridspec

data = pd.read_excel('F:/udayasri/Datasets-Images-CR/CR/Performances/CR-Performances-Data-Set.xlsx', sheet_name='BEST-CR-DB10B20B30B40')
crdata_df = pd.DataFrame(data)
CRD = crdata_df['CR(D,B10,B20,B30,B40)']
CRAmpli = crdata_df['Ampli']
CRBP = crdata_df['BP']
CRBSFC = crdata_df['BSFC']
CRBTE = crdata_df['BTE']
CRME = crdata_df['ME']
CRVE = crdata_df['VE']

IOP Performances:
Injection pressure and Injection timing has major effect on performance parameters. Brake thermal efficiency increases due to in complete combustion of fuel. Maximum fuel consumption is measured at IOP – 190 bar. As IOP increase brake specific fuel consumption increases. Maximum thermal efficiency is measured at IOP – 220bar and Minimum thermal efficiency at IOP – 190bar. Brake specific fuel consumption is measured as minimum at IOP – 190bar and maximum at IOP – 220bar. As IOP increases brake specific fuel consumption decreases. The Performance parameters like brake thermal efficiency increases as IOP increases and mechanical efficiency decreases as IOP increases due to high loads. As IOP increases the Air – fuel mixture is sufficiently compressed, so that less fuel is required to produce same amount of energy. Fuel consumption is reduced at higher IOP between 190 to 220bar. As IOP increases the vibrations decreases. The test results show that the optimum fuel injection pressure is 220 bar with linseed methyl ester with 15lpm of Hydrogen. At this optimized pressure the thermal efficiency is similar to diesel.

Table 4: Optimum-IOP-DB10B20B30B40-Performances

| Diesel | H2 | IOP | IOP(D,B10,B20,B30,B40) | Ampli | BP | BSFC | BTE | ME | VE |
|--------|----|-----|------------------------|-------|----|------|-----|----|----|
| D      | 15 | 190 | 190(D+15)              | 0.5587| 1.7700 | 0.4082 | 15.9600 | 60.1800 | 71.6500 |
| B10    | 10 | 190 | 190(B10+10)            | 0.5538| 1.7700 | 0.4209 | 16.8700 | 46.2800 | 72.4700 |
| B20    | 15 | 190 | 190(B20+15)            | 0.5780| 1.7900 | 0.4107 | 16.0500 | 35.9800 | 71.8900 |
| B30    | 15 | 190 | 190(B30+15)            | 0.65  | 1.79   | 0.42   | 16.33   | 40.01   | 72.05   |
| B40    | 10 | 190 | 190(B40+10)            | 0.7229| 1.7800 | 0.4365 | 16.6000 | 44.0400 | 72.2100 |

Fig 3: Graph showing BEST-IOP-DB10B20B30B40-Performances
Python Code:

```python
# OPTIMUM-IOP-DB10B20B30B40-Performances
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
data = pd.read_excel('F:/udayasri/Datasets-Images-IOP/IOP-Performances/IOP-Performances-Data-Set.xlsx',sheet_name='BEST-IOP-DB10B20B30B40')
idata_df = pd.DataFrame(data)
ID = idata_df['IOP(D,B10,B20,B30,B40)']
IAmpli = idata_df['Ampli']
IBP = idata_df['BP']
IBSFC = idata_df['BSFC']
IBTE= idata_df['BTE']
IME = idata_df['ME']
IVE = idata_df['VE']

Load-Performances:

On the lower sides of loads Brake thermal efficiency increases due to in complete combustion of fuel. Maximum fuel consumption is measured at higher loads – 12kg. As load increase brake specific fuel consumption increases. Maximum thermal efficiency is measured at load – 12kg and Minimum thermal efficiency at 6kg load. Brake specific fuel consumption is measured as minimum at load– 12kg and maximum at load -6kg. As load increases brake specific fuel consumption decreases. The Performance parameters like brake thermal efficiency increases as load increases and mechanical efficiency decreases as load increases due to high loads. As load increases the Air – fuel mixture is sufficiently compressed, so that more fuel is required to produce same amount of energy. Fuel consumption is reduced at lower loads between 6kg to 12kg. As load increases the vibrations decreases.

Table 5: OptimumLoad-DB10B20B30B40-Performances

| Blend | H2 | Load | Load(D,B10,B20,B30,B40) | Ampli | BP    | BSFC  | BTE   | ME    | VE     |
|-------|----|------|-------------------------|-------|-------|-------|-------|-------|--------|
| D     | 15 | 6    | 6(D+15)                 | 0.5587| 1.7700| 0.4082| 15.9600| 60.1800| 71.6500|
| B10   | 10 | 6    | 6(B10+10)               | 0.5538| 1.7700| 0.4209| 16.8700| 46.2800| 72.4700|
| B20   | 10 | 6    | 6(B20+10)               | 0.6623| 1.7700| 0.4450| 16.2500| 44.2000| 72.8700|
| B30   | 10 | 6    | 6(B30+10)               | 0.693 | 1.775 | 0.441 | 16.425 | 44.12  | 72.54  |
| B40   | 10 | 6    | 6(B40+10)               | 0.7229| 1.7800| 0.4365| 16.6000| 44.0400| 72.2100|
**Python Code:**

```python
#OPTIMUM-Load-DB10B20B30B40-Performances
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
data = pd.read_excel('F:/udayasri/Datasets-Images-Load/Load-Performances/Load-Performances-Data-Set.xlsx',sheet_name='BEST-LOAD-DB10B20B30B40')
ldata_df = pd.DataFrame(data)
LD = ldata_df['Load(D,B10,B20,B30,B40)']
LAmpli = ldata_df['Ampli']
LBP = ldata_df['BP']
LBSFC = ldata_df['BSFC']
LBTE = ldata_df['BTE']
LME = ldata_df['ME']
LVE = ldata_df['VE']
```

**Table 6: OPTIMUM-CR-IOP-LOAD-DB10B20B30B40-Performances**

| Diesel | H2  | CR-IOP-Load | CI(L,D,B10,B20,B30,B40) | Ampli | BP   | BSFC | BTE   | ME   | VE   |
|--------|-----|-------------|-------------------------|-------|------|------|-------|------|------|
| D      | 15  | 15          | 15(D+15)                | 0.5587| 1.7700| 0.4082| 15.9600| 60.1800| 71.6500|
| B10    | 15  | 15          | 15(B10+15)              | 0.6878| 1.7700| 0.3140| 22.6700| 49.5700| 71.7800|
| B20    | 15  | 15          | 15(B20+15)              | 0.5780| 1.7900| 0.4107| 16.0500| 35.9800| 71.8900|
| B30    | 10  | 10          | 10(B30+10)              | 0.693 | 1.775 | 0.441 | 16.425 | 44.12  | 72.54  |
| B40    | 5   | 15          | 15(B40+5)               | 0.8883| 1.7800| 0.7244| 11.2000| 41.1800| 72.6800|
| D      | 15  | 190         | 190(D+15)               | 0.5587| 1.7700| 0.4082| 15.9600| 60.1800| 71.6500|
| B10    | 10  | 190         | 190(B10+10)             | 0.5538| 1.7700| 0.4209| 16.8700| 46.2800| 72.4700|
| B20    | 15  | 190         | 190(B20+15)             | 0.5780| 1.7900| 0.4107| 16.0500| 35.9800| 71.8900|
| B30    | 15  | 190         | 190(B30+15)             | 0.65  | 1.79  | 0.42  | 16.33  | 40.01  | 72.05  |
| B40    | 10  | 190         | 190(B40+10)             | 0.7229| 1.7800| 0.4365| 16.6000| 44.0400| 72.2100|
| D      | 15  | 6           | 6(D+15)                 | 0.5587| 1.7700| 0.4082| 15.9600| 60.1800| 71.6500|
| B10    | 10  | 6           | 6(B10+10)               | 0.5538| 1.7700| 0.4209| 16.8700| 46.2800| 72.4700|
| B20    | 10  | 6           | 6(B20+10)               | 0.6623| 1.7700| 0.4450| 16.2500| 44.2000| 72.8700|
| B30    | 10  | 6           | 6(B30+10)               | 0.693 | 1.775 | 0.441 | 16.425 | 44.12  | 72.54  |
| B40    | 10  | 6           | 6(B40+10)               | 0.7229| 1.7800| 0.4365| 16.6000| 44.0400| 72.2100|
Python Code:

```python
# OPTIMUM-CR-IOP-LOAD-DB10B20B30B40-Performances
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec

data = pd.read_excel('F:/udayasri/Datasets-Images-CR/CR-Performances/CR-Performances-Data-Set.xlsx', sheet_name='BEST-CR-IOP-LOAD')
cilpdata_df = pd.DataFrame(data)
CILP = cilpdata_df['CIL(D,B10,B20,B30,B40)']
CILPAmpli = cilpdata_df['Ampli']
CILPB = cilpdata_df['BP']
CILPBSFC = cilpdata_df['BSFC']
CILPTBTE = cilpdata_df['BTE']
CILPM = cilpdata_df['ME']
CILPVE = cilpdata_df['VE']

From table 3 shows the data set for the optimum CR, IOP and at different loads for VCR engine with blend Linseed showed BSFC max at B40 and min at B10, BTE max at B10 and Min at B40, ME max at D and min at B20 and finally VE max at B20 and Min at D. By this it shows the CR performances varies with different blends compared with Diesel and the same showed in graph 2.

From table 4 shows the optimum IOP performances with Max BSFC at B40 and min at B20, BTE max at B10 and min at B20 and similarly ME max at D and min at B30 and VE max at B40 and min at D. the same showed in graph 3. Finally, table 5 shows the optimum load data set shows the variations of BSFC has max at B20 and min at D and BTE max at B10 and min at B20, ME max at D and min at B40 and lastly VE max at B20 and min at B40 the same showed in graph 4. The possible reason for the above behaviour may be the Linseed biodiesel has higher calorific value and also it is less viscous.

Python module is the best programming module to predict the experimental data shown in code-1 the CR-performances. Similarly, codes 2 & 3 shows the IOP and variation of loads in Python module and optimum for CR, IOP and at Load shown in code-4. Python programming codes for various loads and CR performances of BSFC, BP, BTE, ME and VE are generated in table 6 and in graph 5.

4. Conclusion

In current investigation, the performance, load characteristics of direct injection, compression ignition engine fuelled with oil and H and its blends are analysed and compared with diesel oil. The biodiesel is created from oil by a technique of transesterification. The tests properties of biodiesel demonstrate that just about all the necessary properties of biodiesel near with fuel. So the internal-
The combustion engine will perform satisfactorily on linseed oil of H and its blends with fuel. The results of the work area unit summarized as follows:

1. On the lower sides of compression ratios Brake thermal efficiency (BTE) increases due to in complete combustion of fuel.
2. Maximum fuel consumption is measured at compression ratio (-15). As compression ratio’s increase brake specific fuel consumption (BSFC) increases.
3. Maximum thermal efficiency (TE) is measured at compression ratio (-18) and Minimum thermal efficiency. Brake specific fuel consumption is measured as minimum at compression ratio (-18) and maximum at compression ratio (-15). As compression ratio increases brake specific fuel consumption decreases.
4. The Performance parameters like bake thermal efficiency increases as compression ratio increases and mechanical efficiency (ME) decreases as compression ratio increases due to high loads.
5. As compression ratio increases the Air – fuel mixture is sufficiently compressed, so that less fuel is required to produce same amount of energy. Fuel consumption is reduced at higher compression ratios between 15 to 18. As compression ratio increases the vibrations decreases.

From the summarized conclusions we can say, the optimized mix is B20 with relevance performance and combustion characteristics for all masses compared with diesel and it might be feasible fuel in a 4-stroke cylinder injection internal-combustion engine without modifications and thereby we tested constant by victimization python module saving twenty five percent of the diesel fuel.

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