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SPECIFIC FUEL CONSUMPTION TEST ON DIESEL ENGINE WITH VARIOUS TYPES OF FUEL

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Abstract

Diesel fuel has been used as an energy source, and its consumption level is significantly increasing, which can lead to a problem. To solve it, energy conservation with alternative fuels needs to be done. One is biodiesel with waste cooking oil (WCO) as raw material. This type of biodiesel has a low level of oxidation stability. Therefore, a partial hydrogenation (PH) process must be carried out to improve oxidation stability. This alternative fuel was used in an engine performance test using a chassis dynamometer, including torque and power testing. Then, the specific fuel consumption (SFC) was calculated using the torque and power data. The types of fuel used were diesel fuel (D100), a mixture of 90% diesel fuel with 10% biodiesel v/v (B10), a mixture of 80% diesel fuel with 20% biodiesel v/v (B20), a mixture of 70% diesel fuel with 30% biodiesel v/v (B30), a mixture of 90% diesel fuel with biodiesel PH 10% v/v (PH10), a mixture of 80% diesel fuel with biodiesel PH 20% v/v (PH20), and a mixture of 70% diesel fuel with biodiesel PH 30% v/v (PH30). This test was carried out by varying the engine speed from 1700 to 4200 rpm, where the increment interval was 100 rpm. The test results show that the mixture of fuel diesel + biodiesel PH mostly has better torque, power, and specific fuel consumption results than biodiesel.

Keywords: Biodiesel, Power, Partially Hydrogenation, Specific fuel consumption, Torque

1. INTRODUCTION

The transportation and industrial sectors dominate the use of diesel fuel on a large scale, resulting in inevitable environmental pollution. The environmental pollution resulting from the combustion process of diesel fuel produces gas in the form of black smoke [ten Brink et al., 2022] and nitrogen oxides (NO) [Sittichompoo et al., 2022.]. The negative impact of such pollution is the depletion of the ozone layer, which plays an essential role in maintaining the stability of the earth's temperature. Regarding health, smoke generated from diesel combustion can trigger respiratory diseases and even lung cancer. For this reason, many researchers have been conducting studies regarding the more environmentally friendly and harmless diesel fuel alternatives with similar characteristics and usages. One is biodiesel, an alternative fuel for diesel engines with no negative impacts.

Biodiesel can be produced from various ingredients such as vegetable oil [Tshizanga et al., 2017], animal fat [Encinar J. M. et.al., 2021], and algae [Elkelawy, et.al., 2021]. However, using biodiesel from food can cause an imbalance, so the raw material becomes expensive and should not be used. Non-food raw materials for biodiesel include castor oil (jatophra curcas) [Chaudhary et.al., 2019] [Singh, et.al., 2021], rubber seeds [Paul et.al., 2021], tobacco seeds

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[Rajan, et.al., 2021], kapok seeds [Pooja, et.al., 2021] [Udhayakumar, et.al., 2021] as well as food coconut oil [Wirawan, et.al., 2013] and waste cooking oil [Mansir et.al., 2018].

The characteristics of waste cooking oil Biodiesel such as kinematic viscosity, density, flash point, sulfur content, pour point, residual carbon, heating value, water content, and an acid number have values according to the Indonesian National Standard (SNI) [Zainudin, et.al., 2020] for biodiesel fuel in Indonesia. However, the oxidation stability of this biodiesel is still lower than that of diesel fuel due to the number of unsaturated bonds contained in biodiesel (methyl esters). This unsaturated bond has single bonds (mono-unsaturated esters) such as oleic acid and double bonds (poly-unsaturated esters), such as linoleic and linolenic acids [Wei, G et al., 2018]. This oxidation process occurs due to air in the fuel, which produces acids and solids or polymers. Acid content causes corrosion of fuel lines and tanks. Solids or polymers will clog the nozzle and fuel filter. To overcome this problem, adding antioxidants or partial hydrogenation needs to be done. The partial hydrogenation of the biodiesel process is an excellent way to increase oxidation stability by breaking the double bonds [Adu-Mensah, et.al., 2019]. This process has essential variables that influence temperature, stirring, catalyst amount, catalyst selection, hydrogen, and quality of raw materials [Wongjaikham et.al, 2021]. Therefore, partial hydrogenation of biodiesel is expected to optimize the use of biodiesel on engine performance. [Kanth, and Debbarma, 2021] This study aims to determine torque, power, and specific fuel consumption for Diesel engines using various types of fuel. There were seven types of fuel tested: diesel fuel, a mixture of diesel fuel with biodiesel, and a mixture of diesel fuel with partial biodiesel.

2. MATERIALS AND METHODS

2.1 Material

Research materials used diesel fuel, a mixture of 90% diesel fuel and 10% biodiesel (B10), a mixture of 80% diesel fuel and 20% biodiesel (B20), a mixture of 70 % diesel fuel with 30% biodiesel (B30), a mixture of 90% diesel fuel with 10% partially hydrogenated biodiesel (PH10), a mixture of 80% diesel fuel with 20% partially hydrogenated biodiesel (PH20), a mixture of 70% diesel fuel with 30% partially hydrogenated biodiesel (PH30).

2.2 Method

The research method was carried out experimentally with a chassis dynamometer. It is used to test the performance of the diesel engine with the following stages:

1. Ensuring the test equipment is ready, then positioning the test machine in a safe place.
2. The first test used D100. It was then followed by the use of biodiesel B10, B20, B30, PH10, PH20, PH30, respectively.
3. A hose and a measuring cup were prepared to calculate the amount of fuel used by the by-pass method from the fuel tank.
4. The diesel vehicle engine was started first to warm up without a load (idle) for approximately 10 minutes so that the engine would work at normal temperatures

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5. The vehicle was raised on the test equipment (chassis dynamometer).
6. The front wheel of the diesel vehicle was positioned on the roller and the rear wheel on the rear dyno.
7. The right and left sides of the vehicle were tied with belts on the front and rear wheels so that the vehicle was balanced and could increase the grip of the tires on the rollers and increase the safety when testing was carried out.
8. A stopwatch was used to measure the time out of fuel consumption when the engine was running.
9. The engine was started and set to the 4th gear position (the most optimal condition in producing engine performance)
10. The engine was tested to get the torque and power with the spontaneous throttle rotation method
11. The gas pedal of a diesel vehicle was pressed until the engine speed reached the desired speed. The results of these tests were directly recorded on the computer device used for testing.
12. The fuel consumption and the time it took to spend the fuel were observed and recorded.
13. The steps above were repeated for the next fuel change, B10, B20, B30, PH10, PH20, PH30

3. RESULT AND DISCUSSION

3.1. Torque

Torque testing uses Chassis Dynamometer, and the highest value is obtained in diesel fuel with rotation and torque of 1900 rpm and 104.78 ft.lbs respectively. As shown in tables 1 and 2

Table 1: Torque results of diesel fuel and biodiesel mixtures

No	Speed (Rpm)	D100	B10	B20	B30
1	1700	96.75	53.75	41.87	11.81
2	1800	103.94	68.62	81.10	65.26
3	1900	104.78	93.93	101.92	87.99
4	2000	104.18	105.79	108.75	102.96
5	2100	103.32	107.67	108.58	106.42
6	2200	101.84	105.97	106.98	105.38
7	2300	99.82	103.87	105.33	103.68
8	2400	97.54	101.57	103.26	101.85
9	2500	95.24	99.01	100.98	99.86
10	2600	92.91	96.49	98.65	97.88
11	2700	90.46	94.21	96.37	95.93
12	2800	87.89	92.03	94.11	93.82
13	2900	85.38	89.49	91.70	91.46

14	3000	82.97	86.60	89.10	88.89
15	3100	80.23	83.74	86.46	86.03
16	3200	77.37	81.14	83.81	83.06
17	3300	74.95	78.68	81.08	80.38
18	3400	72.34	76.23	78.23	77.65
19	3500	69.35	73.38	74.99	74.39
20	3600	66.41	69.68	71.19	71.10
21	3700	62.98	65.62	67.51	68.09
22	3800	59.51	62.09	64.18	64.99
23	3900	56.10	59.35	61.01	61.80
24	4000	52.71	56.02	57.70	58.36
25	4100	49.24	51.93	53.78	54.57
26	4200	45.06	46.60	49.45	50.79

Table 2: Torque results of partial hydrogenation biodiesel mixtures

No	Speed (Rpm)	PH10	PH20	PH30
1	1700	64.05	26.20	13.78
2	1800	83.49	28.91	53.58
3	1900	101.55	69.13	83.67
4	2000	106.37	92.30	101.23
5	2100	105.77	101.76	105.45
6	2200	104.67	102.46	104.22
7	2300	103.58	100.74	102.44
8	2400	101.98	98.84	100.77
9	2500	99.99	96.75	99.00
10	2600	97.88	94.82	97.14
11	2700	95.77	93.00	95.25
12	2800	93.52	90.93	93.27
13	2900	91.08	88.50	91.01
14	3000	88.65	85.95	88.51
15	3100	86.36	83.56	85.99
16	3200	84.10	81.25	83.45
17	3300	81.64	78.77	80.87
18	3400	78.87	75.99	78.12
19	3500	75.96	73.04	75.01
20	3600	72.90	69.91	71.89
21	3700	69.72	66.40	68.95
22	3800	66.38	62.65	65.65
23	3900	63.00	59.32	62.36
24	4000	59.64	56.17	58.91
25	4100	55.61	52.54	54.76
26	4200	51.25	48.26	50.52

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Combustion of fuel in a diesel engine produces energy. This process begins with the movement of the piston from the top dead Centre (TDC) to the bottom dead Centre (BDC), where air enters through the inlet valve and the outlet valve is closed. Furthermore, the air is compressed through the movement of the piston from BDC to TDC, where the inlet and outlet valves are closed. A few degrees before the piston reaches TDC, the air has a high pressure and temperature, the fuel is sprayed so that the combustion process occurs. This combustion produces an indication pressure that will push the piston to move from TDC to BDC. The outlet and inlet valves are still closed. The thrust movement that occurs between the piston and the crankshaft will produce rotational motion or torque. This torque has to do with acceleration to support the performance of the Diesel engine.

Tables 1 and 2 are processed to obtain the relationship between torque and rotation as shown in Figure 1

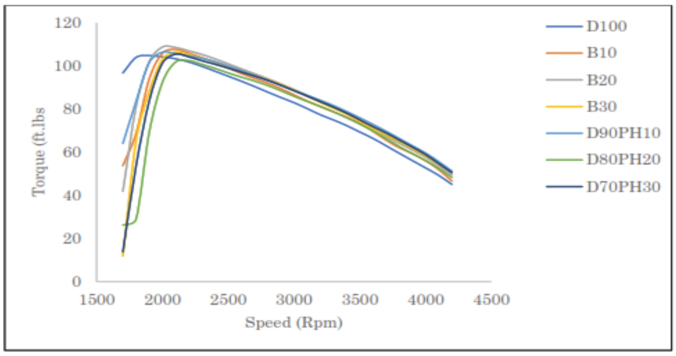

Figure 1: Torque versus rotation speed

3.2. Power

Testing power using diesel fuel oil obtained the highest value at 3000 rpm and power of 47.39 HP each as shown in tables 3 and 4

Table 3: Power results of diesel fuel and biodiesel mixtures

No	Speed (Rpm)	D100	B10	B20	B30
1	1700	31.31	17.40	13.55	3.82
2	1800	35.62	23.52	27.79	22.37
3	1900	37.91	33.98	36.87	31.83
4	2000	39.67	40.28	41.41	39.21
5	2100	41.31	43.05	43.42	42.55
6	2200	42.66	44.39	44.81	44.14
7	2300	43.71	45.49	46.12	45.40
8	2400	44.57	46.41	47.19	46.54
9	2500	45.33	47.13	48.07	47.53
10	2600	46.00	47.77	48.83	48.45
11	2700	46.50	48.43	49.54	49.32
12	2800	46.86	49.06	50.17	50.02

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13	2900	47.15	49.41	50.63	50.50
14	3000	47.39	49.47	50.90	50.77
15	3100	47.36	49.43	51.03	50.78
16	3200	47.14	49.44	51.06	50.61
17	3300	47.09	49.44	50.94	50.50
18	3400	46.83	49.35	50.64	50.27
19	3500	46.22	48.90	49.97	49.57
20	3600	45.52	47.76	48.80	48.73
21	3700	44.37	46.23	47.56	47.97
22	3800	43.06	44.92	46.44	47.02
23	3900	41.66	44.07	45.30	45.89
24	4000	40.14	42.67	43.95	44.45
25	4100	38.44	40.54	41.98	42.60
26	4200	36.04	37.27	39.54	40.61

Table 4: Power results of partial hydrogenation biodiesel mixtures

No	Speed (Rpm)	PH10	PH20	PH30
1	1700	20.73	8.48	4.46
2	1800	28.61	9.91	18.36
3	1900	36.73	25.01	30.27
4	2000	40.51	35.15	38.55
5	2100	42.29	40.69	42.16
6	2200	43.85	42.92	43.66
7	2300	45.36	44.12	44.86
8	2400	46.6	45.17	46.05
9	2500	47.6	46.05	47.12
10	2600	48.46	46.94	48.09
11	2700	49.23	47.81	48.97
12	2800	49.86	48.48	49.73
13	2900	50.29	48.87	50.25
14	3000	50.64	49.1	50.56
15	3100	50.97	49.32	50.76
16	3200	51.24	49.51	50.85
17	3300	51.3	49.49	50.81
18	3400	51.06	49.2	50.57
19	3500	50.62	48.67	49.98
20	3600	49.97	47.92	49.28
21	3700	49.12	46.78	48.57
22	3800	48.03	45.33	47.5
23	3900	46.78	44.05	46.31
24	4000	45.42	42.78	44.87
25	4100	43.41	41.01	42.75
26	4200	40.99	38.59	40.4

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The work compared to the time taken in one Diesel cycle is called the power indicator. This power is obtained from the multiplication of the combustion pressure or the average indicator pressure with the volume of the piston stroke per unit time in one cycle. The power indicator required by the Diesel engine is to overcome the friction between the piston and the cylinder wall and the friction between the shaft and the bearing. In addition, the power indicator must be able to drive several accessories such as a lubricant pump, cooling water pump, movement of the air intake valve and exhaust gas outlet mechanism. So that the resulting shaft power is an indication power minus the power due to friction and accessories

Tables 3 and 4 are processed to obtain the relationship between torque and rotation as shown in Figure 2

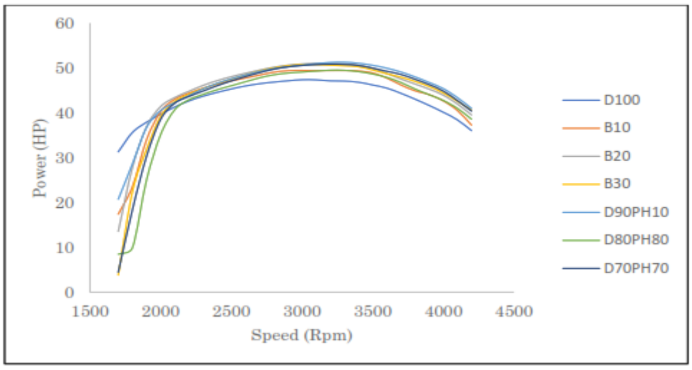

Figure 2: Power versus rotation speed

3.3. Specific Fuel Consumption

Specific Fuel Consumption is a calculation of the amount of fuel used by an engine to produce power per unit time. SFC calculation begins by using the formula

$$m_f = \frac{sgf.V_y.10^{-3}}{t_f}.3600 \ldots (1)$$

Where:

m_f = mass flow rate of fuel (kg/hr)

sgf = spesific gravity (gr/ml)

V_f = volume of fuel (ml)

t_f = the time it takes to run out of fuel (sec)

SFC is calculated by the formula

$$SFC = \frac{m_f}{P}\ (kg/HP.hr) \ldots (2)$$

Where:

P = Power (HP)

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Formula 2 is used to calculate SFC by involving the data in tables 3 and 4. The results of the calculations can be seen in tables 5 and 6

Table 5: Specific Fuel Consumption results of diesel fuel and biodiesel mixtures

No	Speed (rpm)	D100	B10	B20
1	1700	0.2281	0.4375	0.5919
2	1800	0.2005	0.3236	0.2886
3	1900	0.1884	0.2240	0.2175
4	2000	0.1800	0.1890	0.1937
5	2100	0.1729	0.1768	0.1847
6	2200	0.1674	0.1715	0.1790
7	2300	0.1634	0.1673	0.1739
8	2400	0.1602	0.1640	0.1700
9	2500	0.1575	0.1615	0.1669
10	2600	0.1552	0.1593	0.1643
11	2700	0.1536	0.1572	0.1619
12	2800	0.1524	0.1551	0.1599
13	2900	0.1515	0.1541	0.1584
14	3000	0.1507	0.1539	0.1576
15	3100	0.1508	0.1540	0.1572
16	3200	0.1515	0.1540	0.1571
17	3300	0.1516	0.1540	0.1575
18	3400	0.1525	0.1542	0.1584
19	3500	0.1545	0.1557	0.1605
20	3600	0.1569	0.1594	0.1644
21	3700	0.1609	0.1646	0.1686
22	3800	0.1658	0.1694	0.1727
23	3900	0.1714	0.1727	0.1771
24	4000	0.1779	0.1784	0.1825
25	4100	0.1858	0.1878	0.1911
26	4200	0.1981	0.2042	0.2028

Table 6: Specific Fuel Consumption results of partial hydrogenation biodiesel mixtures

No	Speed (rpm)	PH10	PH20	PH30
1	1700	0.3303	1.2408	1.2941
2	1800	0.2393	1.0617	0.3144
3	1900	0.1864	0.4207	0.1907
4	2000	0.1690	0.2993	0.1497
5	2100	0.1619	0.2586	0.1369
6	2200	0.1562	0.2451	0.1322
7	2300	0.1510	0.2385	0.1287
8	2400	0.1469	0.2329	0.1253
9	2500	0.1438	0.2285	0.1225
10	2600	0.1413	0.2242	0.1200

11	2700	0.1391	0.2201	0.1179
12	2800	0.1373	0.2170	0.1161
13	2900	0.1362	0.2153	0.1149
14	3000	0.1352	0.2143	0.1142
15	3100	0.1343	0.2133	0.1137
16	3200	0.1336	0.2125	0.1135
17	3300	0.1335	0.2126	0.1136
18	3400	0.1341	0.2139	0.1141
19	3500	0.1353	0.2162	0.1155
20	3600	0.1370	0.2196	0.1171
21	3700	0.1394	0.2249	0.1188
22	3800	0.1426	0.2321	0.1215
23	3900	0.1464	0.2389	0.1246
24	4000	0.1508	0.2459	0.1286
25	4100	0.1577	0.2566	0.1350
26	4200	0.1670	0.2727	0.1429

Diesel engines require fuel to operate. Of course, fuel plays an important role in the combustion process in the engine. The combustion process in the engine will produce heat which is influenced by the mixture of air and fuel.

Specific fuel consumption (SFC) is a general term which means the ratio of the total fuel consumption to the shaft power generated in an SFC internal combustion engine is also used as a way find out how efficient an internal combustion engine. This SFC can also be used to predict the calorific value of the fuel used for combustion. SFC measurements should be carried out at a constant load for a minimum of two hours. Measurements were made by observing how much fuel was used during the two-hour period of testing.

The data from tables 5 and 6 are processed so that a graph of the relationship of the influence of rotation on the SFC is obtained as shown in Figure 3

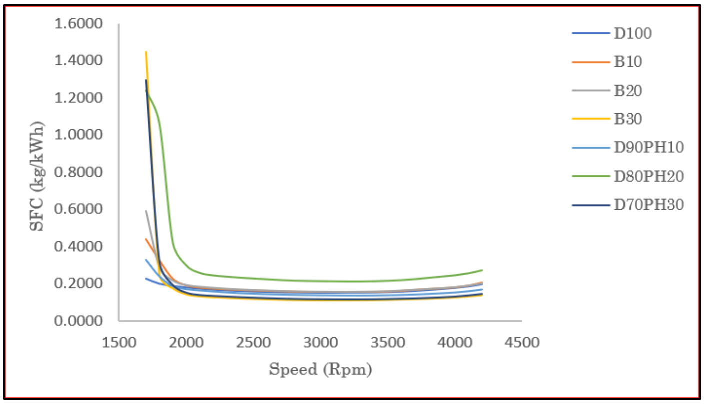

Figure 3: Specific fuel consumption versus rotation speed

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3.4. Mathematic Model

From the experiment on biodiesel mixture, we attempt to establish three mathematical models to predict the torsion, power, and Specific fuel consumption (SFC) with polynomial equation. In the model, the dependence variable (y) will be the torsion, power, and SFC for each model. The independence variables for every model are biodiesel ratio and rotation (X).

For model to predict torsion, the model is written as in Equation 3.

$$f(x) = (-772.2) \times x^4 + 26557.06 \times x^3 - 342212.5 \times x^2 + 1959585.28 \times x - 4206968.35 \ldots\ldots\ldots\ldots(3)$$

$$x_i = \frac{1}{(1 + e^{-a_i})} + \ln(b_i)$$

Where a_i is correspondent to biodiesel ratio in the mixture and b_i is correspondent to rotation (rpm).

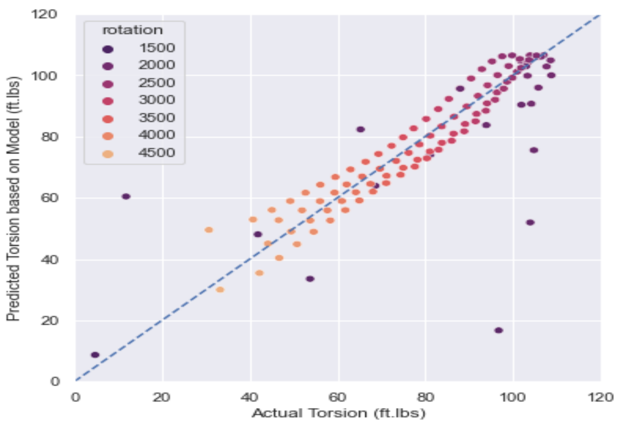

Figure 4: Scatter plot between actual torsion and predicted torsion with biodiesel mixture

The error between actual torsion and predicted torsion is visualized with scatter plot in Figure 4, where the x axis indicates actual torsion, and the y axis indicates predicted torsion. The average error for the model is 17.9%, which is quite vast. However, most of the major errors happen in low rotation per minute. From Figure 4, we annotate some samples of the farther data point as shown in Figure 5. Based on the Figure 5, it is shown that most of the major errors are occurred when the rotation is relatively low below 2000 rpm. For comparison, we find only one data point with rotation above 4000 rpm that has error above 50%. If we take out the data point with rotation below 2000 rpm, we will have average error at 6.8%. Furthermore, if we take out the data point with rotation above 4000 rpm as well, we will have average error at 5.3%.

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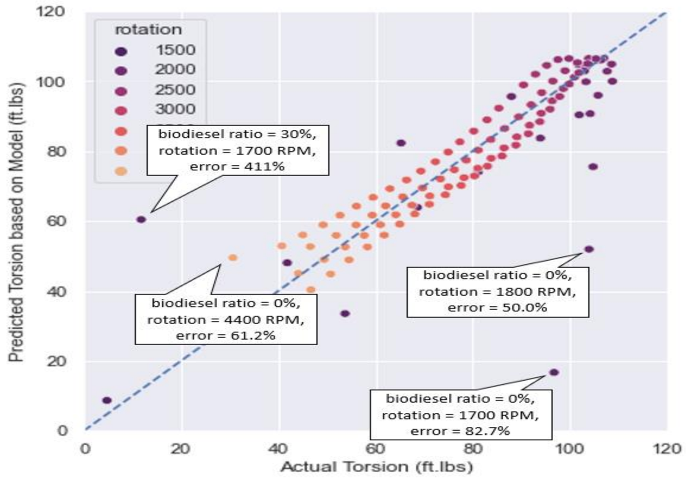

Figure 5: Annotated scatter plot between actual torsion and predicted torsion with biodiesel mixture

The second model for the biodiesel mixture is proposed to predict the power based on the biodiesel ratio and rotation, as written in Equation 4.

$f(x) = (-112.61) \times x^4 + 3859.22 \times x^3 - 49656.74 \times x^2 + 284328.2 \times x - 611206.46$................ (4)

$$x_i = \frac{1}{(1 + e^{-a_i})} + \ln(b_i)$$

Where a_i symbolizes biodiesel ratio in the mixture and b_i symbolizes rotation.

The power predictions obtained from Equation 4 are compared to the actual powers from the prior experiment in Table 3. The comparison is shown in Figure 6.

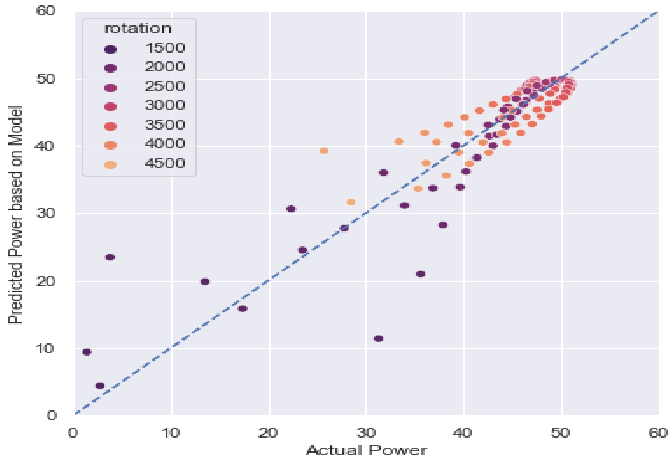

Figure 6: Scatter plot between actual power and predicted power with biodiesel mixture

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Similar to Figure 4 for the torsion, Figure 6 shows that most of the major errors appear when the rotation per minute is around 1500 rpm. There is one major error for the rotation around 4500 rpm. One can say that the model in Equation 3 is optimally predicted the power if the rotation per minute is between 2000 and 4000. This is proved by the declining of average error between actual power and predicted power. The average error for all rotations is 18.6%, whereas the average error for rotations between 2000 and 4000 rpm is 3.7%. This concludes that our models in Equation 3 and Equation 4 are able to accurately predict both for torsion and power regardless of the biodiesel ratio, especially if the rotation per minute is between 2000 rpm and 4000 rpm.

The third model for biodiesel mixture aims to predict the SFC for the biodiesel mixture. Our approach to modelling the SFC is written in Equation 5.

$$f(x) = (-0.27342) \times x^4 + 9.03413 \times x^3 - 111.507 \times x^2 + 609.147 \times x - 1242.00 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$x_i = \frac{1}{(1 + e^{-a_i})} + \ln(b_i)$$

Where a_i symbolizes biodiesel ratio in the mixture and b_i symbolizes rotation.

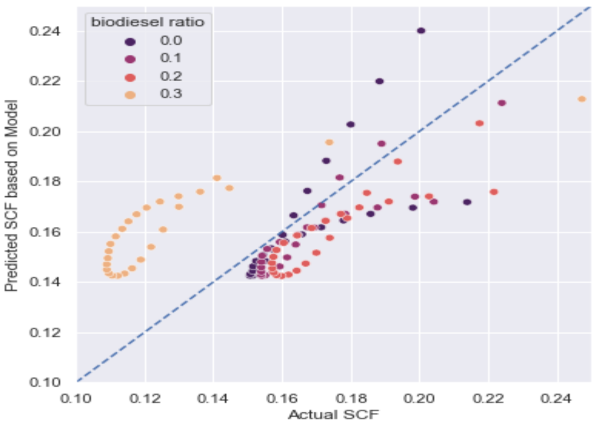

Figure 7: Scatter plot between actual SFC and predicted SFC with biodiesel mixture

The model in Equation 5 to predict SFC based on rotation and biodiesel ratio returns average error of 14.8% in the prediction. However, rather than analysing by the rotation, our finding suggests to analysis based on the biodiesel ratio in mixture, as in Figure 7. It can be seen that the majority errors happen when the 30% biodiesel in mixture incorporated into model. The average error of model drops to 8.6% if the 30% biodiesel ratio is excluded from the model's prediction.

For partial hydrogen, we conduct similar approach to obtain mathematical model for torsion, power, and SFC based on partial hydrogen ratio in the mixture and rotation. The model for predicting torsion in partial hydrogenic mixture is written as in Equation 6.

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$f(x) = (-255.71) \times x^4 + 8931.53 \times x^3 - 117045.76 \times x^2 + 681957.6 \times x - 1490219.28$-----------------(6)

$$x_i = \frac{1}{(1 + e^{-a_i})} + \ln(b_i)$$

Where a_i symbolizes the ratio partial hydrogen in the mixture and b_i correspondent to rotation. The comparison between actual torsion from Table 2 and predicted torsion based on the model in Equation 6 is shown in Figure 8.

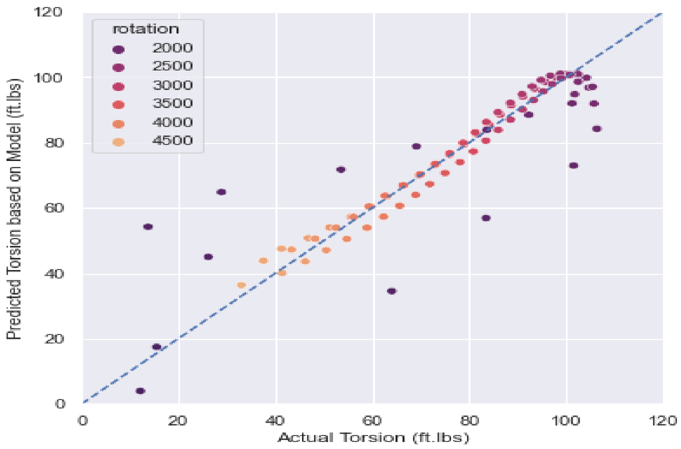

Figure 8: Scatter plot between actual torsion and predicted torsion with partial hydrogen mixture

Model in Equation 6 yields 11.9% average error between actual torsion and predicted torsion. Analogous to prior model of biodiesel mixture, Figure 8 shows that the model vastly miss-predict when the rotation per minute is below 2000 rpm. The average error drops to 4.1% if the rotation below 2000 rpm is overlooked. Moreover, the average error drops to 3.4% if only the rotation between 2000 rpm and 4000 rpm are taken into account.

Equivalently, we obtain model for predicting power in partial hydrogen mixture as written in Equation 7, with a_i symbolizes the ratio partial hydrogen in the mixture and b_i correspondent to rotation.

$f(x) = (-40.254) \times x^4 + 1370.66 \times x^3 - 17600.86 \times x^2 + 101021.74 \times x - 218603.872$…………… (7)

$$x_i = \frac{1}{(1 + e^{-a_i})} + \ln(b_i)$$

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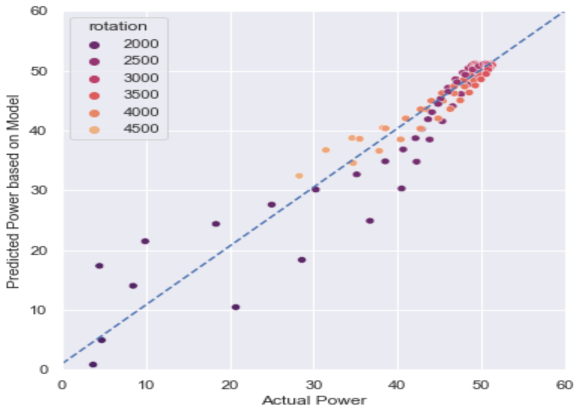

Figure 9: Scatter plot between actual power and predicted power with partial hydrogen mixture

Figure 9. Plots the comparison from actual power in Table 4 and predicted power from Equation 7 for partial hydrogen mixture. The model returns average error of 11.7% if all of the rotations are considered. However much alike prior comparison, the errors drop to 3.5% if only rotations between 2000 rpm and 4000 rpm are considered. This result confirms the previous statement that our approaches for modelling torsion and power, despite the mixture and its corresponding ratio, gives accurate prediction especially for rotations between 2000 and 4000 rpm.

The last model is intended to predict SFC value of partial hydrogen mixture as written in Equation 8. Note that in Equation 8, a_i symbolizes the ratio partial hydrogen in the mixture and b_i correspondent to rotation.

$$f(x) = 3.702 \times x^4 - 127.155 \times x^3 + 1637.29 \times x^2 - 9368.87 \times x + 20101.52 \ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$x_i = \frac{1}{(1 + e^{-a_i})} + \ln(b_i)$$

Contradict from prior equations, the model for predicting SFC value of partial hydrogen yields average error of 29.6%. Even the considered rotations are between 2000 and 4000 rpm, the average error is still at 26.3%. As visualized in Figure 10, it can be seen that the model is decent at predicting when the 10% partial hydrogenic is used in mixture. However, the average error is still at 16.7% even the optimal rotation is used.

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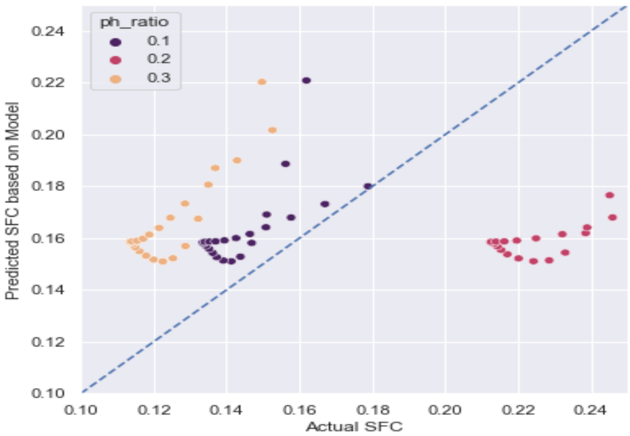

Figure 10: Scatter plot between actual SFC and predicted SFC with partial hydrogen mixture

From the error percentage and visualization in Figure 10, our proposed model in Equation 8 for partial hydrogen mixture is not able to predict accurately.

4. CONCLUSION

At the same volume percentage, where the fuel mixture of partially hydrogenated biodiesel with diesel oil produces a smaller specific fuel consumption value (SFC) than the fuel mixture of biodiesel and diesel oil. However, when compared to diesel oil, it has a higher SFC value.

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