Computational and Experimental Research in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

Engine Performance Testing and Fuel Consumption of Unmanned Aerial Vehicle with Octane Rating Variations

Danartomo Kusumoaji[1,a], Hartono[1], Abdul Rohman[1], Meila Filhasni Yunus[1]

[1]Aeronautical Technology Research Center - National Research and Innovation Agency, Bogor, Indonesia

[a]dana009@brin.go.id

Abstract. *Unmanned aerial vehicles or often known as Drone / UAV are used for various missions, some of which are for aerial photography, monitoring, load testing, spraying fertilizers and so on. The performance of unmanned aircraft is supported by several aspects, one of which is the propulsion or engine of the aircraft. The Aeronautical Technology Research Center, BRIN, Indonesia has several series of unmanned aerial vehicles used for several missions. To support the missions that must be taken by unmanned aircraft, engine performance is one of the important factors for carrying out missions. In this study, engine testing will be carried out to see the performance of the engine by varying the octane rating of the fuel used. This test used an LSU-04 aircraft engine with a 3W-110i B2 engine type with a capacity of 110 cc and a propeller size of 26x8. Engine tests were carried out using 3 types of fuel with octane ratings of 92, 95 and 98. The data taken is engine speed data (rpm), thrust data and fuel consumption data. Tests and measurements were carried out at the highest rpm value of 6000 rpm and the test was carried out for 1 hour. From the test results, the results were obtained that the performance of the engine that has the largest thrust value is the one that uses fuel with an octane rating of 92, namely with a thrust value of 14.13 kgf, while the thrust value for fuel with an octane rating of 95 is 13.35 kgf, and the thrust produced in fuel with an octane rating of 98 is 13.06 kgf. Then from the results of measuring fuel consumption, the most economical value is an engine that uses fuel with an octane rating of 98, which consumes 1007 ml of fuel, while for fuel consumption with an octane value of 95 of 1028 ml and for an octane value of 92 of 1061 ml.*

Keywords: UAV, 3W-110i B2 Engine, 92 Octane, 95 Octane, 98 Octane, Engine Performance

Introduction

Unmanned aerial vehicles or often known as Drone / UAV have experienced very rapid development. Following the regulations on the definition of Unmanned Aircraft (PTTA/UAS/UAV) is a flying machine that functions with remote control by the pilot or is able to control itself using aerodynamic laws [1]. Rapid development is followed by massive utilization as well. According to [2] the use of UAVs is separated into 2 groups, the first is civilian needs (aerial photography, agriculture, monitoring illegal goods, fish theft, pollution monitoring, agrarian utilization, searching for disaster victims etc.) and military needs (enemy monitoring, electronic intelligence, airspace security, etc.). This utilization grows in line with the development of the producer sector, hobby communities, and research bodies to the UAV commercialization sector. Based on the study [3], the commercial population of drones in August 2021 increased 30% from the previous year of 60,000 units to 90,000. While in the industrial sector, the population is at 5,000 to 10,000 units. The rapid growth of the UAV population is due to its relatively affordable price and can be purchased freely in the market [4].

With the increase in users and utilization of UAVs, it is necessary to be supported by increasing pilot capabilities by following pilot certification as users [5] and checking optimal UAV performance to avoid UAV accidents such as those that occurred in South Carolina United States [6], Palembang [7] and Central Jakarta [8]. To support the missions that must be taken by UAVs, engine performance is one of the important factors to carry out the mission. Engine performance is influenced by several factors, including the size of engine capacity, compression number, temperature and air pressure around it, combustion process, and fuel quality [9]. To get optimal engine performance, testing of the fuel used is needed. The use of improper fuel can make the engine combustion chamber dirty faster so that it can reduce engine performance and engine age.

Aviation Technology Research Center (PRTP) – BRIN has several series of unmanned aircraft used for several missions. According to [10] [11] the series that have been developed by PRTP-BRIN include LSU 01, LSU 02, LSU 02 NGLD, LSU 03, LSU 05 and LSU 05-NG variants. Based on [12] the engine used in LSU 01 is an electromotor type, while LSU 02 to LSU 05 uses a piston engine as the drive. Piston engines work by converting energy from a mixture of fuel and oxygen into kinetic energy which is used to rotate the shaft so that the propeller rotates [14]. The engine that is more commonly used in UAVs is the type of 2 stroke (step) than 4 stroke because it has the advantages of being lighter, higher Power to Weight ratio and has a better Specific Propulsive Energy Density (SPED) value [13].

With this background, research was carried out on fuel with the right octane variation for LSU so that performance becomes optimal. This test used an LSU-04 aircraft engine with a 3W-110i B2 engine type with a capacity of 110 cc and a propeller size of 26x8. Based on specifications [15], the 3W-110i B2 engine is a 2-stroke pusher type piston engine with a cylinder combustion chamber capacity of 110 cc capable of producing power of 12.8 HP or equivalent to 9.4 KW. This engine has a light weight of around 3050 gr and is able to work with a speed range of 1200-8500 rpm. Ignition can be operated with a voltage of 6V-8.4V. Ignition on the engine already uses a microprocessor so that it can be operated easily and precisely.

Similar studies on the effect of octane differences in fuel on the performance of 4-stroke engines in motor vehicles have been widely conducted, but very few tests have been conducted on unmanned aircraft. Most studies use experimental methods. The study [16] has conducted research on the effect of octane rating of 95 octane and 97 octane fuel on the performance of Mitsubishi 4G92 4 stroke engines. Research shows that 95 octane fuel shows an average torque, power and pressure of 4.4% greater than using 97 octane fuel. Based on research [17] torque and power to rpm rotation shown by 110cc 4 stroke engine that uses a higher octane rating produces a better trend. Meanwhile, the study [18] examined the performance of Yamaha 110cc engines using 90 octane and 92 octane fuel. This study shows that peak torque and peak power are highest produced by 90-octane fuel. Further recent research [19] regarding the effect of octane number on performance and exhaust emissions in 150cc Honda engines using 90, 92 and 98 octane fuel. This study concluded that 90 octane produces torque and effective power stably compared to other octane fuels. Octane 92 has an effect on increasing torque to be more powerful. While effective power, specific fuel consumption, and maximum thermal efficiency are using 98 octane.

Furthermore, research on testing engine performance and fuel consumption of unmanned aircraft with octane variations was carried out by referring to previous research. The method used in this study also refers to the research above, which uses experimental methods. Engine tests were

Computational and Experimental Research
in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

carried out using 3 types of fuel with octane ratings of 92, 95 and 98. The data taken are engine power data (rpm), thrust data (kgf) and fuel consumption (ml). The tests and measurements were carried out at the highest rpm value of 6000 rpm and the test was carried out for 1 hour. The results will be discussed in the next section. The purpose of this study is in addition to finding the right type of fuel, this research can also add to the treasures of 2-stroke engine research which is still very minimal.

Theoretical Background

In this test, it is necessary to pay attention to the maximum engine rotation capacity so that it remains within safe limits when operating the engine. Then the octane number of the fuel and the choice of propeller type also need to be adjusted to the recommendations of the engine manufacturer in order to maintain good engine performance. Measuring equipment and data collection tools must also be ensured to be functioning normally. Before operating the engine, first ensure that the fuel flow is not blocked or spilled and that the fuel is placed in a safe position. Once everything is confirmed to be safe to operate, the next step is to operate the engine. When the engine is operational, the thrust force measuring device, namely the digital force gauge, will display how much thrust is produced, then the digital tachometer will show the engine rotation value and the digital scale will show the fuel weight figure. The function of the remote control is to move the servo connected to the throttle so that it can regulate the desired amount of power**.** The thrust of an aircraft is generated from the performance of the engine and propeller where the engine will rotate the propeller and the propeller will produce thrust. The cross-sectional shape of the propeller is similar to the cross-sectional shape of a wing, which is called an airfoil. The wings on an airplane will produce lift, while the propeller on the engine will produce thrust. This thrust can be described with an lift equation sourced from NASA :

$$L \text{ or } T = Cl \text{ or } Ct \times r \times \frac{V^2}{2} \times A \tag{1}$$

Where :

L or *T* = Lift or Thrust (KgF)
Cl or *Ct* = Coefficient Lift or Coefficient Thrust
R = Air density (Kg/m^3)
A = Wing or Propeller surface area (m^2)
V = Speed from engine performance (m/s)

Materials and Methods

Testing Methods, Procedure Conditions and Tools

The method used in the study is by experimental testing, namely by directly testing the performance changes that occur in the engine on the influence of octane number variations. This activity took place at the Propulsion Laboratory of the Aeronautical Technology Research Center – BRIN.

Computational and Experimental Research
in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

The tools used in the test are as follows:

1. UAV Engine

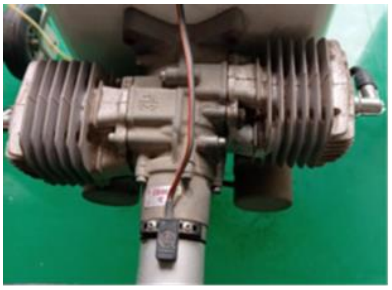

Figure 1. Engine 3W – 110i B2

2. Digital Force Gauge

Figure 2. HP 500 Digital Force Gauge

3. Digital Tachometer

Figure 3. Digital Tachometer HT-5500

Computational and Experimental Research
in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

4. Remote Controller

Figure 4. Remote Controller JR XG7 7-Channel 2.4GHz DMSS Transmitter

5. Digital Scale

Figure 5. Digital Scale CHQ Jzc-TSE 06

6. Propeller

Figure 6. Propeller 26x8

7. Fuel

(a) (b) (c)

Figure 7. Fuel (a) 92 Octane, (b) 95 Octane, (c) 98 Octane

Computational and Experimental Research in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

For testing and data collection procedures carried out can be seen in Figure 8 below. Based on Figure 8 it can be explained that the test begins with searching for related references, next step is prepare fuel with the same quantity size. The third is variance rpm testing. During testing, testing will be carried out with variable rpm (up and down). The lowest limit starts from 1500 rpm to the upper limit of 6000 rpm in increments every 500 rpm. After reaching the upper limit, it will be lowered in multiples of 500 rpm to reach the lowest limit of 1500 rpm. Each increase and decrease of 500 rpm will be tested for 1 minute. The step before will be carried out as many as 5 sets, each set of which is increase and decrease in rpm from the upper limit to the lower limit and vice versa. The test result data of each set will be recorded. The data recorded is rpm, fuel consumption and thrust. After the data is obtained, the data will be analyzed based on the average value of rpm value, thrust produced and fuel consumption per each octane of fuel.

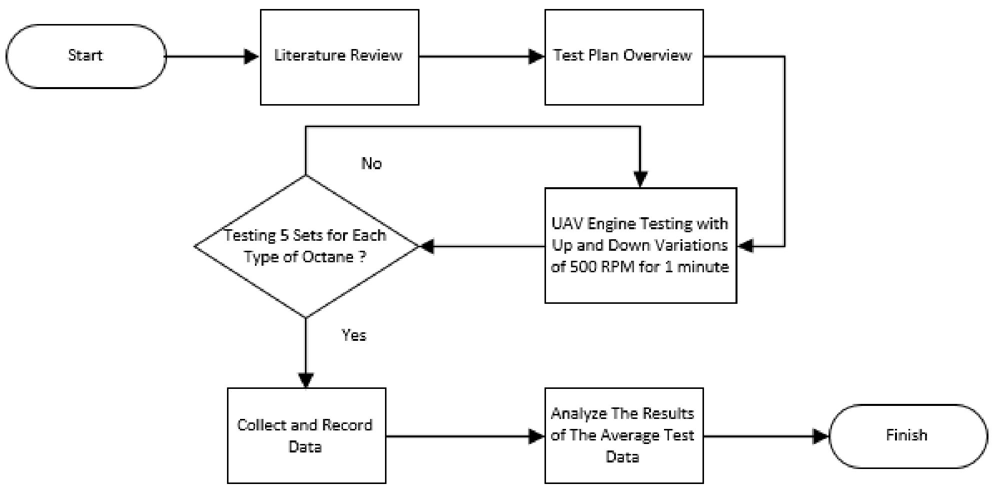

Figure 8. Flowchart Testing Procedure

Results and Discussion

After testing engine performance with varying octane and increasing and decreasing rpm by 5 sets, the test result data will be processed and presented in the form of tables and graphs. The data to be presented is the average data of rpm and thrust. The average value is taken by adding up the total value of each rpm and thrust data then divided by the amount of data [20]. While the data presented for fuel consumption is total fuel consumption data from a total test of 5 sets of each octane of fuel.

Engine Power (rpm) Versus Thrust (kgf) Data

From the data Table 1 below shows the engine power values that are not even in accordance with the initial number determination because the measuring values on the tachometer show unstable numbers. This may be caused by unstable engine speed at the specified number. For example, the engine power value of 1478rpm in the table above is the engine power value which was initially determined at 1500rpm, but due to engine speed that is not always stable, the tachometer shows a variable number so that in the record the value of the observation results is done by taking the average.

Table 1. Engine Power vs Thrust Average

Engine Power Average (rpm)	Thrust Average (kgf)		
	92 Octane	95 Octane	98 Octane
1478	0.91	0.86	0.81
2071	1.22	1.17	1.12
2526	2.52	2.49	2.12
2988	3.31	2.77	2.46
3482	5.54	4.65	4.33
3980	7.63	6.79	6.42
4529	8.33	7.93	7.16
5021	9.12	8.66	7.92
5334	11.47	10.55	10.42
5918	14.13	13.35	13.06

Data Table 1 above showed information that the average of engine power peak of 5918rpm by 92 octane produced the highest thrust value compared to other fuels of 14.13 kgf. While the 95 octane showed the thrust value of 13.35 kgf. For the 98 octane resulted the thrust value of 13.06 kgf. The difference in the thrust produced by engine power with certain octane fuels is caused by adjustments to fuel combustion to the engine specifications used. Each engine has a minimum standard of fuel used. Based on [15], the 3W-110iB2 engine has a minimum standard of 92 octane. While fuel with octane variations is designed with characteristics able to withstand knocking to the temperature and duration of ea”h. T’e existence of this knocking causes engine compression and ignition points that are less than optimal so that the impact on the thrust produced becomes less because only some of the fuel and air are burned.

From the graph shown in Figure 9 it can be seen that the graph in blue line is of 92 octane, red is the graph of 95 octane and green is the graph of 98 octane. When viewed from the movement (trend) of the chart above, the highest thrust value is always indicated by a blue line. The value of the difference in the ratio of each fuel begins to be clearly seen when the engine is at an average rpm value of 2988. This suggests 92-octane fuel is more effective for 3W-110iB2 engines.

Computational and Experimental Research in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

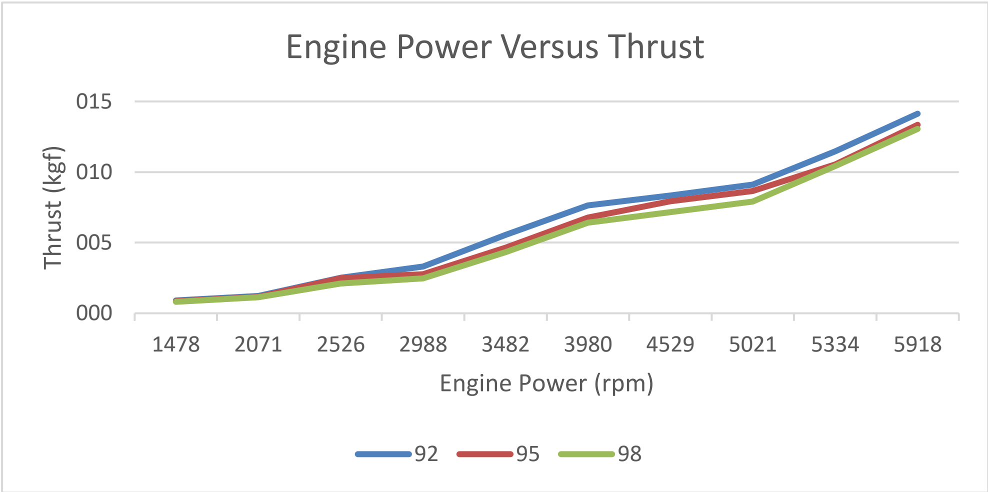

Figure 9. Engine Power vs Thrust Comparison

Fuel Consumption Data

From Table 2 and the graph in Figure 10 show that the highest fuel consumption is produced by 92-octane fuel with a total consumption of 1061 ml. As for the lowest fuel consumption is 98 octane fuel with a total consumption of 1007 ml. This is because the average thrust produced by 92-octane fuel is higher than 98-octane fuel. This is because the average thrust produced by 92-octane fuel is higher than 98-octane fuel. It can be concluded that the thrust produced is directly proportional to fuel consumption. It can be concluded that the thrust produced is directly proportional to fuel consumption.

Table 2. Average Fuel Consumption Data

Octane	Total *Fuel Consumption* Fuel (ml)
92	1061
95	1028
98	1007

Computational and Experimental Research in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

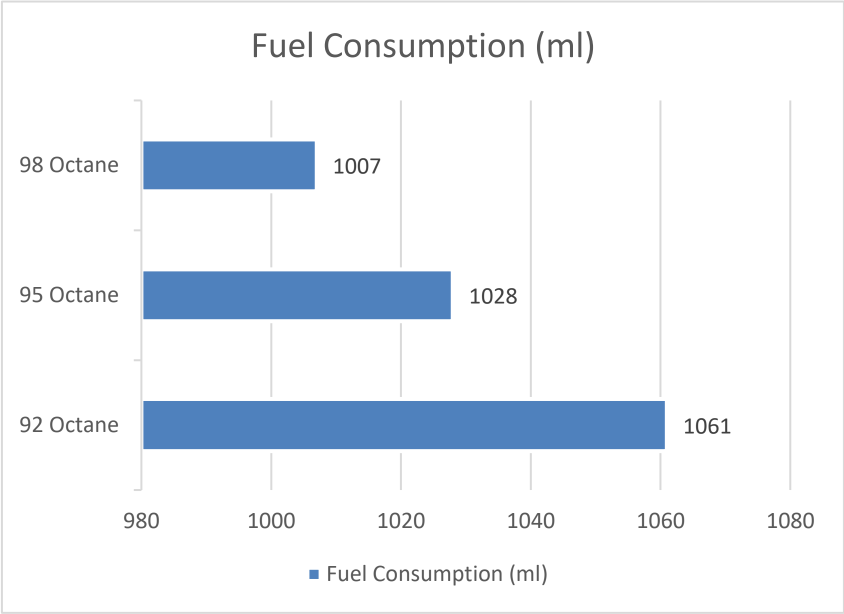

Figure 10. Fuel Consumption

Conclusions

Based on the testing and analysis of the above data regarding testing engine performance and fuel consumption of unmanned aircraft with octane rating variations, it can be concluded that: The average thrust value at peak rpm of 5918 rpm produced from 92 octane rated fuel produces the highest thrust value compared to other fuels of 14.13 kgf. While the 95 octane value fuel produces a thrust value of 13.35 kgf and an octane value of 98 produces a thrust value of 13.06 kgf. Thrust value the largest produced is at peak rpm at rpm 5918. The largest thrust value is produced from fuel with an octane rating of 92 which is 14.13 kgf. The smallest thrust value is produced from fuel with an octane rating of 98 which is 13.06 kgf. The highest fuel consumption is produced by 92-octane fuel with a total consumption of 1061 ml. As for the lowest fuel consumption is 98 octane fuel with a total consumption of 1007 ml. For fuel consumption on 95-octane fuel produces a consumption value of 1028 ml. Based on rpm data, thrust generated and fuel consumption, the most effective fuel for unmanned aircraft, especially LSU 04 with 3W-110iB2 engines, is to use 92 octane rated fuel.

ACKNOWLEDGEMENTS
The author would like to thank Dr. Fadilah Hasim as Head of the Aeronautical Technology Research Center – BRIN for providing support in the form of facilities and opportunities to conduct research. Then the author would like to thank Ir. Atik Bintoro, M.T and Farohaji, PhD who helped and guidance the process of this research.

Computational and Experimental Research
in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

References

[1] Transportation Ministry Regulation No. 33 of 2022 on Concerning Civil Aviation Safety Regulations Part 119 Concerning Aircraft Operation Certification for Air Transport Activities.

[2] Reg Austin, Unmanned Aircraft Systems UAVS Design, Development and Deployment (1st ed), UK: John Wiley & Son, Ltd, 2010.

[3] ASSTA, 2023, https://astta.id/2022/11/24/outlook-industri-drone-indonesia-2023/ (Access on 15 August 2023).

[4] Hartzog, W., & Selinger, E, Surveillance as Loss of Obscurity, Washington and Lee Law Review, 72(3), 1343–1387, 2015, https://scholarlycommons.law.wlu.edu/wlulr/vol72/iss3/10 (Access on 15 August 2023).

[5] Respati, R.E., & Irwansyah, I, "Smart Flight" as a Form of Drone Pilot Training by Bogor Indonesia Drone Forces, Journal of Communication, 14(1), 1-14, 2020.

[6] Septania, R. C, Helicopter Crashes into Tree and Crashes after Avoiding Drones, 2018, https://tekno.kompas.com/read/2018/02/19/19030047/helikopter-tabrakpohon-dan-jatuh-setelah-hindaridrone (Access on 15 August 2023) .

[7] Yayan, A Drone Accident Occurred when Palembang Residents Witnessed a Solar Eclipse, 2016, http://www.harianindo.com/2016/03/09/89035/kecelakaan-drone-terjadiketika-warga-palembang-saksikangerhana-matahari/ (Access on 15 August 2023).

[8] Grace, M. A, The Drone Secured in the BCA Tower Opened, Containing Footage of Vital Object Areas, 2015, https://news.detik.com/berita/d2982635/drone-yang-diamankan-dimenara-bca-dibuka-isinya-rekamanarea-objek-vital (Access on 15 August 2023).

[9] Simanjuntak, D, "Experimental Test Between Pertamak and Pertalite Fuel on the Effect of 4-Stroke Motor Engine Performance", Journal of Mechanical Engineering, 4(2), 2017.

[10] Rohman, A., Aziz, A., Muzayadah, N. L., Aji, D. K., & Luqman, R, Kajian Perencanaan Sertifikasi Militer Pesawat Tanpa Awak LSU-05NG dengan Metode WBS dan CPM, In Seminar Nasional Kebijakan Penerbangan dan Antariksa IV (SINAS KPA-IV), pp. 45-57, 2019.

[11] Aziz, A., Rohman, A., & Rismayanti, I, Implementasi Metodologi PERT pada Rancang Bangun Pesawat LSU 05-NG, *Prosiding Seminar Nasional Kebijakan Penerbangan dan Antariksa IV* (SINAS KPA-IV), pp. 18-32, 2019.

[12] Annual Report, Pustekbang LAPAN, Indonesia, 2013.

[13] Agus Bayu Utama, "Effect of Fuel Consumption of Lapan Surveillance Uav (Lsu-02) Aircraft Propulsion Engines in the Determination of Fuel Flow Sensors",

Computational and Experimental Research in Materials and Renewable Energy (CERiMRE)
Volume 6, Issue 2, page 61-71
eISSN : 2747-173X

Submitted : October 14, 2023
Accepted : November 12, 2023
Online : November 30, 2023
DOI : 10.19184/cerimre.v6i2.43757

Potpourri of R&D Results: Technology on Aircraft, Rockets, and Satellites, 148-153, 2015.

[14] David F Anderson &; Scott Eberhardt, “Understanding Flight”, Second Edition, Mc. Graw Hill Int Book, US, 2010.

[15] Annex A 3W-110iB2, 2017, https://3w-modellmotoren.de/wp-content/uploads/2016/11/3W-110iB2-CS-Annex-A-tech.-details-EN-Rev-4_2016.pdf (Access on 15 August 2023).

[16] Muhammad, T. I., “Part-Load Performance and Emissions of a Spark Ignition Engine Fueled with Ron95 and Ron97 Gasoline: Technical Viewpoint on Malaysia's Fuel Price Debate”, Energy Convertion and Management 88, pp. 928-935, 2014.

[17] Purnomo's Good Trio, “Performance Differences between Premium 88 Motorcycles and Pertamax 92 Motorcycles”, UNS, Semarang, 2013.

[18] Nizar, B.W, “Analysis of Fuel Variations on the Performance of a 4-stroke Gasoline Motor”, UMS, Surakarta, 2016.

[19] Muhammad, B.A,Laduni, Ena Marlina, Nur Robbi, “The Effect of Octane Number on Performance and Exhaust Emissions of Honda New Mega Pro 150 CC”, Islamic University of Malang, 2022.

[20] Sekaran, U, & Bougie, R.J, Research Methods for Business: A skill Building Approach, 7th Edition, John Wiley & Sons Inc, New York, US, 2016.

[21] Benson, T, The Lift Equation, Glenn Research Center-NASA. https://www.grc.nasa.gov/WWW/k12/VirtualAero/BottleRocket/airplane/lifteq.html (Access on 16 November 2023).