Journal of Science Technology (JoSTec)

Published by: Inovasi Pratama Internasional. Ltd
Journal homepage: https://ejournal.ipinternasional.com/index.php/jostec
DOI: https://doi.org/10.55299/jostec.v5i1.478

Impact of the fuel mixture ratio of AVGAS 100LL and RON 92 fuel on combustion characteristics

Sabam Danny Sulung[1], Daniel Dewantoro Rumani[2], Ikhwanul Qiram[3], Muhammad Nur Cahyo Hidayat Nasrullah[4], Untung Lestari Nur Wibowo[5]

[1,2,4,5]Indonesian Aviator Academy – Banyuwangi, Indonesia
[3]Department of Mechanical Engineering, PGRI Banyuwangi University, Indonesia

ARTICLE INFO

Article history:

Received July 07, 2023
Revised July 26, 2023
Accepted August 10, 2023

Keywords:

Bunsen burner
AVGAS 100 LL
Aviation gasoline
Cessna 172S
Lycoming engine

ABSTRACT

AVGAS 100LL is an aviation fuel used in piston engine aircraft, particularly in training aircraft such as the Cessna 172S with Lycoming engines. The use of lead in this fuel can have various health-related concerns. Therefore, reducing the use of leaded fuel has become a solution to address these issues. This study aimed to investigate the combustion characteristics of AVGAS fuels, including AVGAS 100%, AVGAS 75% + PERTAMAX 25%, and AVGAS 50% + PERTAMAX 50%. The research involved conducting combustion tests using a Bunsen burner. The results showed that the addition of PERTAMAX to AVGAS significantly influenced the temperature, color, flame height, and flame area produced. The temperature values were higher for AVGAS 100% compared to AVGAS mixed with PERTAMAX. On the other hand, the flame height and flame area were lower for AVGAS 100% compared to the blended fuels. These findings indicate that the addition of PERTAMAX affects the combustion characteristics of AVGAS fuels. Further studies are recommended to explore and expand our understanding of the effects of blending AVGAS with alternative fuels.

Corresponding Author:

Ikhwanul Qiram,
Department of Mechanical Engineering,
PGRI Banyuwangi University,
Jl. Ikan Tongkol No.22, Kertosari,
Banyuwangi District, Banyuwangi Regency, East Java 68416.
Email: ikhwanulqiram@gmail.com

1. INTRODUCTION

The fuel used in piston-powered aircraft is known as Aviation gasoline (AVGAS), which is commonly used for flight training and crop spraying. Piston engines in aircraft operate under higher performance requirements compared to spark-ignition engines in cars (Bishop & Elvers, 2021). AVGAS is a specialized fuel designed to meet the needs of aircraft engines and has characteristics that prevent detonation, a condition that can potentially jeopardize flight safety and operational reliability (Ershov et al., 2021). In this case, AVGAS utilizes a special additive known as TEL or tetraethyl lead. This additive has proven effective in addressing knocking issues in aircraft engines (Kumar et al., 2019). The function of TEL is to help suppress knocking, which generates very high pressures within the engine and can cause severe damage. Without TEL, the octane rating of the fuel would be too low to meet aircraft requirements. Therefore, using fuel with a lower octane rating than required can increase the risk of engine failure in delivering the necessary power for the aircraft (Kumar et al., 2020). One common type of AVGAS used in general aviation is AVGAS 100 LL. This AVGAS meets the standard requirements of ASTM D910 or DEF STAN 91-90 (Karakoç et al., 2018).

While AVGAS plays a crucial role as an additive to prevent knocking in piston aircraft engines, it has significant environmental implications, particularly concerning its impact on human health. AVGAS 100 LL contains lead, which can enter the human body through inhalation and cause various health problems (Kumar et al., 2018). Exposure to lead in the bloodstream can be a risk factor for cancer in adults. Additionally, its impact on children can lead to decreased intelligence quotient (IQ) levels and academic impairments when accumulated over time. Apart from environmental and health factors, economic considerations also contribute to the reduction in AVGAS 100 LL usage (Shiek et al., 2021). The price of AVGAS 100 LL tends to be higher compared to MOGAS (motor gasoline) used for motor vehicles. Therefore, blending AVGAS and MOGAS before filling the aircraft's fuel tank becomes an alternative to reduce costs in flight training. Now, what are the actual impacts when blending AVGAS and MOGAS fuels?. This research aims to experimentally investigate the flame characteristics of AVGAS and MOGAS blend, specifically using PERTAMAX fuel with an RON 92 rating produced by Pertamina Indonesia. The research process will be conducted using the Bunsen burner method (Cai et al., 2020). Several tests have been conducted to understand the combustion flame characteristics of aviation fuels in order to find alternative fuels that can approximate the qualifications of existing aviation fuels (Hui et al., 2012; Hwang et al., 2020). Therefore, by understanding the characteristics of the blended fuel between AVGAS and MOGAS, it is expected to determine a comparison between the blend and pure AVGAS.

2. RESEARCH METHOD

2.1 Thinking Framework

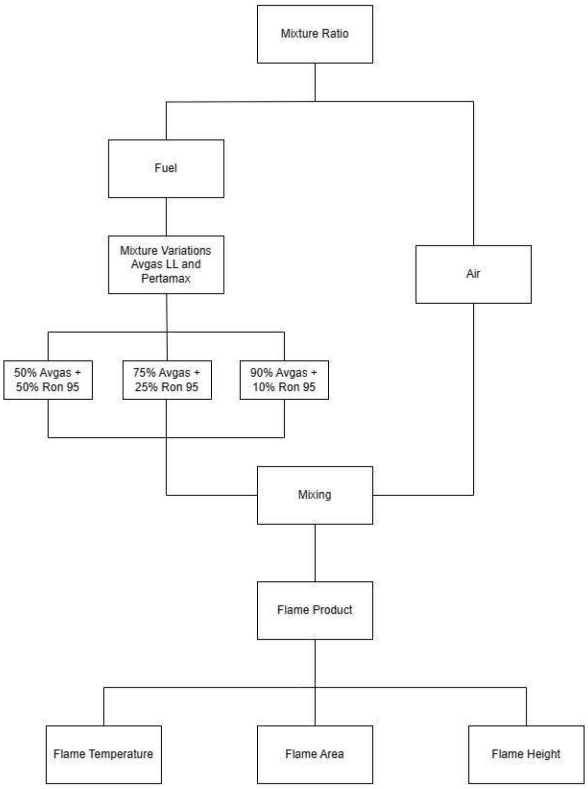

Fig. 1. Thinking Framework.

This research utilizes an experimental method. Visual data is obtained by conducting tests and recorded using a camera. The collected data is then analyzed using image analysis software, such as ImageJ, and processed to provide insights into the observed phenomena through the creation of tables and graphs using Microsoft Excel. Temperature measurements are obtained using a type-K thermocouple. The visualization of flame patterns and flame color is achieved by extracting frames from recorded videos using a video converter, enabling a frame-by-frame comparison during the discussion and analysis phase.

2.2. Pengujian Temperatur Api

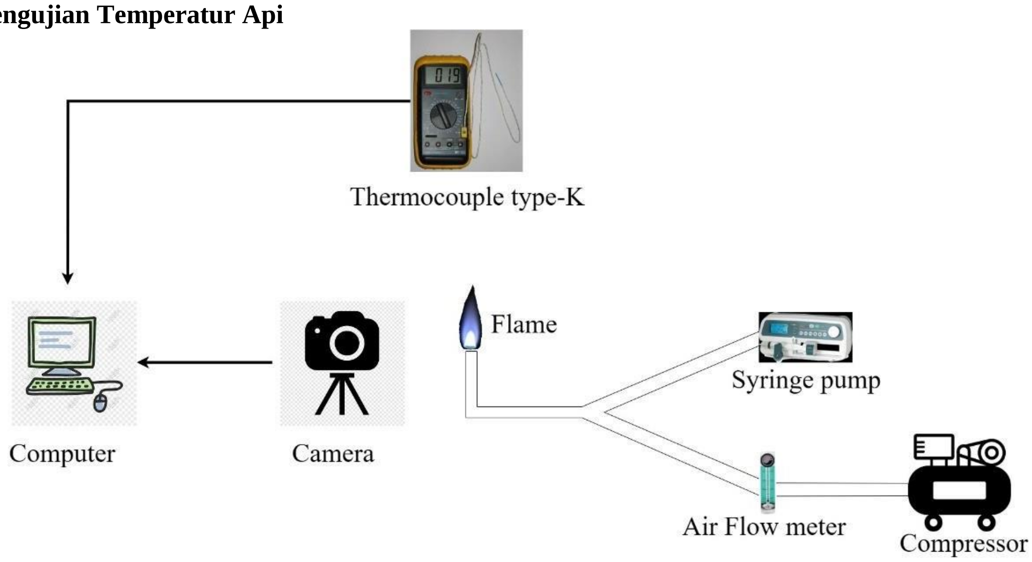

Fig. 2. Schematic diagram of the experimental set-up.

In this research, the temperature measurement was carried out using a reliable and widely used method known as the type-K thermocouple. The thermocouple, a device consisting of two dissimilar metal wires, was carefully positioned in the vicinity of the flame to accurately capture the temperature variations. Prior to data collection, the experimental setup was carefully calibrated to ensure accurate readings. To prepare for the measurements, the syringe pump, responsible for controlling the fuel flow rate, was precisely adjusted based on the predetermined values established in the experimental design. This meticulous calibration process aimed to achieve a consistent and controlled fuel-air mixture, which is crucial for obtaining reliable and reproducible temperature data.

After adjusting the syringe pump, a waiting period of 5 minutes was observed to allow the flame to stabilize. This waiting period ensured that any transient effects or fluctuations in the flame were minimized, and a steady-state condition was reached. By ensuring a stable flame, the subsequent temperature measurements could be conducted under consistent conditions, reducing the potential for errors or inconsistencies in the data. Once the flame reached a steady state, temperature measurements were performed at multiple points of interest. These points included the flame envelope, the flame tip, and the midpoint of the flame. By capturing temperature data at these distinct locations, a comprehensive understanding of the flame characteristics and temperature distribution could be obtained. Throughout the data collection process, strict attention was given to maintaining the accuracy and reliability of the temperature measurements. Proper positioning and alignment of the thermocouple, along with careful handling of the experimental apparatus, were ensured to minimize any potential sources of error or interference. Overall, the meticulous approach taken in the temperature measurement process aimed to provide reliable and precise data, facilitating a comprehensive analysis of the combustion characteristics and temperature profiles in the experimental setup.

2.3. Pengambilan data tinggi, lebar dan luas api.

In this study, the visualization of the flame was captured using a high-speed camera recording at 60 frames per second (fps). The recorded video footage was subsequently processed using a video cutter tool to extract seven distinct frames representing different layers of the flame. These frames were carefully selected to provide a comprehensive representation of the flame structure and dynamics. Once the frames were obtained, further analysis was conducted to measure the dimensions of the flame, including its height, width, and area. This involved carefully assessing each frame and employing appropriate measurement techniques to ensure accuracy. The obtained measurements were then recorded and entered into Microsoft Excel for further data analysis and visualization. To facilitate a detailed understanding of the flame characteristics, separate graphs were created using the measured dimensions. Each graph presented the variation of a specific dimension (height, width, or area) across the different frames, allowing for a comprehensive assessment of the flame's spatial characteristics and changes over time.

By employing this systematic approach to data visualization and analysis, a detailed understanding of the flame's dimensions and their variations could be achieved. This information is vital for gaining insights into the flame structure and dynamics, contributing to a comprehensive assessment of the combustion process under investigation.Data visualisasi api yang telah direkam menggunakan kamera 60 fps kemudian diolah menggunakan video cutter untuk diambil tujuh tangkapan layer dengan frame yang berbeda. Setelah tangkapan layar diperoleh kemudian diolah untuk mendapatkan pengukuran dimensi pada tinggi, lebar dan luas api. Lalu dari angka yang didapat di masukkan kedalam Microsoft excel untuk kemudian dibentuk grafik terpisah.

3. RESULTS AND DISCUSSIONS

3.1. Visual Flame color

Image 3 was captured through a screen capture of the previously recorded video, aiming to compare the seven different frames. Visually, the seven captured frames exhibit distinct phenomena. Among the frames, it can be observed that as the percentage of AVGAS increases, the number of stable flames also increases. For the AVGAS 50% mixture, the visual representation of the flame structure varies in each frame. Subsequently, for the AVGAS 75% mixture, a more consistent flame pattern is observed, which is also the case for the AVGAS 100% fuel. This indicates that as the content of PERTAMAX increases in the AVGAS fuel, flame stability decreases. This can be attributed to the tendency of an air-fuel mixture with higher PERTAMAX content to become less homogeneous. The decrease in RON (Research Octane Number) of the AVGAS fuel due to the addition of PERTAMAX also contributes to the less homogeneous fuel mixture compared to AVGAS fuel with lower or no PERTAMAX content. Moreover, a higher percentage of PERTAMAX content leads to a reddish color at the flame tip. This indicates a rich fuel mixture, resulting in incomplete and uncontrolled combustion, leading to stronger radiation in the red light spectrum. The reddish flame tip is also caused by diffusive combustion of partially burned substances, generating stronger radiation in the red light spectrum and blending with the blue light, resulting in a bluish-red color at the edges of the blue flame. Overall, these observations highlight the influence of AVGAS fuel mixture ratios and the presence of PERTAMAX on flame characteristics, including stability, color, and combustion behavior.

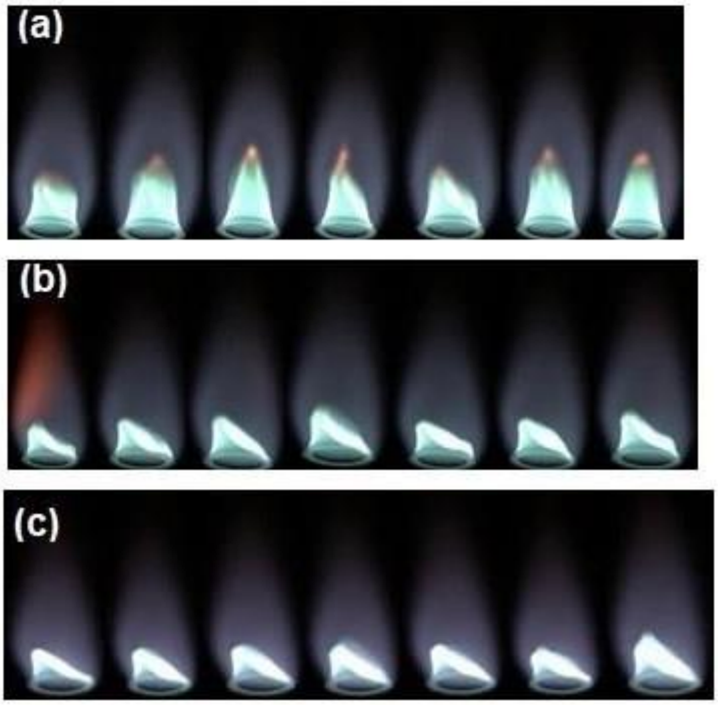

Fig. 3. a) 50% AVGAS, 9 mililiter/hours, b) 75% AVGAS, 9 mililiter/hours, c) 100% AVGAS, 9 mililiter/hours

3.1. Flame height and flame area

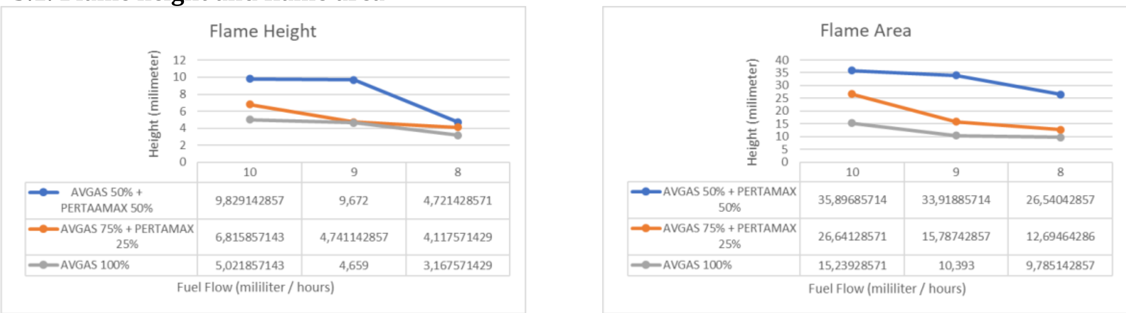

Fig. 4. a) Flame height, b) Flame Area

Flame height and flame area diperoleh dengan mengolah tangkapan layer video pengambilan data pada tujuh frame yang berbeda, kemudian diukur menggunakan software image-j. Setelah data terkumpul, diambil nilai rata-ratanya lalu ditampilkan dalam bentuk grafik. Dapat diketahui pada grafik yang ditampilkan oleh gambar 4, bahwa semakin sedikit kandungan PERTAMAX pada AVGAS dapat mempengaruhi flame height and flame area yang dihasilkan. flame height and flame area pada bahan bakar 50% AVGAS + 50% PERTAMAX menunjukan nilai yang paling tinggi yakni 10,305 mm pada debit bahan bakar 9 ml/jam, kemudian diikuti dengan bahan bakar campuran 75% AVGAS dan 25% PERTAMAX yang menghasilkan 6,636 mm, namun pada debit bahan bakar 10 ml/jam sedangkan tinggi api yang paling besar pada bahan bakar 100% AVGAS adalah di angka 5,002 pada debit bahan bakar 10 ml/jam. Namun ketiganya memiliki tren yang sama yakni semakin besar turun debit bahan bakar, maka juga membuat nilai flame height and flame area semakin menurun.

3.3. Flame temperature

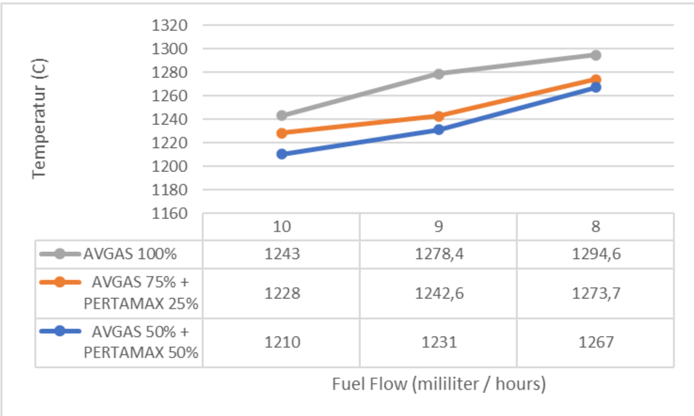

Fig. 5. Flame temperature

Testing the temperature values is necessary to understand the combustion characteristics. One important aspect that can be determined from temperature is the quality of air-fuel mixture, whether it is good or poor (Bhikuning et al., 2022; Huda et al., 2019). As shown in the figure 5, the temperature values for pure AVGAS without any PERTAMAX mixture at fuel flow rates of 10, 9, and 8 ml/h are higher compared to AVGAS fuel with PERTAMAX content. Additionally, the fuel mixture of 25% PERTAMAX in AVGAS occupies the second highest position in terms of temperature, followed by the fuel mixture of 50% AVGAS and PERTAMAX, which exhibits the lowest temperature values among the tested fuels.

These results indicate that the addition of PERTAMAX in AVGAS fuel can influence the measured temperature values. This can be attributed to the fact that AVGAS has a higher octane rating compared to PERTAMAX. Thus, when PERTAMAX is added to AVGAS, the octane rating is affected and decreases compared to AVGAS without PERTAMAX or with a lower PERTAMAX content. Fuels with higher octane ratings generally result in slower combustion processes as they are responsible for reducing knocking in engines(Khan et al., 2021). On the other hand, fuels with lower octane ratings undergo rapid combustion, leading to faster heat release and lower temperatures(Singh & Sarathy, 2021). The temperature values obtained in this study demonstrate that pure AVGAS achieves a temperature of 1294.6 °C, while the fuel mixture of 75% AVGAS and 25% PERTAMAX exhibits the highest temperature value at 1273.7 °C. The fuel mixture of 50% AVGAS and 50% PERTAMAX shows the highest temperature value at 1267 °C.

4. CONCLUSION

The FAA has issued a service bulletin, FAA Service Instruction No. 1070AB, allowing the blending of AVGAS and MOGAS fuels under certain stringent conditions. However, it is important to understand that there are significant impacts on the combustion process that occurs in the aircraft's piston engine. The conducted research provides conclusive evidence that the blending of AVGAS and MOGAS fuels can affect temperature, flame area, flame height, and flame color. Visual analysis of the flame color revealed that an increase in PERTAMAX content in AVGAS results in a reddish-yellow flame tip, indicating incomplete combustion. Moreover, an increase in PERTAMAX content in AVGAS leads to larger flame areas and higher flame heights. These findings suggest that higher PERTAMAX content in the fuel mixture contributes to larger and more intense flames during combustion.

In terms of flame temperature, it was observed that pure AVGAS fuel without any mixture exhibited the highest temperature values, whereas AVGAS with a 50% PERTAMAX blend exhibited the lowest temperature values. These results indicate that the addition of PERTAMAX to AVGAS affects the combustion process, resulting in variations in flame temperature. However, further extensive research is warranted to gain a deeper understanding of the blending of AVGAS and MOGAS fuels. While the conducted study sheds light on the potential impact of this fuel mixture on combustion characteristics, there is still room for further exploration to acquire more comprehensive insights into the blending of AVGAS and MOGAS fuels in aircraft piston engines.

ACKNOWLEDGEMENTS

This research was financially supported by the Research and Community Service Unit of the Indonesian Civil Pilot Academy in Banyuwangi. The financial support provided by this unit was crucial in facilitating the successful execution of the study. The resources and funding provided allowed the researchers to conduct the necessary experiments, collect data, analyze results, and draw meaningful conclusions. The support from the Indonesian Civil Pilot Academy highlights their commitment to promoting research and academic development in the field of aviation. The findings of this study contribute to the existing body of knowledge in the field and have implications for the aviation industry as a whole. Further research and collaboration in this area are encouraged to expand our understanding of the effects of blending AVGAS and MOGAS fuels.

REFERENCES

Bhikuning, A., Hafnan, M., & Wijaya, J. D. I. (2022). PENGARUH PENCAMPURAN MINYAK TANAH DENGAN BAHAN BAKAR MINYAK DIESEL, BIODIESEL DAN LAINNYA - REVIEW. *Jurnal Rekayasa Mesin*, *13*(3), 717–730. https://doi.org/10.21776/jrm.v13i3.1090

Bishop, G. J., & Elvers, B. (2021). Aviation Gasoline (Avgas)*. In *Handbook of Fuels* (pp. 529–531). Wiley. https://doi.org/10.1002/9783527813490.ch25

Cai, T., Tang, A., Zhao, D., Zhou, C., & Huang, Q. (2020). Flame dynamics and stability of premixed methane/air in micro-planar quartz combustors. *Energy*, *193*, 116767. https://doi.org/10.1016/j.energy.2019.116767

Ershov, M. A., Klimov, N. A., Burov, N. O., Abdellatief, T. M. M., & Kapustin, V. M. (2021). Creation a novel promising technique for producing an unleaded aviation gasoline 100UL. *Fuel*, *284*, 118928. https://doi.org/10.1016/j.fuel.2020.118928

Huda, A. A., Widodo, A. S., & Siswanto, E. (2019). *PENGARUH LIP THICKNESS TURNCATED NOZZLE SUDUT LUAR TERHADAP KARAKTERISTIK API DIFUSI CONCENTRIC JET FLOW*.

Hui, X., Kumar, K., Sung, C.-J., Edwards, T., & Gardner, D. (2012). Experimental studies on the combustion characteristics of alternative jet fuels. *Fuel*, *98*, 176–182. https://doi.org/10.1016/j.fuel.2012.03.040

Hwang, B. J., Kang, S., Lee, H. J., & Min, S. (2020). Measurement of laminar burning velocity of high performance alternative aviation fuels. *Fuel*, *261*, 116466. https://doi.org/10.1016/j.fuel.2019.116466

Karakoç, T. H., Colpan, C. O., & Şöhret, Y. (2018). Advances in Sustainable Aviation. In T. H. Karakoç, C. O. Colpan, & Y. Şöhret (Eds.), *Advances in Sustainable Aviation*. Springer International Publishing. https://doi.org/10.1007/978-3-319-67134-5

Khan, K., Sohaib, M., Rashid, A., Ali, S., Akbar, H., Basit, A., & Ahmad, T. (2021). Recent trends and challenges in predictive maintenance of aircraft's engine and hydraulic system. In *Journal of the Brazilian Society of Mechanical Sciences and Engineering* (Vol. 43, Issue 8). https://doi.org/10.1007/s40430-021-03121-2

Kumar, T., Mohsin, R., Ghafir, M. F. A., Kumar, I., & Wash, A. M. (2018). Review of alternative fuel initiatives for leaded aviation gasoline (AVGAS) replacement. *Chemical Engineering Transactions*, *63*, 175–180. https://doi.org/10.3303/CET1863030

Kumar, T., Mohsin, R., Majid, Z. A., Ghafir, M. F. A., Yusuf, N. K., Kim, J., Wash, A. M., & Sahri, D. M. (2019). Response surface methodology application in optimization of performance and exhaust emissions of RON 98, aviation gasoline 100LL and the blends in Lycoming O-320 engine. *Fuel*, *256*, 115909. https://doi.org/10.1016/j.fuel.2019.115909

Kumar, T., Mohsin, R., Majid, Z. Abd., Ghafir, M. F. A., & Wash, A. M. (2020). Experimental study of the anti-knock efficiency of high-octane fuels in spark ignited aircraft engine using response surface methodology. *Applied Energy*, *259*, 114150. https://doi.org/10.1016/j.apenergy.2019.114150

Shiek, S. S., Mani, M. S., Kabekkodu, S. P., & Dsouza, H. S. (2021). Health repercussions of environmental exposure to lead: Methylation perspective. *Toxicology*, *461*, 152927. https://doi.org/10.1016/j.tox.2021.152927

Singh, E., & Sarathy, S. M. (2021). The Role of Intermediate-Temperature Heat Release in Octane Sensitivity of Fuels with Matching Research Octane Number. *Energy & Fuels*, *35*(5), 4457–4477. https://doi.org/10.1021/acs.energyfuels.0c03883