Journal of Information Technology, computer science and Electrical Engineering (JITCSE)
Vol. 1 No. S1 (2024): Special Edition
ISSN: 3046-3900, DOI: 10.61306/jitcse.v1i1.16

The Experiment and Simulation on Impact Characteristics of AVGAS Spray Based on Impact Phenomenon

1st Dimas Endrawan Putra
Graduate Faculty of Mechanical Engineering Jember State University
Jember State University
Jember, Indonesia
Dimas.endrawan@gmail.com

2nd Nasrul Ilminnafik*
Graduate Faculty of Mechanical Engineering Jember State University
Jember State University
Jember, Indonesia
nasrul.teknik@unej.ac.id

3rd M Fahrur Rozy Hentihu
Graduate Faculty of Mechanical Engineering Jember State University
Jember State University
Jember, Indonesia
fahrur.teknik@unej.ac.id

4th Muh. Nurkoyim Kustanto
Graduate Faculty of Mechanical Engineering Jember State University
Jember State University
Jember, Indonesia
nurkoyin@unej.ac.id

5th Danang Yudistiro
Graduate Faculty of Mechanical Engineering Jember State University
Jember State University
Jember, Indonesia
danang.ft@unej.ac.id

Abstract— **Avition gasoline (avgas) is one of the fuels used for combustion of piston-type aircraft engines and uses ignition in the form of spark plugs or internal combustion engines. In recent years, the use of avgas fuel itself is very high used in high-wing light aircraft engines, namely Cessna. avgas spray phenomenon that collides with the cylinder wall may occur during fuel injection, so it will produce a changed radius and spray height, which will affect the mixing of fuel and air, later engine performance and exhaust emissions will also be affected. Therefore, it is important to know and study the spray impact phenomenon in avgas-fueled aircraft engines. This research is a spray experiment with a specified pressure and sprayed on the combustion chamber wall so that the results of the image can be studied coupled with data from experimental research, it can make research from computational fluid dynamics (CFD) simulations, providing valuable insights for future research in this field.**

Keywords— avgas, ansys, tumbukan, spray, CFD

I. INTRODUCTION

The characteristics of avgas-fueled aircraft engines require thrust and air mixture in the engine [1]-[3]. In recent years, the use of avgas fuel itself is very high used in high-wing light aircraft engines, namely Cessna [3]-[5], but until now there has been no research on the spray collision that occurs in this aircraft engine, the phenomenon of avgas spray colliding with the cylinder wall may occur during fuel injection, so it will produce a changed radius and spray height, which will affect the mixing of fuel and air, later engine performance and exhaust emissions will also be affected [3], [4], [6]-[11]. Therefore, it is important to know and study the spray impact phenomenon in avgas-fueled aircraft engines.

The study of avgas-fueled spray characteristics, mainly based on fuel density, injection pressure, and impact angle, has the goal of understanding how these factors affect spray behavior and engine performance [12]-[15]. Several previous studies have revealed the relationship between fuel density and spray characteristics [16]-[18]. For example, the average peak velocity of the spray tends to be positively correlated

with the spray center velocity [19], [20]. Studies have shown that the higher the injection pressure, the higher the spray velocity and spray penetration [14], [15], [21]. This in turn can result in more efficient combustion and better engine performance. The angle of impact is also an important factor in spray characteristics [10], [11], [22]. Studies have shown that lower impact angles tend to result in faster spray penetration [10]-[12], [22], [23]. An optimal impact angle can provide better fuel distribution and higher combustion efficiency [4], [9]. In addition to these factors, studies have also compared spray characteristics between avgas fuel and other fuels [3], [6]. These studies show that avgas fuel has a wider spray angle and shorter penetration time compared to its blends at the same injection pressure [13], [15], [18], [24]. In addition, avgas fuel sprays tend to have a more symmetrical shape and thinner spray boundaries compared to ethanol-avgas blends [25], [26].

The research considers the influence of all aspects on spray characteristics and through these experiments provides an important understanding in engine performance optimization. The research methods used, starting using experimental jets with a specified pressure and jetted on the combustion chamber wall.

so as to obtain researchable image results coupled with data from experimental research, it can make research from computational fluid dynamics (CFD) simulations, providing valuable insights for future research in this field.

II. EXSPERIMENTAL

A. Experimental Tools and Procedures

This data collection uses an experimental system by visualizing a constant volume jet of fuel. The experimental equipment used is as follows:

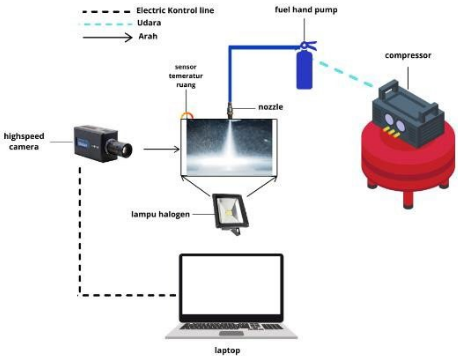

Fig 1. Flow of data collection

The burst of fuel that occurs in this combustion chamber uses pressure from a fuel hand pump whose pressure is supplied from a compressor with a pressure adjusted to the original pressure on an airplane, namely 2 Bar (30 Psi), the burst can later be seen with the help of a halogen lamp placed at the bottom with a certain angle in order to get the desired burst results, installation of a high-speed camera to take the burst that comes out until it hits the wall is recorded on a laptop, for the temperature in the combustion chamber itself is sterilized with a room temperature sensor set at 26^{o}C to be stable at the time of data collection, this data collection is carried out in an air-conditioned room whose temperature is stable set at 26^{o}c.

Data collection will occur when the fuel hand pump is pressed to spray fuel through the nozzle then a burst occurs, at that time the camera will record the movement of the burst until the burst ends repeatedly until it gets satisfactory results then sends the data in the computer to be stored, allowing complete recording of the avgas spray process. Under the experimental conditions of using a high-speed camera system to study the avgas spray phenomenon on the wall, with the aim of obtaining a better spray distribution, this experiment uses a single-hole nozzle. The specific conditions of the parameters are shown in Table 1.

TABLE 1 EXPERIMENTAL CONDITION

Kondisi injeksi	Parameters	Kondisi lingkungan	parameter
fuel	Avgas	Temperatur ruang/ C	26
Spray mass/mg	1	Sudut semburan ke dinding/ o	90
Tekanan injeksi/Bar	2	Jarak nozzle ke dinding/ cm	7,21
Waktu semburan/ms	1	-	-
Tipe nozzle	Single hole	-	-
Diameter lubang nozzle/ mm	2	-	-

B. *Ansys CFD Simulation Procedure*

One of the data support using CFD is the Ansys application to see how the movement of the impacted fluid, basically in the experimental taking of the spray, there will be an impact by describing the development of the spray after contact with the wall, namely the spray height (H) and spray radius (R) as in Figure 2. The figure shows a diagram of the vertical wall spray parameters. In the figure, the spray radius R is the penetration distance of the spray jet along the wall direction after contacting the wall; the wall spray height H is the penetration distance perpendicular to the wall; L is the distance from the injector to the wall surface; parameters such as diffusion diameter and volume height can be used to reflect the fuel volume on the wall and the air volume [27], [28].

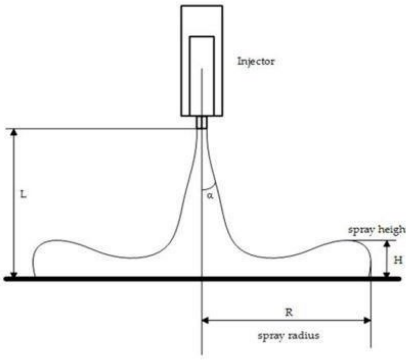

Fig 2. Calculation of impact bursts [27]

With the formula the calculation formula for the penetration of the spray passing through the wall [29], [30] is as follows:

$$S = B * (tW - t0) * (Pamb / P0) * (L / cos(q)) * tan(j)$$

Where:

- S: spray penetration distance (including free spray and collision with wall).
- B: wall collision constant.
- t0: start time of injection.
- tW: time when the spray hits the wall.
- Pamb: environmental back pressure.
- L: distance from nozzle to wall.
- q: angle of inclination of the wall to the horizontal plane.
- j: angle between the entire oil jet and the spray wall.

This empirical formula is suitable for evaluating the penetration of a single spray. By knowing the formula for the experimental spray, the spray can also be implemented in CFD by looking at its behavior and movement where Ansys software has an automatic mesh feature that uses real-time meshing techniques and only needs to enter the size and type of base material. The meshing in question is a design image of a size with the material we want as in Figure 3.

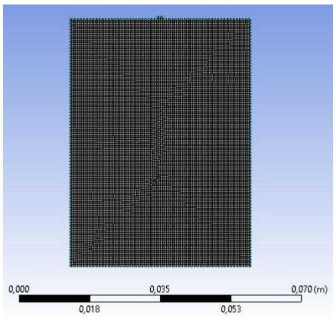

Fig 3. Ansys meshing

The meshing is generated directly when we input the size and is calculated immediately. This experimental simulation is of a combustion chamber with a constant volume jet. The model is a combustion chamber with a length of 4.5 cm and a width of 6.15 cm, and a nozzle with a size of 0.2 cm is drawn in the center with a height of 0.05 cm. To achieve calculation accuracy and calculation speed simultaneously, the meshing size was reduced to 0.0005 mm using CFD ansys simulation software, to simulate the avgas spray process in the combustion chamber with constant pressure. Then the original pressure of 2 bar is varied to 3 and 4 bar as well, the initial conditions of fluent basic fluid and eulurian multiphase parameters added with viscous k-omega are shown in Table 2.

TABLE 2. MATERIAL SOLUTION SETUP

Multiphase eulurian	Phase 2 implict
Viscous model	k-omega SST Mixture
Phases	Air- primary Avgas- secondary
Boundry condition	Mixture, pressure outlate, gauge 200000
	Velocity inlet, gauge 200000 Avgas, velocity inlet, magnitude 2 m/s Avgas, backflow 1
Calculation	200

III. RESULT AND DISCUSSION

A. Experimental Setup

The experimental setup uses avgas fuel with adjusted pressures of 2 bar, 3 bar and 4 bar with a spout distance of 7.21 cm and a wall width of 4.5 cm and then sprayed at room temperature.

Fig 4. Avgas R, H and α burst results.

Obtained burst results with a criterion pressure, the pressure criteria that are varied, namely 2, 3 and 4 bar.

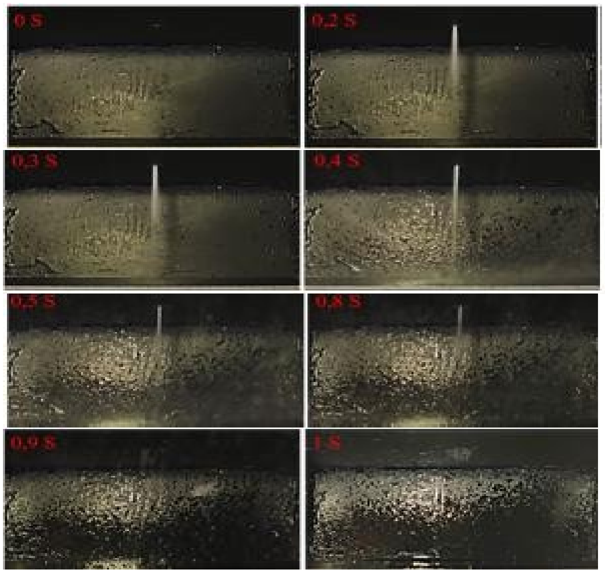

Fig 5. Journey of the burst

Figure 5 shows photographs of the shape of the avgas fuel spray as it develops over time. The spray that comes out and looks slightly distorted before hitting the wall and the front of the body shows a more pronounced diffusion phenomenon. A "mist" appears at the edge of the sprayed head [19]. At 0.2s, after the onset of injection, a clear oil beam can already be seen. Avgas oil beam After five measurements at each pressure, it was found that the cone angle of the avgas fuel jet did not change significantly. The results agree with the conclusion that the cone angle change is small at high injection pressures. At this point, the phenomenon of avgas spray hitting the wall has occurred. The spray radius increases obviously at the spraying stage after impact. The author found that the change of injection pressure on the spray cone angle is mainly affected by the injection pressure [20] and the influx of air around the spray bundle. The injection pressure and environment are not changed in this test, so in the whole process of spraying the injector can generate maximum data. Observation shows that there is an obvious thinning oil mist area around the outer wall of the avgas mist, and the thin avgas mist area becomes gradually larger as time passes.

B. Numerical Simulation (ANSYS Simulation)

By using CFD applications to help see in more detail how the burst is produced and its growth coupled with the temperature of the burst and the results of the burst, the CFD application Ansys is used, using the simulation setup and mesh obtained.

C. Simulation Setup

At this setting stage there are several steps, namely geometry, mesh, setup, and solution, in the geometry section, the nozzle size is made, the nozzle distance and the spout space are set here with a predetermined size, namely

TABLE 3. GEOMETRY SIZE

Length	4,5 cm
Wide	6,15 cm
Nozzle height	0,05 cm
Total area	6,2 cm
Diameter of the nozzle	0,2 cm

By determining the size of the blast room, the sketch can be made, then using line from sketch to apply the room is frozen so that it becomes a form of combustion room with a nozzle that is ready to be simulated.

D. Mesh Convergence

The meshing used uses an element size of 0.0005 m so as to get a tighter and smoother size as in Figure 3. added with the inlet section for the input of the burst and the wall or wall for part of the blast chamber as in Figure 6.

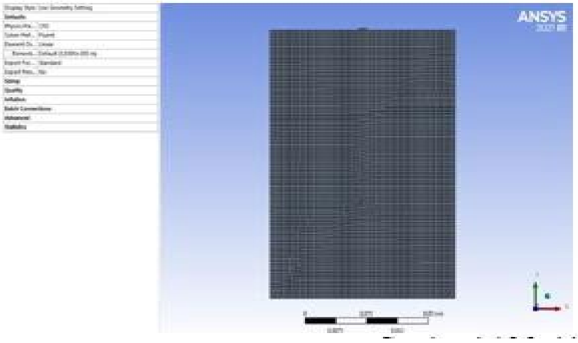

Fig 6.Meshing

F. Setup and solution

a setup using:

TABLE 4 SETUP

Set Up	Double precision
Solver Proces	1
Multiphase	Eulerian
Formulation	Implicit
Phase	2
Viscous	SST-k-omega, Mixture
Material	Air
	N-Octane Liquid (C8H18)

Material Setup set on Boundary Conditions is centered on the inlet and set on the mixture and N-octane parts. Determination of velocity magnitude was obtained during the experiment where the pressure at 2 bar was 2.79 m/s, 3 bar was 2.87 m/s, 4 bar was 3.02 m/s. at the time of determining the nominal initial gauge 2 BAR was changed to pascal [Pa] so that 2 bar = 200000 Pa, 3 bar = 300000 Pa, and 4 bar = 400000 Pa. After setting the Boundary conditions, continue with setting Initialization and Patch to determine which part will be focused on the mesh field, so that the final part will be Run Calculation with 200 iterations and reporting interval 1 and the iteration results are obtained from the 3 pressures.

G. Result Ansys

Based on the iteration results, 3 different pressures are obtained where based on the results of the burst obtained at 2 bar pressure the heat generated due to collisions is 3.52e + 00, 3 bar pressure the heat generated by collisions is 3.62e + 00, and 4 bar pressure produces heat of 3.80e + 00, where of the three collisions the 4 bar pressure collision is the largest heat generated by avgas fuel can be seen in Figure 7.

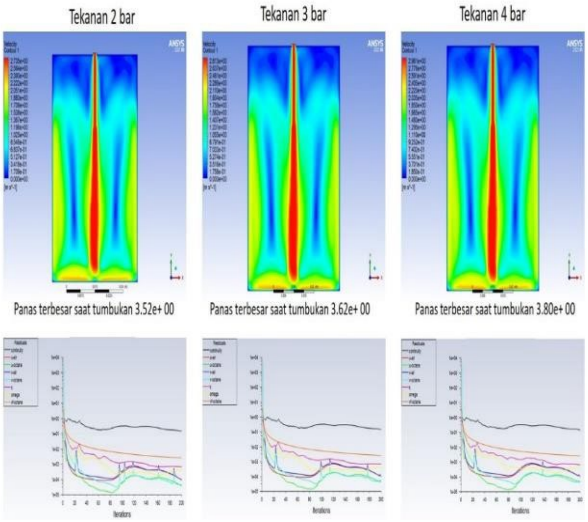

Fig 7. Iterations results for each pressure

H. Numerical Simulation Results and Discussion

Based on experimental results and Ansys results obtained that the pressure produces a different burst pattern from the air pressure fariation entered in the burst as in the experimental burst of 2 bar pressure it can be seen that the avgas burst is triangular and visible spray results but the atomization of the burst is split before being impacted by the wall and the heat disappears when the burst process has not been impacted by the wall, whereas at 3 bar and 4 bar jets it can be seen that the impact process makes the atomization split due to high pressure, so that the heat carried from the fuel jet is not lost on the way to the impact, while in the Ansys experiment it was found that the highest heat was generated by a pressure of 4 bar where in Figure 5. 7 It can be seen that the highest heat is 3.80e+00 at the time after being impacted by the wall at 0.2 seconds, this is compared to other experimental pressures where at 2 bar pressure 3.51e+00 at 0.4 seconds and at 3 bar pressure 3.62e+00 at 0.3 seconds.

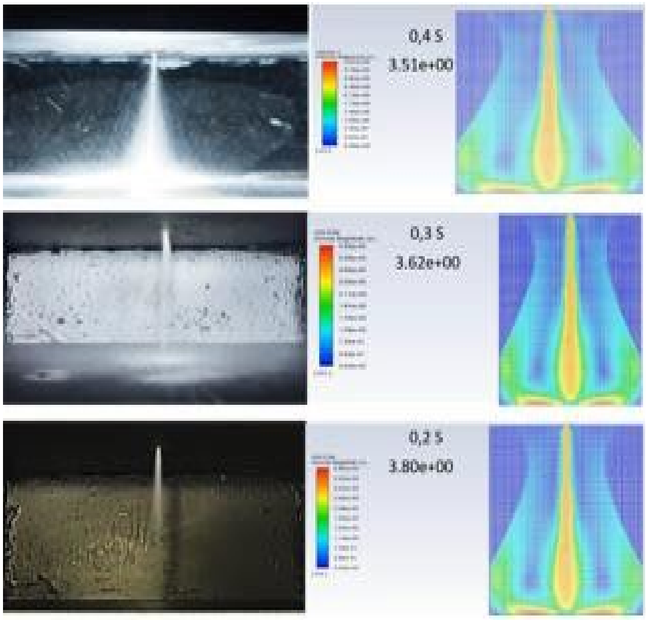

Fig8. burst difference

CONCLUSION

It was found that the greater the pressure, the more concentrated the resulting burst on the blast wall so that the atomization of the fuel jet itself would be split when the burst hit the wall and collided, while in the blast panaya seen from the changes in the Ansys application can be seen bursts that have greater pressure can collide faster than with smaller pressures and also the heat release generated is greater than 4 bar pressure, which is 3.80e+00 compared to other burst pressures, as in Figure 8.

REFERENCES

[1] R. Mahmud, T. Kurisu, K. Nishida, Y. Ogata, J. Kanzaki, and T. Tadokoro, "Experimental study on flat-wall impinging spray flame and its heat flux on wall under diesel engine–like condition: First report—effect of impingement distance," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 233, no. 8, pp. 2187–2202, Jul. 2019, doi: 10.1177/0954407018778153.

[2] K. Yamagishi *et al.*, "Computations and Experiments of Single-Point Autoignition Gasoline Engine with Colliding Pulsed Supermulti-Jets, Single Piston and Rotary Valve," in *SAE Technical Papers*, SAE International, 2016. doi: 10.4271/2016-01-2334.

[3] Q. Zhang, J. Xia, J. Wang, Z. He, Y. Qian, and X. Lu, "Experimental investigation on spray and combustion characteristics of dual-fuel collision of biodiesel and n-butanol," *Fuel*, vol. 340, May 2023, doi: 10.1016/j.fuel.2023.127613.

[4] "STUDY OF SPRAY BREAKUP AND MIXTURE IN A GASOLINE DIRECT INJECTION ENGINE BY USING SIMULATION MUZAMMIL BIN MOHAMAD ALIAS Report submitted in partial fulfillment of the requirements for the award of Bachelor of Mechanical Engineering with Automotive Engineering FACULTY OF MECHANICAL ENGINEERING UNIVERSITY MALAYSIA PAHANG," 2013.

[5] M. Hilmi Bin and M. Zin, "COMPUTATIONAL STUDY OF FUEL SPRAY STRUCTURE," 2013.

[6] S. Wu, S. Yang, M. Wooldridge, and M. Xu, "Experimental study of the spray collapse process of multi-hole gasoline fuel injection at flash boiling conditions," *Fuel*, vol. 242, pp. 109–123, Apr. 2019, doi: 10.1016/j.fuel.2019.01.027.

[7] B. K. Fritz, W. C. Hoffmann, W. E. Bagley, G. R. Kruger, Z. Czaczyk, and & R. S. Henry, "MEASURING DROPLET SIZE OF AGRICULTURAL SPRAY NOZZLES-MEASUREMENT DISTANCE AND AIRSPEED EFFECTS," 2014.

[8] R. Jumadi *et al.*, "Analysis of spray characteristics and high ambient pressure in gasoline direct injection using computational

[9] S. J. M. Algayyim, A. P. Wandel, T. Yusaf, and I. Hamawand, "The impact of n-butanol and iso-butanol as components of butanol-acetone (BA) mixture-diesel blend on spray, combustion characteristics, engine performance and emission in direct injection diesel engine," *Energy*, vol. 140, pp. 1074–1086, 2017, doi: 10.1016/j.energy.2017.09.044.

[10] A. F. Alhikami and W. C. Wang, "Experimental study of the spray ignition characteristics of hydro-processed renewable jet and petroleum jet fuels in a constant volume combustion chamber," *Fuel*, vol. 283, Jan. 2021, doi: 10.1016/j.fuel.2020.119286.

[11] S. Wu, S. Yang, M. Wooldridge, and M. Xu, "Experimental study of the spray collapse process of multi-hole gasoline fuel injection at flash boiling conditions," *Fuel*, vol. 242, pp. 109–123, Apr. 2019, doi: 10.1016/j.fuel.2019.01.027.

[12] Y. Duan, D. Han, P. Li, C. Wang, H. Lin, and Z. Huang, "Experimental study on injection and macroscopic spray characteristics of ethyl oleate, jet fuel and their blend on a diesel engine common rail system," *Atomization and Sprays*, vol. 25, Jan. 2015, doi: 10.1615/AtomizSpr.2015011145.

[13] Y. Wang, B. Li, Y. Li, and F. Chen, "Experiment and simulation of spray impingement for gasoline direct injector," *Jiangsu Daxue Xuebao (Ziran Kexue Ban)/Journal of Jiangsu University (Natural Science Edition)*, vol. 32, pp. 410–415, Jul. 2011, doi: 10.3969/j.issn.1671-7775.2011.04.008.

[14] M.-R. Wei, F. Liu, H. Wen, Y.-C. Liu, and Y.-S. Zhang, "Numerical simulation and experimental research of DME spray wall-impingement," vol. 27, pp. 5–10, Apr. 2006.

[15] H. Luo, "Experimental Investigations on Fuel Spray and Impingement for Gasoline Direct Injection Engines," 2021. doi: 10.5772/intechopen.95848.

[16] C. Mundo, C. Tropea, and M. Sommerfeld, "Numerical and Experimental Investigation of Spray Characteristics in the Vicinity of a Rigid Wall."

[17] F. J. Salvador, J. J. Lopez, J. De la Morena, and M. Crialesi-Esposito, "Experimental investigation of the effect of orifices inclination angle in multihole diesel injector nozzles. Part 1 – Hydraulic performance," *Fuel*, vol. 213, pp. 207–214, Feb. 2018, doi: 10.1016/j.fuel.2017.04.019.

[18] P. Pischke, D. Martin, and R. Kneer, "COMBINED SPRAY MODEL FOR GASOLINE DIRECT INJECTION HOLLOW-CONE SPRAYS," 2010.

[19] K. Kannaiyan and R. Sadr, "Experimental investigation of spray characteristics of alternative aviation fuels," *Energy Convers Manag*, vol. 88, pp. 1060–1069, 2014, doi: 10.1016/j.enconman.2014.09.037.

[20] A; Muddapur, Sahu, ; Srikrishna, and J. V Jose, "Spray-Wall Impingement in a Multi-Hole Gdi Injector for Split Injection at Elevated Wall Temperature and Ambient Conditions." [Online]. Available: http://hdl.handle.net/11159/495822

[21] W. Mathews, C. Lee, and J. Peters, "Experimental investigations of spray/wall impingement," *Atomization and Sprays - ATOMIZATION SPRAYS*, vol. 13, pp. 223–242, Mar. 2003, doi: 10.1615/AtomizSpr.v13.i23.40.

[22] Y. Liu, Q. Xiang, Z. Li, S. Yao, X. Liang, and F. Wang, "Experiment and simulation investigation on the characteristics of diesel spray impingement based on droplet impact phenomenon," *Applied Sciences (Switzerland)*, vol. 8, no. 3, Mar. 2018, doi: 10.3390/app8030384.

[23] X. Zhu, L. Zhao, Z. Zhao, N. Ahuja, J. Naber, and S.-Y. Lee, "An Experimental Study of Diesel Spray Impingement on a Flat Plate: Effects of Injection Conditions," Universitat Politecnica de Valencia, Sep. 2017. doi: 10.4995/ilass2017.2017.4733.

[24] H. Luo, K. Nishida, S. Uchitomi, Y. Ogata, W. Zhang, and T. Fujikawa, "Effect of temperature on fuel adhesion under spray-wall impingement condition," *Fuel*, vol. 234, pp. 56–65, Dec. 2018, doi: 10.1016/j.fuel.2018.07.021.

[25] M. You and G. E. Arteel, "Effect of ethanol on lipid metabolism," *Journal of Hepatology*, vol. 70, no. 2. Elsevier B.V., pp. 237–248, Feb. 01, 2019. doi: 10.1016/j.jhep.2018.10.037.

[26] K. Thanikasalam *et al.*, "Ethanol content concerns in motor gasoline (mogas) in aviation in comparison to aviation gasoline (avgas)," in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Jun. 2018. doi: 10.1088/1757-899X/370/1/012009.

[27] Y. Liu, Q. Xiang, Z. Li, S. Yao, X. Liang, and F. Wang, “Experiment and simulation investigation on the characteristics of diesel spray impingement based on droplet impact phenomenon,” *Applied Sciences (Switzerland)*, vol. 8, no. 3, Mar. 2018, doi: 10.3390/app8030384.

[28] Q. Zhang, J. Xia, J. Wang, Z. He, Y. Qian, and X. Lu, “Experimental investigation on spray and combustion *Fuel*, vol. 340, May 2023, doi: 10.1016/j.fuel.2023.127613.