

# Design and Performance Evaluation of an Arduino-Based Vacuum Carbon Cleaner for Gasoline Engines

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**Abstract** -This study addresses the degradation of gasoline engine performance caused by carbon deposit accumulation in the combustion chamber. The objective of this research is to design and evaluate the performance of an Arduino-based vacuum carbon cleaner device. A quantitative experimental method was employed to analyze the effectiveness of suction systems and monitoring sensors, including a Type-K thermocouple and DC voltage sensor. The system integrates a 12V DC pump and a pneumatic vacuum valve as suction mechanisms. The Arduino microcontroller functions as the central automation unit that processes sensor readings, monitors engine temperature and voltage conditions, and controls the suction operation automatically based on predefined parameters. The developed device has dimensions of 40 × 28 cm, a tank weight of 2.45 kg, and a volume of 2,628.76 cm<sup>3</sup>, allowing approximately 26 suction cycles per operation. Experimental results show that the fastest engine warm-up occurs at 2500 RPM with an average time of 5.18 minutes. The optimal reaction time for carbon cleaning fluid is 10 minutes. The DC pump demonstrates faster suction performance (11.77 s) compared to the pneumatic valve (14.21 s at 6 bar), although it requires stable voltage conditions. These findings indicate that the developed system is effective in supporting combustion chamber maintenance through an Arduino-based automation mechanism, but requires further optimization in energy efficiency and suction performance.

**Keywords** -Vacuum Carbon Cleaner, Arduino, DC Pump, Combustion Chamber, Engine Maintenance

## 1. INTRODUCTION

Periodic vehicle maintenance is essential to ensure optimal performance and extend the service life of automotive engines [1], [2]. One of the commonly performed maintenance procedures is the removal of carbon deposits in the combustion chamber, which directly influences combustion efficiency and fuel consumption [3], [4]. Carbon accumulation due to prolonged use and poor fuel quality can significantly reduce engine efficiency and combustion quality [5], [19]. The absence of standardized vacuum carbon cleaner devices results in inconsistent cleaning performance across service practices [4], [15]. Therefore, this study proposes an Arduino-based vacuum carbon cleaner system integrating sensors and suction mechanisms to improve cleaning effectiveness and monitoring capability [8], [9]. Several studies have investigated combustion chamber cleaning systems and engine maintenance technologies. Ladommatos et al. [3] explained that carbon deposits significantly reduce combustion efficiency and increase fuel consumption. Kim and Park [18] reported that intake valve carbon accumulation negatively affects thermal efficiency and emission characteristics. Lee and Min [19] demonstrated that poor fuel quality accelerates deposit formation in gasoline engines. Previous studies mainly focused on chemical cleaning methods and manual maintenance procedures without integrating automation systems [15], [16]. In addition, Rahman et al. [20] analyzed suction-based cleaning systems but did not implement real-time monitoring and automatic control. Research related to microcontroller applications in automotive maintenance has also been widely conducted. Banzi and Shiloh [8] introduced Arduino

applications for embedded control systems, while Monk [9] discussed sensor integration and automation using Arduino platforms. Ibrahim [10] explained that microcontroller-based control systems improve operational consistency and monitoring capability. However, most previous studies focused only on monitoring systems or general automation without integrating suction performance evaluation in vacuum carbon cleaning applications. Based on the reviewed literature, the novelty of this research lies in the integration of an Arduino-based automation system with dual suction mechanisms, namely a 12V DC pump and pneumatic vacuum valve, combined with real-time temperature and voltage monitoring. Unlike previous studies that focused only on manual cleaning methods or independent monitoring systems, this study provides an integrated experimental evaluation of suction performance, reaction time, and operational effectiveness in a compact vacuum carbon cleaner prototype for gasoline engines.

## 2. RESEARCH METHOD

This study employs a quantitative experimental approach to evaluate system performance and reliability of the developed device [6], [7]. To provide a comprehensive understanding of the system configuration, the overall design of the vacuum carbon cleaner is illustrated in Figure 1.

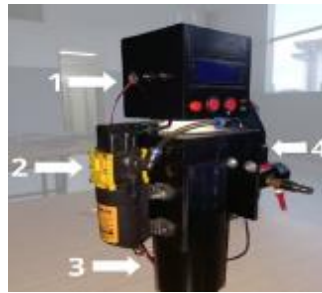


Figure 1. Vacuum Carbon Cleaning System.

The research workflow is structured systematically to ensure accurate data acquisition and analysis, as presented in Figure 2 [6].

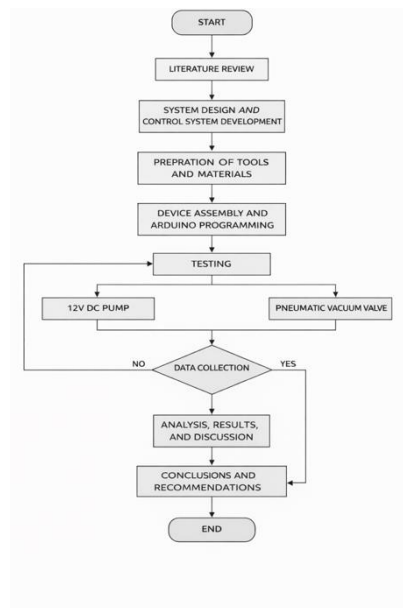


Figure 2. Research Flowchart

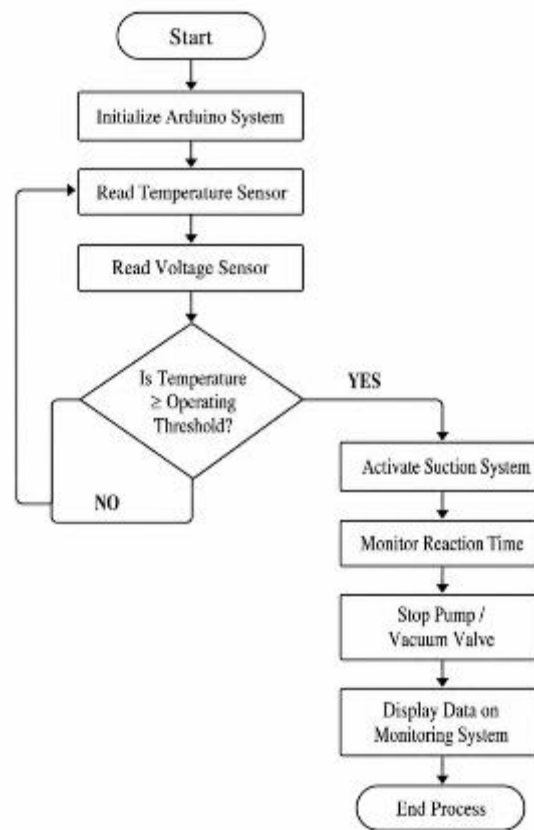


Figure 3. Arduino Flowchart

Furthermore, the interaction between system components is represented using a block diagram, as shown in Figure 4 [9].

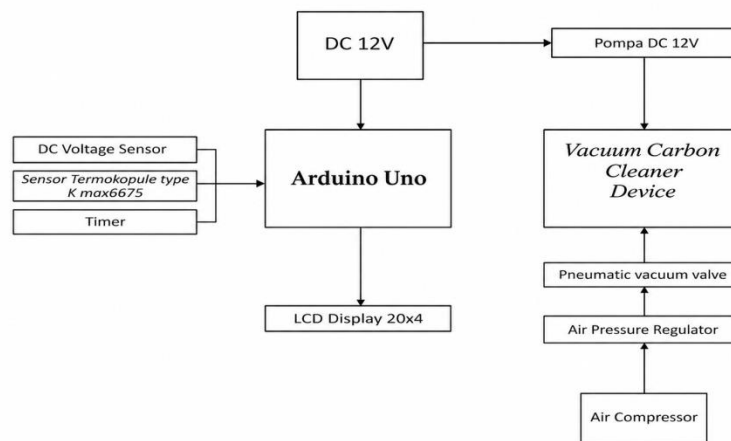


Figure 4. Block Diagram

The physical design of the developed device is illustrated in Figure 5, showing the integration of mechanical and control subsystems [10].

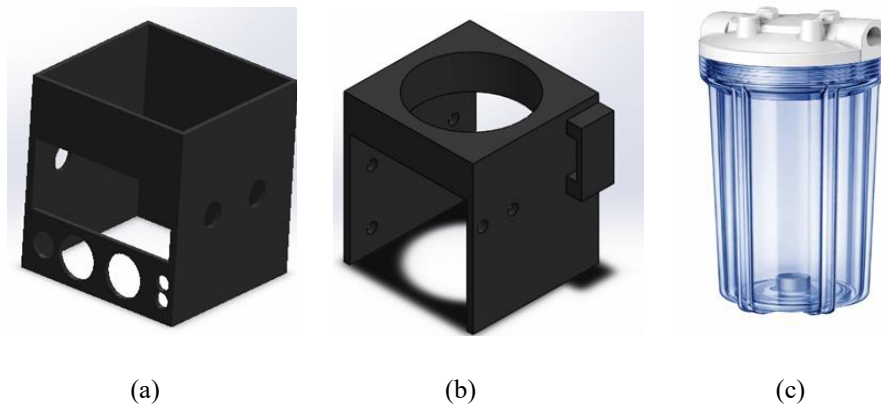


Figure 5. Design of the Vacuum Carbon Cleaner Device: (a) Arduino Control Box, (b) Suction Bracket, and (c) Water Filter Housing

The experiment includes system assembly, calibration, and performance testing. Measurements include temperature, voltage, and suction performance.

Flow rate is calculated using:

$$Q = V / t \quad (1)$$

Mass flow rate:

$$\dot{m} = \rho Q \quad (2)$$

These equations are fundamental in fluid mechanics and are used to evaluate suction performance and system efficiency [11], [12], [13].

### 3. RESULTS AND DISCUSSION

This section presents the experimental results obtained from the developed vacuum carbon cleaner system, followed by a detailed analysis of its performance. The results are discussed based on key parameters, including temperature characteristics, electrical stability, reaction time, and suction performance.

To evaluate the thermal characteristics of the engine during the cleaning process, temperature measurements were conducted using a Type-K thermocouple sensor. The position of the sensor installation is shown in Figure 6.



Figure 6. Thermocouple Sensor Position

The experimental data obtained at different engine speeds are summarized in Table 1.

Table 1. Engine Temperature Measurement

RPM	Initial Temperature (°C)	Trial Time (min)				Final Temperature (°C)
		1	2	3	Average	
750	34 - 40	9,15	11,28	11,88	10,77	81-85
1500	38 - 44	6,16	6,45	7,12	6,57	83-84
2500	34 - 42	4.50	5,56	5,55	5,18	82-85

Based on Table 1, it can be observed that increasing engine speed significantly reduces the time required to reach the operating temperature. This trend is consistent with fundamental internal combustion engine theory, where higher rotational speed increases combustion frequency and heat generation rate [1], [14]. The relationship between engine speed and temperature rise is further illustrated in Figure 7

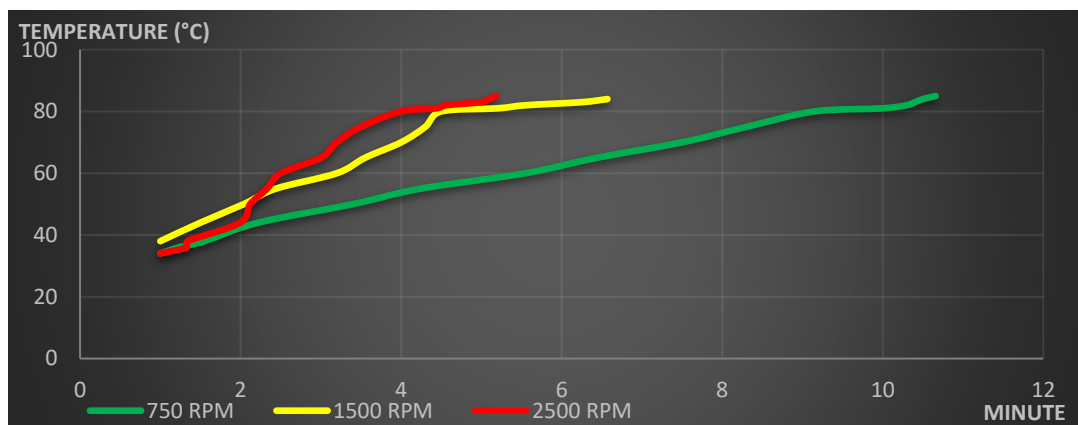


Figure 7. Thermocouple Performance Graph

To ensure stable operation of the system, battery voltage was monitored during the cleaning process. The placement of the voltage sensor is shown in Figure 8.



Figure 8. . DC Voltage Sensor Position

The voltage measurement results over time are presented in Table 2.

Table 2. Battery Voltage Measurement

Trial	Initial Voltage (V)	Voltage at 1 minute (V)	Voltage at 5 minute (V)	Voltage at 10 minute (V)	Voltage Drop (V)
1	12.6	12.5	12.4	12.3	0.3
2	12.7	12.6	12.5	12.4	0.3
3	12.8	12.7	12.6	12.5	0.3

1	12,20	12,0	11,92	11,97	0,28
2	12,48	12,41	12,33	12,31	0,17
3	12,33	12,33	12,31	12,31	0,02

From Table 2, it is evident that a gradual voltage drop occurs during system operation, particularly when the DC pump is actively used. This behavior is typical in battery-powered systems where increased load leads to voltage reduction due to internal resistance and power consumption [11]. The voltage trend is illustrated in Figure 9.

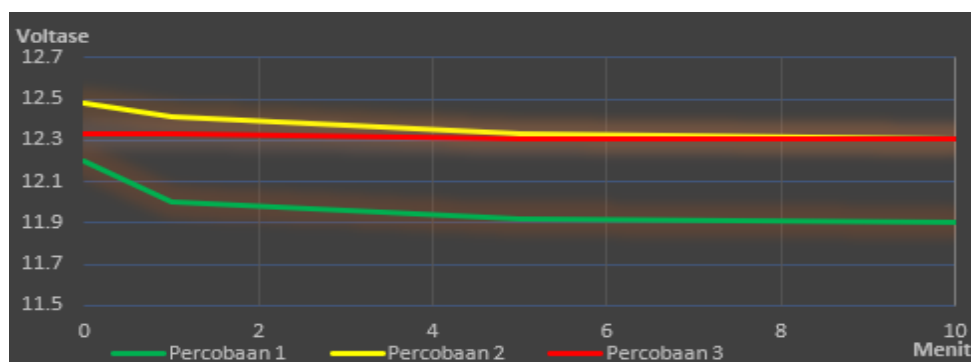


Figure 9. Battery Voltage Performance Graph

To evaluate the effectiveness of the carbon cleaning process, observations were conducted using an endoscopic camera. The condition of the combustion chamber at different reaction times is shown in Figure 10.

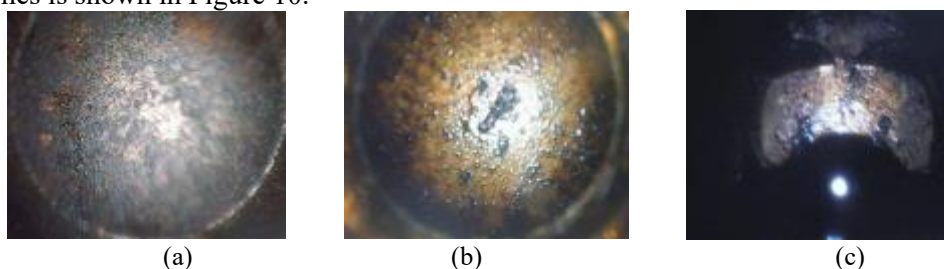


Figure 10. Combustion Chamber Endoscopic Observation : (a) 5 minute, (b) 10 minute, (c) 15 minute

The results indicate that the carbon cleaner fluid begins to react effectively after 5 minutes, with optimal cleaning performance achieved at approximately 10 minutes. This behavior is consistent with typical chemical cleaning processes, where sufficient reaction time is required to break down carbon deposits [3], [18]. At 15 minutes, no significant additional cleaning effect is observed, indicating diminishing returns. Therefore, a reaction time of 10 minutes is considered optimal in terms of efficiency and operational effectiveness.

The suction performance of the 12V DC pump was evaluated based on the time required to extract a fixed volume of fluid. The calculated flow rate is presented in Table 3.

Table 3. Flow Rate of 12 V DC Pump

Trial	Time (s)	Flow Rate mL/s
1	12,43	8,04

2	11,54	8,66
3	11,36	8,80
Avarage	11,77	8,49

Based on Table 3, the DC pump demonstrates relatively fast suction performance with an average time of 11.77 seconds. However, the relatively low flow rate indicates the presence of system losses such as frictional resistance and pressure drop within the flow path [12], [13]. The performance trend is illustrated in Figure 11. From a fluid dynamics perspective, the higher flow rate achieved by the 12V DC pump compared to the pneumatic vacuum valve can be explained by the stability of continuous suction generated by the electric motor system. The DC pump directly converts electrical energy into mechanical rotational energy, producing a relatively constant pressure difference throughout the suction process. According to Bernoulli's principle and continuity equations in fluid mechanics, a stable pressure differential contributes to higher flow velocity and volumetric flow rate [11], [12]. In contrast, the pneumatic vacuum valve depends on compressed air pressure distribution, which is affected by pressure fluctuations and energy losses within the pneumatic line system. Friction losses, turbulence, and pressure drops reduce the effective suction velocity, resulting in a lower average flow rate of  $7.04 \times 10^{-6} \text{ m}^3/\text{s}$  compared to the DC pump flow rate of  $8.49 \times 10^{-6} \text{ m}^3/\text{s}$  [13].

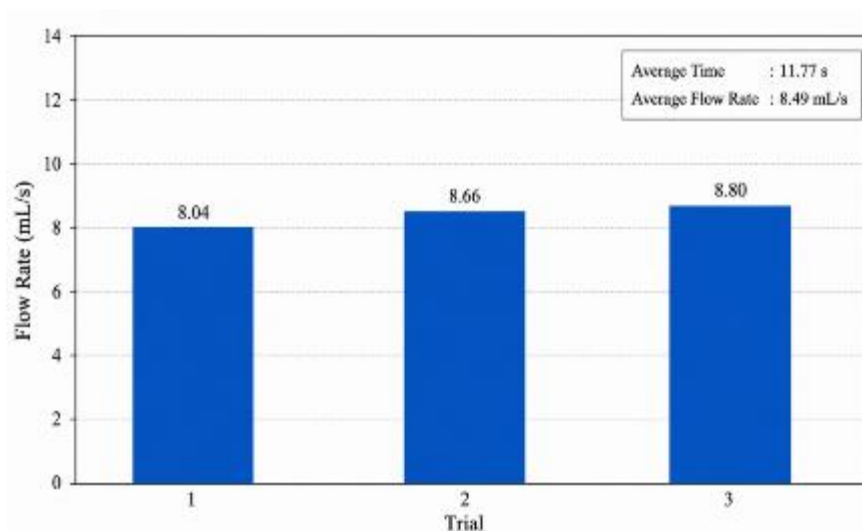


Figure 11. DC Pump Performance Graph

The performance of the pneumatic vacuum valve was analyzed under different pressure conditions. The experimental results are summarized in Table 4.

Table 4. Pneumatic Vacuum Valve Measurement

Pressure (bar) (V = 100ml)	Trial Time (s)				Q	
	1	2	3	Avarage	mL/s	m <sup>3</sup> /s
2	24,8	25,8	25.2 3	25.01	4.0	4,0 x 10 <sup>-6</sup>
4	19,4 1	18,3 2	18.9 2	18.88	5.29	5,29 x 10 <sup>-6</sup>
6	14,0 0	14,1 6	14,4 9	14.21	7.04	7,04 x 10 <sup>-6</sup>

From Table 4, it can be observed that increasing the supply pressure significantly improves suction performance. This behavior aligns with fluid dynamics principles, where higher pressure differentials increase flow velocity and volumetric flow rate [11], [12]. This relationship is further illustrated in Figure 12.

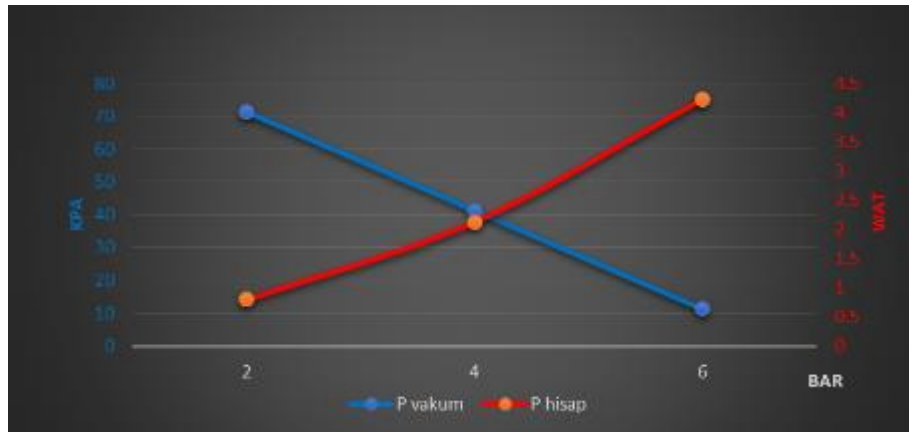


Figure 12. Pneumatic Vacuum Valve Performance Graph

#### 4. CONCLUSION

The Arduino-based vacuum carbon cleaner system has been successfully developed and experimentally evaluated. The Arduino microcontroller effectively performs monitoring and automation functions by processing temperature and voltage sensor data to control the suction operation. The system demonstrates effective cleaning performance, with optimal operation achieved at 2500 RPM and 10-minute reaction time. Experimental results indicate that the 12V DC pump provides faster suction performance with an average flow rate of  $8.49 \times 10^{-6} \text{ m}^3/\text{s}$ , while the pneumatic vacuum valve achieves  $7.04 \times 10^{-6} \text{ m}^3/\text{s}$  at 6 bar pressure. Although the pneumatic system shows relatively stable operation during continuous testing, this observation is qualitative and requires further quantitative investigation in future studies. Further improvements are required to enhance energy efficiency, minimize pressure losses, and optimize suction performance.

#### REFERENCES

- [1] Heywood, J. B. Internal Combustion Engine Fundamentals. New York: McGraw-Hill; 2018.
- [2] Stone, R. Introduction to Internal Combustion Engines. 4th ed. London: Palgrave Macmillan; 2012.
- [3] Ladommatos, N., Abdelhalim, S., Zhao, H., & Hu, Z. The effects of carbon deposits on engine performance. SAE Technical Paper. 2019.
- [4] Taylor, C. F. The Internal Combustion Engine in Theory and Practice. MIT Press; 2015.
- [5] Bosch. Automotive Handbook. 10th ed. Wiley; 2018.
- [6] Kuo, B. C. Automatic Control Systems. 9th ed. Wiley; 2014.
- [7] Ogata, K. Modern Control Engineering. 5th ed. Prentice Hall; 2010.
- [8] Banzi, M., & Shiloh, M. Getting Started with Arduino. Maker Media; 2014.
- [9] Monk, S. Programming Arduino: Getting Started with Sketches. McGraw-Hill; 2016.
- [10] Ibrahim, D. Microcontroller Based Applied Digital Control. Wiley; 2006.
- [11] Çengel, Y. A., & Cimbala, J. M. Fluid Mechanics: Fundamentals and Applications. McGraw-Hill; 2018.
- [12] Fox, R. W., McDonald, A. T., & Pritchard, P. J. Introduction to Fluid Mechanics. Wiley; 2015.
- [13] White, F. M. Fluid Mechanics. 8th ed. McGraw-Hill; 2016.
- [14] Pulkrabek, W. W. Engineering Fundamentals of the Internal Combustion Engine. Pearson; 2013.
- [15] SAE International. Fuel System Cleaning and Carbon Deposit Control. SAE Standard; 2020.

- [16] Zhao, H. *Advanced Direct Injection Combustion Engine Technologies*. Woodhead Publishing; 2010.
- [17] Ferguson, C. R., & Kirkpatrick, A. T. *Internal Combustion Engines: Applied Thermosciences*. Wiley; 2015.
- [18] Kim, J., & Park, S. Experimental study on intake valve carbon deposits and engine performance. *Applied Thermal Engineering*. 2021.
- [19] Lee, S., & Min, K. Effects of fuel quality on combustion chamber deposits. *Energy Conversion and Management*. 2020.
- [20] Rahman, M. M., et al. Performance analysis of small engine cleaning systems using suction-based methods. *Journal of Mechanical Engineering Science*. 2022.
- [21] Kalghatgi, G. *Fuel/Engine Interactions*. SAE International; 2014.
- [22] Heywood, J. B., & Sher, E. *The Two-Stroke Cycle Engine: Its Development, Operation, and Design*. Taylor & Francis; 2017.
- [23] Turns, S. R. *An Introduction to Combustion: Concepts and Applications*. 3rd ed. McGraw-Hill; 2012.