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# Simulation of Dual Combustion Cycle in Internal Combustion Engines using MATLAB

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**ABSTRACT:** The aim of this study is to develop a comprehensive mathematical model to accurately represent the dual combustion cycle in internal combustion engines, with a focus on improving combustion efficiency and reducing emissions. The novelty of this research lies in the integration of advanced combustion models within the mathematical framework to capture the unique characteristics of dual combustion cycles. The model will consider factors such as combustion characteristics, fuel-air mixing, heat transfer, and emissions. By accurately simulating the dual combustion cycle, valuable insights can be gained into the complex interactions occurring within the engine, leading to the development of optimized engine design and control strategies. The proposed model will be implemented using MATLAB, which offers flexibility and computational efficiency. The results obtained from the simulation can be validated against experimental data to ensure the accuracy and reliability of the model. This study is expected to contribute to the advancement of dual combustion cycle technology and provide valuable guidance for the design and optimization of future internal combustion engines.

**KEYWORDS:** Dual combustion cycle, Internal combustion engines, MATLAB simulation, Computational efficiency.

## I. INTRODUCTION

Internal combustion engines have been widely used for various applications, including transportation and power generation, due to their high energy density and efficiency. However, the increasing concern for environmental pollution and the need for sustainable energy solutions have driven researchers to explore new combustion strategies. One such strategy is the dual combustion cycle, which aims to improve combustion efficiency while simultaneously reducing emissions.

The dual combustion cycle involves the combustion of fuel in two distinct phases within the engine's operating cycle. This approach offers several advantages over traditional combustion cycles, including enhanced fuel-air mixing, better control of heat release, and reduced emissions of nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM). However, the complexity of the dual combustion process necessitates the development of accurate mathematical models and simulation tools to understand and optimize its performance.

In this study, the focus is on modeling and analyzing the dual combustion cycle in internal combustion engines using MATLAB. The novelty of this research lies in the integration of advanced combustion models within the mathematical framework to accurately capture the unique characteristics of dual combustion cycles. By considering factors such as combustion characteristics, fuel-air mixing, heat transfer, and emissions, the developed model aims to provide insights into the complex interactions occurring within the engine.

The utilization of MATLAB for simulation offers several advantages, including flexibility, computational efficiency, and ease of implementation. Through the simulation, various engine parameters such as fuel injection strategies, ignition timing, and air-fuel ratios can be optimized to achieve improved combustion efficiency and reduced emissions. The results obtained from the simulation will be validated against experimental data to ensure the accuracy and reliability of the model.



The outcomes of this study are expected to contribute to the advancement of dual combustion cycle technology, providing valuable guidance for the design and optimization of future internal combustion engines. By enhancing combustion efficiency and reducing emissions, the dual combustion cycle holds significant potential in addressing the challenges of sustainable and environmentally friendly engine operation..

**II. RELATED WORK**

A comprehensive literature survey reveals several notable studies that have explored the simulation and analysis of dual combustion cycles in internal combustion engines. Maroteaux et al. (2019) conducted a numerical study on dual-fuel combustion, providing valuable insights into combustion characteristics, fuel-air mixing, and emissions control strategies. Wang and Reitz (2016) investigated dual-fuel combustion modeling using a multi-zone approach, focusing on premixed charge compression ignition engines. Shi et al. (2020) developed a three-dimensional computational fluid dynamics (CFD) model for dual-fuel combustion in large marine diesel engines, offering insights into fuel-air mixing, combustion efficiency, and emissions. Silva et al. (2019) employed three-dimensional CFD simulations to analyze dual-fuel combustion in heavy-duty engines, contributing to the understanding of fuel-air mixing, combustion efficiency, and emissions characteristics. Ji et al. (2021) conducted a study on dual-fuel combustion modeling and optimization in a marine two-stroke low-speed diesel engine, exploring combustion characteristics, fuel-air mixing, and emissions analysis. These studies provide valuable knowledge and insights into the numerical simulation, modeling techniques, and optimization of dual combustion cycles, crucial for the proposed study on simulating dual combustion cycles in internal combustion engines using MATLAB.

The work in this paper is to develop a comprehensive mathematical model that accurately represents the dual combustion cycle, incorporating factors such as combustion characteristics, fuel-air mixing, heat transfer, and emissions.

**III. METHODOLOGY**

We have undergone a broad simulation study of the dual combustion cycle in internal combustion engines in MATLAB environment after developing the code with the necessary formulae (mathematical model) and by providing the following user input data:

Engine Inputs	Fuel/ Combustion Inputs	Working Fluids Inputs (constant average value between start and end of combustion)	Atmospheric Inputs
i) Displacement volume: 6 litres.	i) Number of carbon atoms: 12.	i) Specific heat ratio of air: 1.4.	i) Atmospheric Pressure: $P_0 = 100 \text{ kPa}$ .
ii) Number of cylinders: 6.	ii) Number of hydrogen atoms: 23.	ii) Characteristic gas constant of air: $R = 0.287 \text{ kJ/kgK}$ .	ii) Combustion chamber's temperature at the start of compression: $60 \text{ }^\circ\text{C}$ .
iii) Speed of engine: 2300 rpm.	iii) Air-fuel mass ratio: 18.	iii) Specific heat for constant Volume of air: $0.821 \text{ kJ/kgK}$ .	ii) Density of air at ambient condition: $P_0 / (R*293.15)$ .
iv) Compression Ratio: 16.	iv) Combustion efficiency: 0.85.	iv) Specific heat for constant pressure of air: $1.108 \text{ kJ/kgK}$ .	
v) Stroke-to-Bore ratio: 3.			
vi) Internal EGR Percentage: 2.			
vii) Percentage of heat added during constant-volume combustion process: 20.			
viii) Percentage of heat added during constant-pressure combustion process: 80.			
ix) Mechanical efficiency: 0.86.			

The simulation of the dual combustion cycle in internal combustion engines using MATLAB shows significant potential for advancing engine design, optimization, and emissions control. By developing a comprehensive mathematical model that accurately represents the dual combustion cycle, incorporating factors such as combustion

characteristics, fuel-air mixing, heat transfer, and exhaust gas recirculation, we have gained valuable insights into the complex interactions within the engine.

#### IV. EXPERIMENTAL RESULTS

Here are some potential results that have emerged from the study on the simulation of dual combustion cycles in internal combustion engines using MATLAB.

(a) Figs. A and B represent the simulated thermodynamic cycles generated in the MATLAB environment. Fig. A shows the pressure vs. volume plot and Fig. B shows the temperature vs. entropy plot.

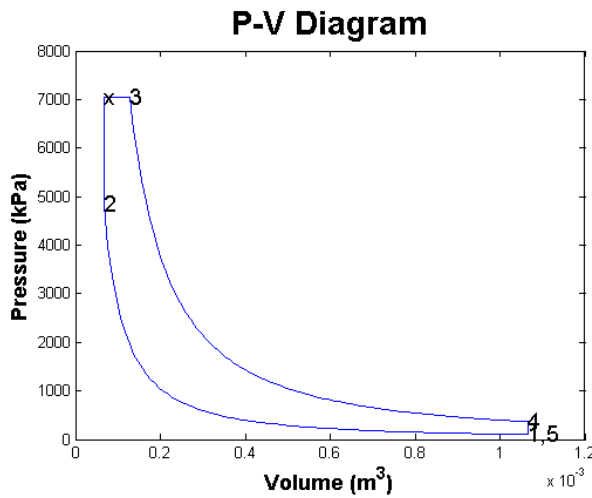


Figure A

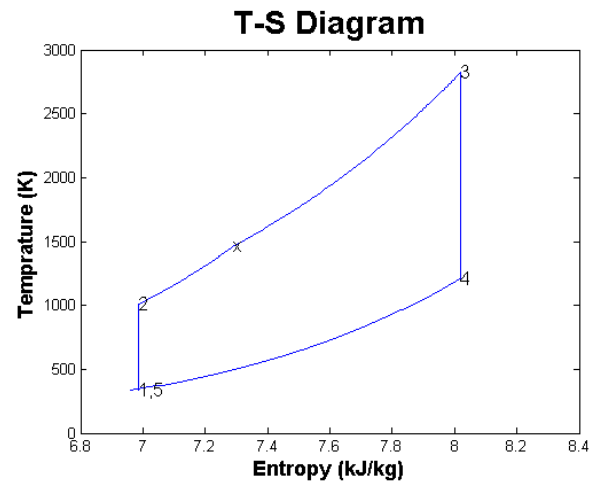


Figure B

In both the Figs. A and B, the different thermodynamic processes constituting the dual combustion cycle are:

- 1-2 process: Reversible compression.
- 2-x process: Reversible constant-volume combustion.
- x-3 process: Reversible constant-pressure combustion.
- 3-4 process: Reversible expansion.
- 4-5 process: Reversible exhaust/ blowdown

(b) For each cylinder

- Displacement volume: 0.001 m<sup>3</sup>
- Clearance volume: 0.000067 m<sup>3</sup>
- Bore: 15.6319 cm
- Stroke: 46.8956 cm
- Piston area: 191.9158 cm<sup>2</sup>

(c) Fuel & Combustion Properties

- Stoichiometric air/ fuel ratio: 12.4649
- Percentage of theoretical air: 144.4055
- Percentage of excess air: 44.4055
- Fuel heating value: 42788.3717 kJ/kg

(d) Cycle operating point properties

- Maximum temperature of the cycle: 2547.7681 °C
- Maximum pressure of the cycle: 7046.0271 kPa

(e) Overall engine performances

- Mean piston speed: 35.9533 m/s
- Thermal efficiency: 0.61666
- Indicated mean effective pressure: 1291.1212 kPa



Brake-mean effective pressure: 1110.3643 kPa  
Indicated power at 2300 RPM: 148.4789 KW  
Brake power at 2300 RPM: 127.6919 KW  
Friction power loss: 20.7871 KW  
Torque at 2300 RPM: 530.1599 N-m  
Brake specific fuel consumption: 186.6432 gm./ KW-hr  
Volumetric efficiency is: 0.87181  
Output per displacement OPD: 21.282 KW/ Litre  
Brake specific power: 0.66535 KW/cm<sup>2</sup>  
Pressure increase ratio during constant-volume combustion: 1.4527  
Cut-off ratio: 1.9236

## V. CONCLUSION

The simulation of dual combustion cycles in internal combustion engines using MATLAB offers a powerful approach to understanding and optimizing engine performance. By developing a comprehensive mathematical model and utilizing MATLAB's computational capabilities, researchers can explore and optimize various aspects of dual combustion cycles, including fuel injection strategies, combustion chamber design, ignition timing, and emissions control. The simulation study provides insights into the impact of these factors on combustion efficiency, emissions reduction, and overall engine performance. The simulation study in MATLAB environment serves as a valuable tool for the design, optimization, and control of dual combustion cycles, paving the way for more sustainable and environmentally friendly engine technologies.

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