Portable Autonomous CO_2 Capture and Solid Carbon Production System for Aviation Applications

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Abstract - This paper presents a novel portable and autonomous system designed to capture carbon dioxide (CO2) directly from aircraft exhaust gases and convert it into solid carbon and oxygen through an electrochemical process. The system is compactly integrated near the aircraft's engine wings, where it captures CO2 from exhaust emissions and channels it into a conversion module. Inside the module, the captured CO2 is reduced into solid carbon particles with a fine circular grain structure, while oxygen is simultaneously released into the atmosphere. The produced carbon is collected in an onboard storage tank equipped with an emergency ejection mechanism supported by a parachute for safe release in designated collection zones far from human settlements. This feature ensures aircraft safety while allowing post-flight recovery and reuse of the collected carbon. The system operates autonomously with minimal manual control, using the aircraft's electrical power supply and sensor feedback for continuous emission processing. Although the process increases fuel consumption by approximately 20 percent due to the added power demand and aerodynamic load, it offers a promising approach to achieve in-flight carbon reduction and promote sustainable aviation. The recovered solid carbon can be repurposed in pigment, rubber, or composite material manufacturing, thereby supporting a circular economy, and providing dual environmental and industrial benefits.

***Key Words*:** CO2 capture, solid carbon conversion, aviation emissions, electrochemical reduction, portable carbon capture, autonomous emission control, sustainable aviation, parachute storage, carbon reuse, green aircraft technology

1. INTRODUCTION

The aviation industry is one of the fastest-growing contributors to global carbon dioxide (CO2) emissions. Modern aircraft engines burn large quantities of aviation fuel, releasing CO2 and other greenhouse gases directly into the upper atmosphere, where their environmental impact is greater due to reduced atmospheric mixing and longer residence time. With the rapid increase in air traffic worldwide, the total emission of CO2 from aircraft has become a serious environmental challenge that demands immediate technological intervention.

Conventional methods of carbon capture and storage are designed primarily for stationary sources such as power plants and industrial chimneys. These systems are large, heavy, and require complex infrastructure, making them unsuitable for airborne applications. Furthermore, most traditional carbon capture systems only store the captured CO2 without converting it into any usable product, which limits their long-term practicality for mobile platforms like aircraft.

To overcome these challenges, this study introduces a Portable Autonomous CO2 Capture and Solid Carbon Production System specifically designed for aviation applications. The system operates by capturing CO2 directly from aircraft exhaust gases, converting it into solid carbon and oxygen through an electrochemical process, and safely storing the solid carbon onboard. The generated oxygen is released back into the atmosphere, improving the air composition around the exhaust flow.

The entire process is autonomous and requires minimal manual control. The compact system is installed near the aircraft engine wings, where the exhaust gases pass through a CO2 capture unit. The captured gas is then directed to an electrochemical conversion chamber that separates carbon from oxygen. The produced carbon particles are collected in a detachable storage tank, which can be released with the help of a parachute mechanism during emergencies or after storage saturation. The dropped storage units can be recovered from pre-selected remote zones for further processing and recycling of the carbon material.

The proposed concept not only addresses the issue of aviation-related CO2 emissions but also creates a new opportunity for resource recovery through the utilization of solidified carbon. Although the system slightly increases fuel consumption due to added weight and power requirements, it provides a significant step toward reducing the environmental impact of air travel. By integrating emission capture, conversion, and onboard carbon storage, this system demonstrates a practical and sustainable approach to cleaner aviation technologies.

2. RESEARCH GAP

The aviation sector remains a major source of carbon dioxide emissions, yet very few studies have focused on capturing CO2 directly during flight. Most existing carbon capture technologies are large, stationary, and unsuitable for aircraft due to weight, space, and power limitations. Current efforts mainly target alternative fuels or efficiency improvements, which reduce but do not eliminate CO2 emissions.

Additionally, conventional systems store captured CO2 in liquid or gaseous form, requiring heavy pressurized tanks and complex infrastructure. No existing approach converts CO2 into a stable, solid by-product during flight. There is also limited research on autonomous, compact systems capable of functioning under high exhaust velocity and variable pressure conditions in aircraft environments.

This gap highlights the need for a lightweight, portable, and self-operating CO2 capture system that can convert emissions into a safe and useful form. The proposed Portable Autonomous CO2 Capture and Solid Carbon Production System aims to bridge this gap by transforming CO2 into solid carbon while releasing oxygen, offering a practical path toward sustainable aviation.

3. PROBLEM STATEMENT

Aircraft engines release large amounts of carbon dioxide directly into the atmosphere, contributing significantly to global warming. Existing carbon capture technologies are bulky, stationary, and unsuitable for in-flight use due to high weight and power requirements. Currently, there is no compact and autonomous system capable of capturing and processing CO2 during flight.

To address this issue, a portable and lightweight system is needed that can capture CO2 from aircraft exhaust, convert it into solid carbon, and safely store it without affecting flight performance. The proposed Portable Autonomous CO2 Capture and Solid Carbon Production System aims to fulfill this need and reduce aviation-related emissions effectively.

4. OBJECTIVES

The following are the main objectives of this project:

1. To design a lightweight and compact CO_2 capture system suitable for installation near aircraft engine exhausts.
2. To develop an autonomous electrochemical unit that converts captured CO_2 into solid carbon and oxygen during flight.
3. To integrate a safe storage mechanism with an emergency parachute-based ejection system for solid carbon disposal.
4. To evaluate the system's potential in reducing aviation emissions and promoting sustainable air travel.

5. DESIGN AND METHODOLOGY

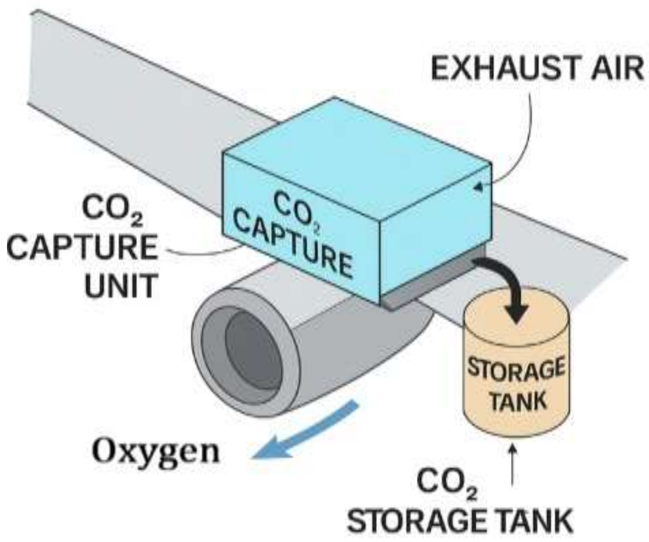

Fig: The System structure

The proposed portable autonomous co₂ capture and solid carbon production system is designed to operate directly on an aircraft by attaching near the engine wings. the system consists of three major units: a co₂ capture unit, an electrochemical conversion module, and a solid carbon storage and ejection system. The complete setup is powered by the aircraft's auxiliary electrical supply and functions automatically with the help of sensors and controllers.

this design achieves direct in-flight co₂ capture and conversion without interfering with aircraft performance. although it slightly increases power consumption and aerodynamic drag, the environmental benefits of emission reduction and carbon reuse outweigh these limitations.

6. WORKING PRINCIPLE

- **co_2 capture unit** the exhaust gases leaving the aircraft engine first pass through a compact capture chamber. this chamber is equipped with high-temperature resistant filters coated with advanced sorbent materials such as amine-based compounds or metal-organic frameworks. these materials selectively absorb co_2 from the exhaust stream while allowing other gases to pass. the design ensures minimal pressure loss and stable performance under varying exhaust velocities.
- **electrochemical conversion module** the absorbed co_2 is directed into an electrochemical cell, where it undergoes a controlled reduction reaction. the cell contains a catalyst-coated electrode system powered by a low-voltage electrical supply. during this process, co_2 molecules are split into solid carbon and oxygen according to the overall reaction: $co_2 \rightarrow c\ (solid) + o_2$ the solid carbon is produced as fine granular particles, while oxygen is released through a separate outlet into the atmosphere. this conversion helps neutralize harmful emissions while producing a useful by-product.
- **storage and ejection system:** the solid carbon produced in the conversion chamber is collected in a sealed onboard storage tank. the tank is lightweight and detachable, designed with heat insulation to maintain safety during operation. once it reaches capacity, or in emergency conditions, it can be released from the aircraft using a parachute mechanism. the ejected storage unit descends safely to a designated recovery zone, located away from human settlements, where the collected carbon can later be processed for industrial use.
- **autonomous operation and control** the entire system operate automatically using real-time sensor data to monitor exhaust flow rate, temperature, and pressure. a control unit adjusts co_2 absorption and conversion rates accordingly. this minimizes manual intervention and ensures continuous operation throughout the flight.

7. ADVANTAGES

- Captures and converts harmful CO_2 emissions directly during flight, reducing the environmental impact of aviation.
- Produces solid carbon as a reusable by-product that can be used in pigment, ink, or composite material manufacturing.
- Operates autonomously with minimal manual control, ensuring safe and continuous emission management.
- Compact and lightweight design suitable for installation near aircraft engine wings without major structural changes.
- Includes a parachute-based ejection system for safe disposal and recovery of stored carbon in emergencies.
- Releases oxygen as a by-product, improving the air composition in the surrounding atmosphere.
- Promotes sustainable aviation practices and supports the development of green aircraft technologies.

8. APPLICATIONS

- Can be installed on commercial, cargo, and defense aircraft to reduce in-flight CO_2 emissions.
- Useful for research aircraft and experimental aviation programs focusing on green and sustainable technologies.
- Applicable in airports for testing and demonstrating on-ground engine emission reduction systems.
- Can support future hybrid or electric aircraft designs by integrating with onboard environmental management systems.
- Provides a foundation for developing large-scale airborne carbon capture and recycling industries.

9. FUTURE SCOPE

- The system can be further optimized by using lightweight composite materials to reduce the additional load on the aircraft.
- Advanced catalysts and sorbents can be developed to improve CO_2 absorption and conversion efficiency.
- Integration with artificial intelligence can enable smart control for real-time monitoring and adaptive operation.
- Future versions can include in-built recycling units to process the collected solid carbon during long-distance flights.

- Large-scale testing on different aircraft models can help standardize the technology for commercial aviation use.
- Collaboration with aerospace industries can lead to the development of next-generation green aircraft systems.

10. CONCLUSION

The proposed portable autonomous CO_2 capture and solid carbon production system offers an innovative solution to reduce carbon emissions directly from aircraft exhaust. By combining CO_2 absorption, electrochemical conversion, and onboard storage, the system effectively transforms harmful emissions into reusable solid carbon while releasing oxygen back into the atmosphere. Its lightweight and compact design allows easy integration with aircraft structures without major modifications. Although the system slightly increases power consumption and aerodynamic load, the environmental benefits and potential industrial reuse of the collected carbon make it a promising step toward sustainable aviation. With further optimization, large-scale testing, and material advancements, this technology can play a key role in future green aircraft systems and contribute to reducing the aviation industry's overall carbon footprint.

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