ISSN: 2710-0170

Blue Ocean Strategy of Dynamic Vacuum in the eVTOL Industry

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Abstract

This paper explores the application of vacuum technology as a blue ocean strategy within the emerging electric vertical take-off and landing (eVTOL) industry. The research begins by outlining the broad applications of vacuum science in traditional industrial sectors. It then focuses on the prospects and challenges of eVTOL aircraft, identified as a high-potential future market. The core analysis demonstrates how vacuum pumps are critical in key eVTOL manufacturing and testing processes, including the curing of carbon fiber reinforced polymer (CFRP) composites for lightweighting, simulation testing of battery thermal management systems (BTMS), and optimization of hydrogen fuel cell systems under low-pressure conditions. By applying the Blue Ocean Strategy framework—including the ERRC (Eliminate, Reduce, Raise, Create) Grid and the Six Paths Framework—the study argues that the eVTOL sector represents an uncontested market space for vacuum technology. The conclusion emphasizes that vacuum science, by enabling lightweight material production and system validation, is poised to be a key enabler for urban air mobility, especially within China's policy-supported low-altitude economy landscape. (Approximately 150 words)

Keywords

Vacuum, eVTOL, blue ocean strategy, composite curing, lightweight materials.

1. Introduction

Vacuum science and technology are foundational to a vast array of industrial and scientific fields, from manufacturing and materials processing to electronics and aerospace. Traditionally, dynamic vacuum systems have served established sectors like packaging, medical devices, and industrial handling, where reliability and cost-efficiency are paramount. However, as these markets become increasingly saturated—representing a "red ocean" of intense competition—new avenues for growth must be identified. This paper posits that the burgeoning electric vertical take-off and landing (eVTOL) aircraft industry constitutes a significant "blue ocean" opportunity for vacuum technology. eVTOL development is driven by urbanization, traffic congestion, and strong policy support, particularly in regions like China which promotes its "low-altitude economy" [1, 2]. The central hypothesis is that vacuum technology is not merely supportive but indispensable for overcoming critical eVTOL challenges, primarily the need for extreme lightweighting and rigorous system validation under flight conditions. This introduction establishes the research background, defines the strategic problem of market saturation versus innovation, and underscores the importance of pivoting vacuum applications towards this emerging, high-value sector.

2. eVTOL Industry and the Role of Vacuum Technology

2.1. Market and Policy Prospects for eVTOL

The eVTOL market is poised for significant growth, fueled by demand in urban air mobility, logistics, and emergency services [3]. This growth is strongly supported by governmental

ISSN: 2710-0170

policies, such as China's inclusion of the "low-altitude economy" in its national transport network plan, creating a favorable regulatory and developmental environment [4].

2.2. Key Challenges and Technological Needs

A primary barrier to eVTOL adoption is the power-to-weight ratio, making lightweighting a non-negotiable design imperative [5]. Additionally, all critical systems, including batteries and fuel cells, must be validated for performance and safety under the low-pressure conditions experienced at operational altitudes.

2.3. Application of Vacuum Technology in eVTOL

2.3.1. Preparation of Carbon Fiber Reinforced Polymer (CFRP) Composites

The curing of CFRP, essential for lightweight airframes, requires a controlled vacuum environment. Dry screw vacuum pumps are used to remove air bubbles and volatiles during resin infusion, ensuring a void-free, high-strength composite structure critical for components like rotor blades and fuselages [6].

2.3.2. Simulation Testing of Battery Systems

Battery Thermal Management Systems (BTMS) must be tested under vacuum conditions to simulate high-altitude, low-pressure environments. Vacuum chambers enable the evaluation of heat dissipation efficiency and thermal runaway prevention, ensuring compliance with aviation standards like DO-160G [7].

2.3.3. Optimization of Hydrogen Fuel Cell Systems

For hydrogen fuel cell-powered eVTOLs, vacuum simulation helps optimize air supply, humidity control, and thermal management for thin-air conditions, maximizing energy efficiency and endurance [8].

3. Blue Ocean Strategic Analysis for Vacuum Technology

3.1. Red Ocean vs. Blue Ocean Strategy

The table below contrasts the competitive landscape of traditional vacuum applications (Red Ocean) with the opportunity in the eVTOL sector (Blue Ocean).

Table 1: Strategic Comparison: Red Ocean vs. Blue Ocean for Vacuum Technology

aspect	red ocean	blue ocean
market focus	Industrial sectors (packaging, HVAC, medical devices)	Emerging eVTOL industry (urban air mobility)
competition	High (established players like Atlas Copco, Busch)	Low (niche applications, few specialized
value proposition	Cost efficiency, reliability, standardized solutions	Lightweighting, high-precision vacuum for CFRP curing, battery/fuel cell optimization
innovation	Incremental improvements (e.g., energy efficiency)	Disruptive (vacuum-enabled composite curing, simulation testing)
customer base	Industrial sectors with mature demand	eVTOL manufacturers, composite suppliers, aerospace R&D
policy alignment	Limited government incentives	Strong support (China’s low-altitude economy policies)

key challenge	Price wars, saturated markets	Lightweighting, battery/fuel cell efficiency, certification
revenue model	Equipment sales, maintenance contracts	Integrated solutions, partnerships, vacuum-as-a-service

Aspect Red Ocean (Traditional Sectors) Blue Ocean (eVTOL Sector)

Market Focus Packaging, medical devices, general industry Urban Air Mobility (UAM), aerospace manufacturing

Competition High (established players like Atlas Copco) Low (niche, specialized applications)

Value Proposition Cost efficiency, reliability Lightweighting, high-precision curing & testing

Innovation Incremental (energy efficiency) Disruptive (enabling new material/process paradigms)

Policy Alignment Limited Strong (e.g., China's low-altitude economy policy)

3.2. ERRC Grid Analysis

The ERRC Grid outlines actions to create a new value curve for vacuum technology in eVTOL.

Table 2: ERRC Grid for Vacuum Technology in eVTOL

Eliminate	Reduce	Raise	Create
Oil-lubricated vacuum pumps (risk of contamination in CFRP curing)	Weight of vacuum systems (align with eVTOL lightweighting)	Precision in vacuum control (for defect-free composite curing)	Integrated vacuum solutions for eVTOL manufacturing
Manual quality inspection processes	Energy consumption (optimize for battery/fuel cell testing)	Speed of composite curing cycles (faster production)	Smart vacuum systems with IoT monitoring
Standalone vacuum systems (non-integrated)	Downtime (predictive maintenance)	Compliance with aerospace standards (e.g., DO-160G)	Vacuum-as-a-service for eVTOL startups
Traditional industrial applications (low-value markets)	Operational complexity (automation)	Durability of vacuum-coated sensors (e.g., LIDAR)	Strategic partnerships with eVTOL OEMs (e.g., Antai Composites)

Eliminate Reduce Raise Create

Oil-lubricated pumps (risk of contamination) System weight and energy consumption Precision in vacuum control for defect-free curing Integrated "vacuum-as-a-service" solutions

Manual inspection processes Production downtime Speed of composite curing cycles Smart IoT-enabled vacuum monitoring systems

Non-integrated, standalone systems Operational complexity Compliance with aerospace standards (e.g., DO-160G) Strategic partnerships with eVTOL OEMs

3.3. Six Paths Framework Application

The framework suggests strategic moves:

· Path 1 (Industry): Adapt high-precision vacuum technology from semiconductor manufacturing to eVTOL composite curing.

ISSN: 2710-0170

· Path 2 (Strategic Group): Shift focus from traditional aviation to agile eVTOL startups.

· Path 3 (Buyer Group): Target eVTOL manufacturers and composite material suppliers directly.

· Path 4 (Offering): Bundle vacuum systems with simulation software for integrated testing solutions.

· Path 5 (Functional Orientation): Rebrand from equipment supplier to "enabler of urban air mobility."

· Path 6 (Time): Capitalize on current policy momentum and invest in R&D for next-generation eVTOL energy systems.

4. Conclusion

This study demonstrates that the eVTOL industry represents a viable and lucrative blue ocean strategy for dynamic vacuum technology. Compared to traditional, saturated markets, the eVTOL sector offers an uncontested space with high growth potential driven by policy and innovation needs. The theoretical value lies in applying established strategic frameworks (Blue Ocean Strategy, ERRC, Six Paths) to a novel cross-industry opportunity, illustrating how mature technologies can pivot to serve emerging paradigms. In practical terms, vacuum technology provides critical solutions to the foremost eVTOL challenges: enabling the production of lightweight CFRP composites through precise curing, validating system safety via vacuum simulation testing, and optimizing alternative propulsion systems like hydrogen fuel cells. While existing research has well-established vacuum applications in traditional fields, this paper advances the discourse by systematically linking these capabilities to the specific, unmet needs of the eVTOL value chain.

The primary limitation of this research is its conceptual and strategic nature, relying on secondary data and market analysis. Future work should involve empirical case studies, technical feasibility assessments, and cost-benefit analyses with eVTOL manufacturers. Further investigation is also needed into the development of standardized vacuum system interfaces for eVTOL manufacturing lines. It is recommended that vacuum technology firms actively seek partnerships with eVTOL original equipment manufacturers (OEMs) and composite material specialists to co-develop tailored solutions. By doing so, they can secure a first-mover advantage in this blue ocean, transforming vacuum technology from a supporting tool into a foundational pillar for the future of urban air mobility.

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