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THE AERODYNAMIC BEHAVIORAL STUDY OF CANARD PLANE WITH FAN WING CONFIGURATION

Ua У цій роботі досліджується оптимізація аеродинамічної схеми «качка» за умови використання пропульсивних силових установок інтегрованих в крило для підвищеної ефективності системи. Основні цілі — дослідження на стійкість та керованість; зменшення лобового опору повітря за рахунок застосування перспективної аеродинамічної схеми, яка дозволяє ефективніше використовувати явище заповнення сліду за крилом при використанні пропульсивної силової установки в його конструкції. У дослідженні також наголошується на стратегічних аспектах дизайну крила, фюзеляжу та прилеглих аеродинамічних поверхнях, які можуть покращити аеродинамічні характеристики. Збереження ефекту Коанда при цьому сприяє створенню зони низького тиску, покращуючи загальну ефективність. Робота також вказує на важливість легкості конструкції для безпеки та

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надійності. Чисельне моделювання підтверджує потребу у фізичних експериментах для підтвердження результатів. Експериментальні симуляції вказують на можливості стабільного та керованого польоту. Легкі, надійні конструкції та передові аеродинамічні концепції відкривають перспективи

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This study explores the optimization of the canard aerodynamic scheme by integrating wing-mounted propulsion systems to enhance efficiency. Key objectives include stability, controllability, and reducing frontal air resistance by employing an advanced aerodynamic scheme that effectively utilizes the wake filling phenomenon behind the wing when integrated with wing-mounted propulsion. The study emphasizes strategic design considerations for the wing, fuselage, and adjacent aerodynamic surfaces, which can enhance aerodynamic characteristics. Preserving the Coanda effect creates a low-pressure zone, improving overall efficiency. The paper underscores the importance of lightweight construction for safety and reliability. Numerical modeling underscores the need for physical experiments to validate results. Experimental simulations indicate possibilities for stable and controlled flight. Lightweight, reliable designs, and cutting-edge aerodynamic concepts offer prospects for improved efficiency and flight productivity.

Introduction

The optimization of flight performance and efficiency in aircraft design hinges on the intricacies of aerodynamic wing shaping. In the realm of aircraft equipped with integrated propulsion wing power plants, the interplay between wing design and airflow dynamics assumes even greater significance. This article delves into the essential factors that amplify aerodynamic attributes and design efficiency for such aircraft, focusing particularly on the innovative concept of Cannard planes.

Cannard aircraft, characterized by a distinct configuration wherein the front wing is strategically elevated above the main wing, offer a unique solution to prevent turbulent airflow as it approaches the main wing. This delicate arrangement ensures smoother airflow interaction and fosters improved overall performance.

A pivotal advancement within the realm of Cannard planes lies in the utilization of propulsion wings, a revolutionary technology enabling precise control of lifting forces. This control capability empowers adjustments in speed across the upper wing surface, with applications such as employing the reverse mode to effectively modify airflow over the wing's upper region. This maneuver enhances the aircraft's in-flight maneuverability and control. This fine-tuned control is achieved through the integration of a pair of independent rotary propulsion units within the wing structure, at least one per half-wing, effectively serving as ailerons. The variable rotation speed around the longitudinal axis further augments control finesse.

This article introduces a groundbreaking exploration into the unexplored aerodynamic potential of FanWing aircraft, within the context of Cannard planes. This novel proposition aims to refine rotor performance, optimize airflow along the aircraft's surface, and simultaneously address the reduction of drag forces in the event of a rotary power plant malfunction. These advancements are poised to significantly impact the aviation industry, promising elevated efficiency and heightened safety standards.

Recent research endeavors have heavily focused on flow control systems within boundary layers, meticulously investigating both passive and active control methodologies. While passive methods have garnered attention for their practical implementation and cost-effectiveness, this study underscores the critical importance of achieving equilibrium through a strategic blend of passive and active flow control techniques. Of particular relevance is the application of active flow control mechanisms for the optimization of propulsion wing aircraft performance.

To ensure the effective utilization of an integrated power system for the wing, achieving minimal frontal resistance of the experimental model and imparting significant kinetic energy to the airflow over the wing's surface is crucial [1]. In cases involving wings with rotor propulsion, the airflow provides substantial additional acceleration, leading to reduced pressure on the wing's surface according to Bernoulli's principle.

Consequently, this results in an increased pressure differential and lift force between the upper and lower wing surfaces [2, 3]. Incorporating a rotor propulsion system introduces the capability to artificially control lift force by altering speeds over the upper wing surface (e. g., through reverse mode). By employing a pair of independent rotor propulsion units, positioned at least one each on the wing's span, they can serve as control elements for rotations around the longitudinal axis, differentially adjusting rotation speeds. Demonstrating the FanWing concept entailed various experimental endeavors. Initial aerodynamic pipe investigations for the wing's test section were conducted by Albanese and Pebbles [4] at the University of Rome, yielding both flow visualization and data on characteristics including lift and drag coefficients.

Comparable research quickly emerged from scholars like Forshaw [5] and Coghlan [6] at Imperial College London, confirming that the efficiency of the scheme hinges on the Tip Speed Ratio (TSR), the ratio of fan blade tangential velocity to aircraft velocity at zero angle of attack. The TSR calculation utilized the external diameter of the tangential rotor propulsion wheel, normalized to free stream velocity. Thus, in terms of the displacement coefficient, this parameter can be expressed as: $TSR = 1/J$. Coghlan noted that the state of zero drag is attained at TSR values near 2,7, with a lift coefficient of nearly 6 units. Meanwhile, maximum lift coefficient values above 10 were measured at low flow speeds relative to rotor rotation. However, these investigations relied on somewhat imperfect models, prompting significant refinement of the FanWing concept through geometry optimization for enhanced efficiency. The novelty of the proposed research for wings lies in optimizing airflow along the profile and reducing frontal resistance when the rotor propulsion system is inactive. Numerous scientific inquiries have delved into flow control systems within the boundary layer, given their practical significance. Passive and active methods are employed for flow and boundary layer control, with simple and cost-effective control techniques being ideal for aviation. Lately, emphasis has been on passive means. For wings with rotor propulsion, combining both control methods is prudent, with a focus on active means. Mohamed Gad-el-Hak's work provides a detailed description and application possibilities for flow control methods, elucidating their rational application under low Reynolds numbers [7]. Duddempudi and colleagues utilized URANS methods to optimize the profile shape for the Fan-Wing scheme. Slimane Benferhat conducted similar research using CFD, focusing on the nose profile [8]. Their results highlighted that much lift is generated in the fan region due to the suction effect along the open fan blades. Their work achieved a remarkable reduction in pressure coefficient for the wing-rotor system through profile optimization. Figure 1 illustrates the static pressure distribution around the FanWing wing. Mikis Tsagarakis and Dominik Blonski meticulously explore optimal wing aerodynamic profiles for extended low Reynolds number flight in their study, forming the basis for subsequent investigations [9, 10]. They evaluate various profiles' pros and cons and establish the interplay between geometric parameters and aerodynamics. Fabricio De Gregorio and Edward Lumsden's research presents detailed vortex trap calculations on the wing's surface, promoting laminar flow and improving aerodynamic characteristics [11, 12]. Tae-An Kim's work focuses on conventional tangential fans and optimizing their exhaust shape, particularly positioning regarding the flow stabilizer representing the upper wing surface behind the rotor propulsion [13].

From 2010 onwards, a considerable amount of research has centered on the airflow emanating from the rotor propulsion and passing over the wing. Selva S. and Du S. discuss problems related to forming laminar flow behind the wing, as well as optimizing vortex shape and its influence on lift and thrust [14, 15]. Lin M.'s work outlines potential developments for aircraft of this type and provides insights into geometric parameters like wingspan and aspect ratio [16]. Salar Askari and Shojai-fard's investigations revolve around optimizing wing profiles, addressing sharp edges on the upper profile by substituting them with smoother, round ones to minimize pressure discontinuities [17]. CFD analysis demonstrates that pressure differences increase with higher Reynolds numbers, leading to enhanced aerodynamic forces and moments on the profile. The flow lines on the upper profile converge more closely with increasing fan rotational speed. Numerical solutions show that the velocity gradient on profile surfaces increases with Reynolds numbers, which corresponds to a higher friction coefficient on profile surfaces.

When it comes to achieving pitch stability in aircraft, the traditional approach involves using a horizontal tail. However, this isn't the only method at our disposal. An alternative option is a canard design, which places a smaller wing, known as a canard, in front of the main wing. In this article, we will simplify the analysis of this configuration to shed light on its unique characteristics.

Before setting up the analysis need establish a reference line for our fuselage. We'll denote this as the fuselage reference line. The canard is positioned at a specific angle of attack (α_h) with respect to this reference line, while the main wing has its angle of attack (α_w) as well. We'll assume that the thrust aligns with the fuselage reference line, the relative velocity (v_∞) is aligned, and we are at an angle (gamma) to the horizon. Our center of gravity is positioned at the front, and we'll measure all distances accordingly, fig. 1.

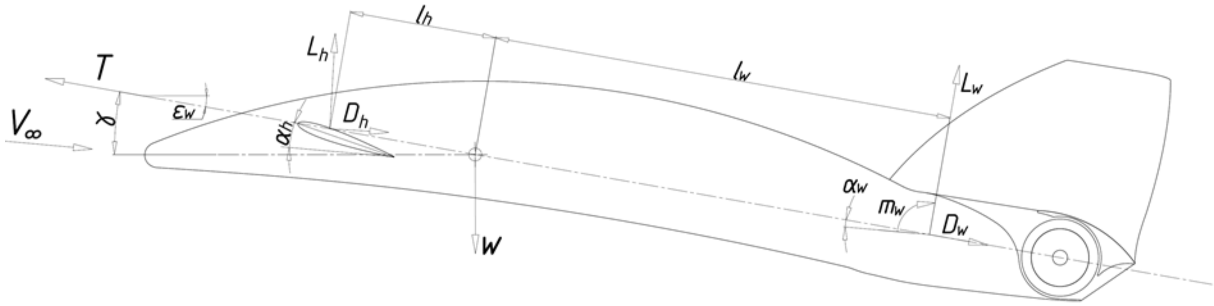

Fig. 1. Free body diagram for canard airplane

Now, we introduce the key parameters for calculation:

L_h: Lift of the horizontal stabilizer (canard wing);
L_w: Lift of the main wing;
S_h: Area of the canard wing ;
S_w: Area of the main wing;
c_h: Aerodynamic chord of the canard wing;
c_w: Aerodynamic chord of the main wing;
α_h: Mounting angle of the canard;
α_w: Mounting angle of the main wing.

For forces and moments analyzing we have lift (*L*), drag (*D*), and pitching moment (*M*) to consider.

Main wing: Lift on the main wing acts perpendicular to the direction of flight, while drag is aligned with the direction of flight. The pitching moment is also generated by the main wing.

Canard wing: The presence of the canard leads to an increase in angle of attack, referred to as "epsilon upwash," which affects the lift and drag on the horizontal tail. The horizontal tail also generates a pitching moment.

For the aircraft to be in trim, we must satisfy specific equations:

$$Cl_w + \frac{S_n}{S_w} \cdot Cl_h = C_w \cdot \cos\gamma. \tag{1}$$

Lift Equation: The sum of the coefficients of lift on the main wing and horizontal tail, adjusted by their respective areas and mounting angles, must equal the coefficient of weight or weight over the dynamic pressure term.

$$Cm = Cm_w + \frac{S_n}{S_w} \cdot \frac{c_h}{c_w} \cdot Cm_h - \frac{l_w}{c_w} \cdot Cl_w - \frac{S_h \cdot l_h}{S_w \cdot c_w} \cdot Cl_h = 0. \qquad (2)$$

Pitching Moment Equation: The pitching moment about the center of gravity must be zero. This equation balances the pitching moments generated by the main wing, horizontal tail, and their respective lift coefficients.

$$Cm_\alpha = \frac{-l_w}{c_w} \cdot Cl_{w,\alpha} - \frac{S_h \cdot l_h}{S_w \cdot c_w} \cdot Cl_{h,\alpha} < 0; \qquad (3)$$

$$Cl_w = Cl_{w,\alpha}\left(\alpha + \alpha_{0w} - \alpha_{L0w}\right); \qquad (4)$$

$$Cl_h = Cl_{h,\alpha}\left(\alpha + \alpha_{0h} - \alpha_{L0h} + \varepsilon_h + \varepsilon_l \cdot S_l\right); \qquad (5)$$

$$\varepsilon_h = \varepsilon_{h0} + \varepsilon_{h,\alpha} \cdot \alpha. \qquad (6)$$

Stability Condition: The derivative of the pitching moment equation with respect to alpha (Cm_α) must be less than zero, ensuring stability.

From our analysis, we gather some valuable insights:

The canard's lift (L_h) must be negative, implying it should sit in front of the center of gravity.

The lift coefficient on the canard (Cl_α) should be greater than zero.

The main wing (L_w) must generate positive lift.

Stability primarily comes from the main wing, not the canard. The canard has a destabilizing effect due to its position.

The canard design is less suitable for short takeoff and landing scenarios.

Canard designs often require high aspect ratio horizontal tails for efficiency.

Flaps should be present on both the main wing and canard for takeoff and landing.

Canard designs offer favorable stall characteristics, often preventing main wing stalls.

While traditional horizontal tail configurations remain prevalent, understanding the principles and trade-offs of canard designs provides a broader perspective on aircraft stability and performance. Canards can offer unique advantages, such as improved stall characteristics and efficient lift generation, but they also come with challenges, including potential obstructed pilot visibility. Exploring different aircraft configurations is essential for advancing aviation technology and enhancing aircraft capabilities.

In conclusion, the integration of propulsion wing power plants into Cannard planes opens up exciting possibilities for improved aerodynamic performance and flight characteristics. By exploring the unique capabilities of propulsion wings and implementing active flow control methods, this research aims to unlock the full potential of such aircraft configurations. The findings have practical implications for the development of more efficient and maneuverable aircraft in the future, contributing to advancements in aviation technology.

Problem Statement

The primary objective of this experiment is to comprehensively investigate and analyze the aerodynamic characteristics of the aircraft. The study is structured into several essential stages, each aimed at understanding and enhancing the aircraft's performance. The outlined stages are as follows:

Geometrical Parameter Definition and Aerodynamic Analysis: The initial step involves identifying and defining the basic geometrical parameters of the aircraft. Utilizing advanced numerical modeling techniques within the Pansym software and CFD Dassault Xflow, the aerodynamic characteristics of the aircraft will be meticulously calculated and simulated. This phase is crucial in gaining insights into the aircraft's behavior in various flight conditions.

Static Ground and Rejected Take-Off Tests: In the subsequent phase, comprehensive static tests will be conducted both on the ground and during rejected take-off scenarios. These tests will provide crucial real-world data that can be compared with the simulation results obtained in the first stage. By performing these tests, the team can validate the accuracy of the numerical models and better understand the aerodynamic behavior during critical moments of take-off.

Data Comparison and Analysis: The data collected from both numerical modeling and static tests will be thoroughly compared and analyzed. The objective is to identify any discrepancies and differences between the simulation and real-world results. This rigorous analysis will enable the team to pinpoint any shortcomings or areas for improvement in the aircraft's aerodynamic performance.

Identifying and Addressing Shortcomings: Based on the comparison and analysis of the data, any shortcomings in the aircraft's aerodynamic characteristics will be identified. These shortcomings will be documented and described in detail. Moreover, the research team will propose potential solutions and improvements to address these identified issues. By doing so, this study aims to contribute to the overall advancement of aircraft design and performance.

In conclusion, this experiment seeks to gain a comprehensive understanding of the aircraft's aerodynamic behavior through a well-structured and systematic approach. By combining advanced numerical modeling, real-world testing, and rigorous data analysis, the research team aims to enhance the aircraft's performance and ensure safer and more efficient flights. The findings of this study will provide valuable insights for the aerospace industry, furthering our knowledge and capabilities in the field of aerodynamics.

Basic geometrical parameters

The object of this study revolves around a canard aircraft featuring an innovative fanwing propulsion system. (Tab. 1)

***Table* 1.**

General characteristics

Scheme type	Fan-Wing	Propulsive wing
Overall length	680 mm	1350 mm
Wingspan	960 mm	1240 mm
Wing area	860 cm^2	1000 cm^2
Front wing area	128 cm^2	180 cm^2
Cruise speed	15 m/s (54 km/h)	
Powerplant	2 × Sunnysky X2212 KV980 II 4S (180W)	

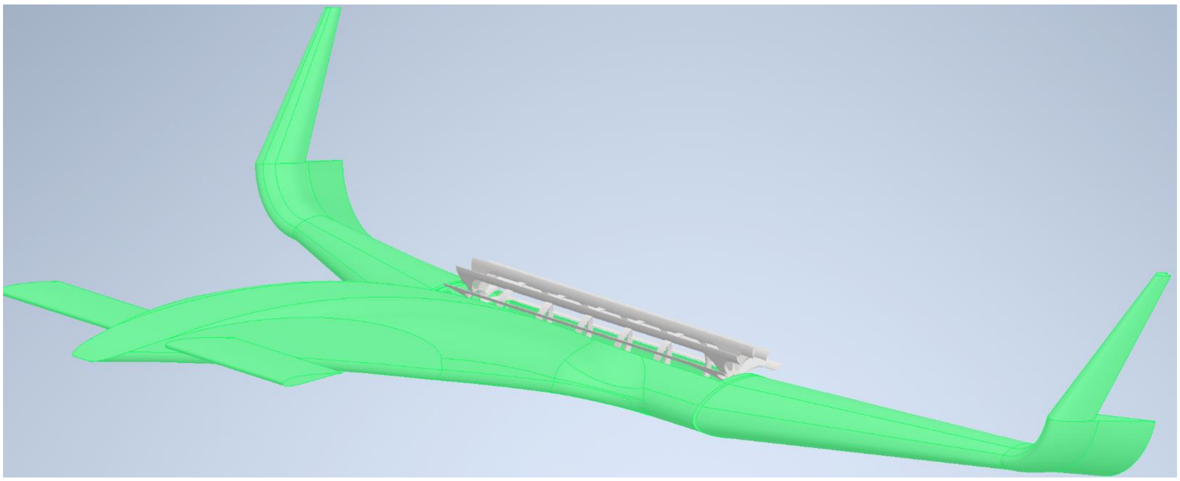

Fig. 2. Experimental concept design model of an aircraft with single Fan-Wing propulsion

The experimental model involves the selection of two fundamental wing configurations: the Fan-Wing design, as illustrated in Fig. 2, incorporating a front-mounted rotor, and the Propulsive Wing setup, showcased in Fig. 3, which places the rotor at the rear along with the use of a deflector. The decisive factor determining this choice is the presence of a fuselage that smoothly transitions into a thick wing. This arrangement adversely impacts the aerodynamic characteristics of the rotor due to shading, necessitating the choice of the second scheme for comprehensive investigations.

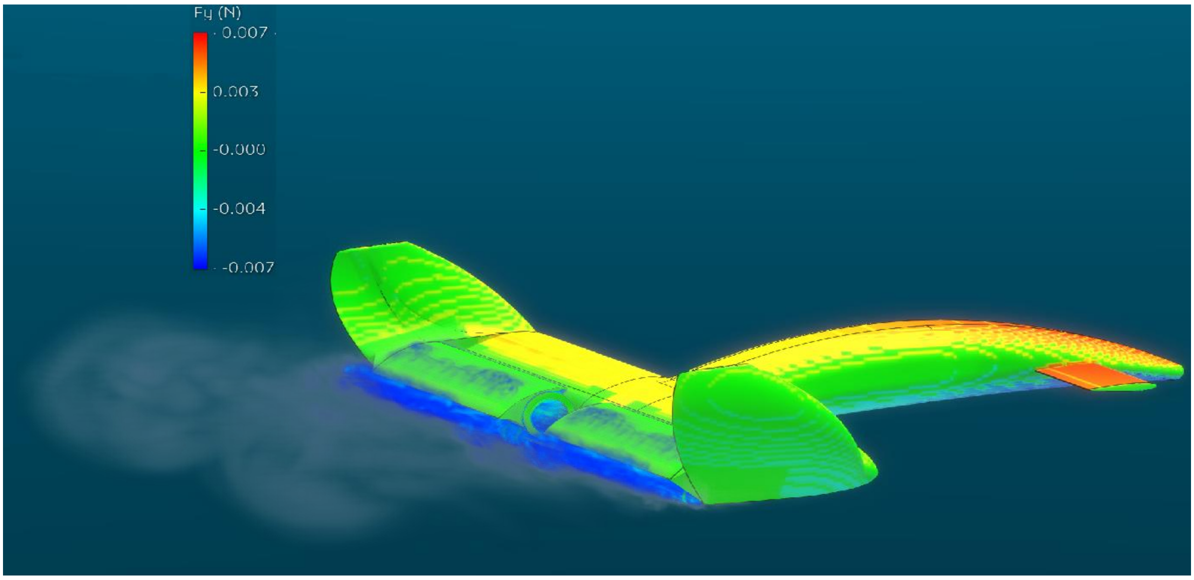

Fig. 3. Experimental Computational Fluid Dynamics (CFD) validation for an aircraft model with propulsion power plant

Powering this configuration are the Sunnysky X2212 KV980 II 3-4s electric motors, distinguished by their exceptional maximum rotational capability of 15,000 revolutions per minute. This attribute serves as a key feature in achieving the necessary angular velocity vital for our research objectives.

Within the wing structure, the rotor comprises a meticulously designed assembly of 20 blades, boasting a diameter of 60 mm and an operative length of 354 mm. Furthermore, the rotor is thoughtfully encompassed by an aerodynamic deflector. Significantly, this particular rotor configuration generates a static thrust of 18 *N*, further emphasizing its operational efficiency.

Calculation method

In order to ascertain the intricate aerodynamic characteristics, the investigation employed a modeling approach rooted in a category of computational methods known as aero-hydrodynamics of particles and Boltzmann lattice equations. Within the realm of nonequilibrium statistical mechanics, the Boltzmann equations assume the role of delineating the gas behavior at a mesoscopic scale. Noteworthy is their capacity to not only emulate hydrodynamic limits, but also aptly simulate rarefied mediums under diverse conditions encompassing aerospace, microhydrodynamics, and even vacuum scenarios. This technological paradigm aptly accommodates the simulation of intricate Computational Fluid Dynamics (CFD) processes, seamlessly transitioning through a spectrum of states, realistically capturing the dynamics of geometries, intricate multiphase flows, free surface phenomena, and the interplay between liquids and structural elements.

The algorithm, rooted in particle kinetics, expeditiously resolves problems while operating on relatively accessible hardware infrastructure. The utilization of the sampling method obviates the necessity for conventional grid construction by zones, thereby mitigating the constraint of surface complexity. During the grid-generation process, the technology adeptly adapts to optimize grid values automatically, exhibiting finer resolution within model boundaries and accommodating variations in input geometry and the inclusion of mobile components.

To effectively model turbulence, a high-precision approach, known as the Wall-Modeled Large Eddy Simulation (WMLES), is employed. This technique rests on modernized Large Eddy Simulation (LES) methods, built upon the foundation of the WALE (Wiskott-Aldred-Lagrée-Essers) viscosity model, tailored to address the computation of near-wall flows. This strategy yields a robust local model of vortex viscosity behavior, seamlessly navigating the complexities of the wall region. Importantly, the computational processing time associated with this approach remains comparable to that of programs focused solely on Reynolds analysis of Navier-Stokes equations (RANS).

The modeling process incorporates a unified nonequilibrium wall function to portray the boundary layer behavior. This comprehensive wall model stands effective across a broad spectrum of scenarios, negating the need for users to select from a range of disparate models and consider the associated limitations of each scheme.

The capabilities of advanced playback facilitate realistic visualizations, providing a lucid comprehension of the intricate flow patterns and thermal characteristics. This integrated approach ushers in a new realm of scientific inquiry, effectively bridging theory and experimentation for a more profound understanding of complex aerodynamic phenomena.

The numerical simulation calculation

In the pursuit of elevating aerodynamic efficiency, this study centers on a meticulous analysis of the aircraft's propulsion wing and frontal surface. The core goal is to achieve peak aerodynamic efficiency by seamlessly integrating computational fluid dynamics (CFD) simulations with robust experimental validation.

A crucial aspect explored in this research is the derivative of the pitching moment coefficient in relation to the lift coefficient. This parameter plays a pivotal role as it directly influences the aircraft's longitudinal static stability. The investigation delves into the pitching moment measured at various origins, aiming to pinpoint the center of gravity position that yields the correct pitching moment coefficient-to-lift coefficient slope. The origin's position, measured in millimeters relative to the aircraft's nose, provides spatial context.

A central focus of this research is to determine the aircraft model's maximum angle of attack, a pivotal parameter significantly shaping its aerodynamic behavior. The study aims to understand the angle's growth and decline within the supercritical limits. A controlled, gradual decline in the angle of attack is particularly advantageous, directly contributing to enhanced aircraft safety and improved handling, especially during extreme and emergency scenarios.

Despite the fixed aircraft geometry, the neutral point position remains consistent. By adjusting the origin position toward the aircraft's nose, the distance between the origin and the neutral point increases, fig. 4.

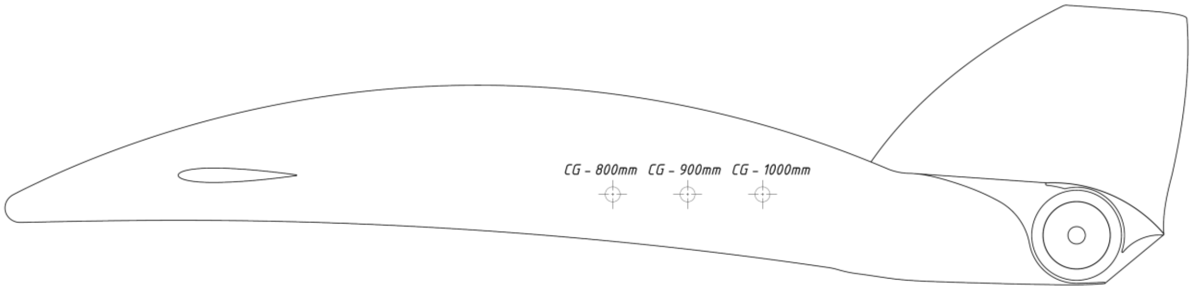

Fig. 4. Center of gravity variations in aircraft for exploring longitudinal stability

This alteration amplifies the slope of the pitching moment coefficient, leading to a more stable aircraft. The study reveals that positioning the origin 1000 mm from the nose, although close to the neutral point, resulted in erratic longitudinal moment coefficient values that deviated from linearity. Ultimately, a center of gravity position of X_CG=900mm was established for in-flight conditions, fig. 5.

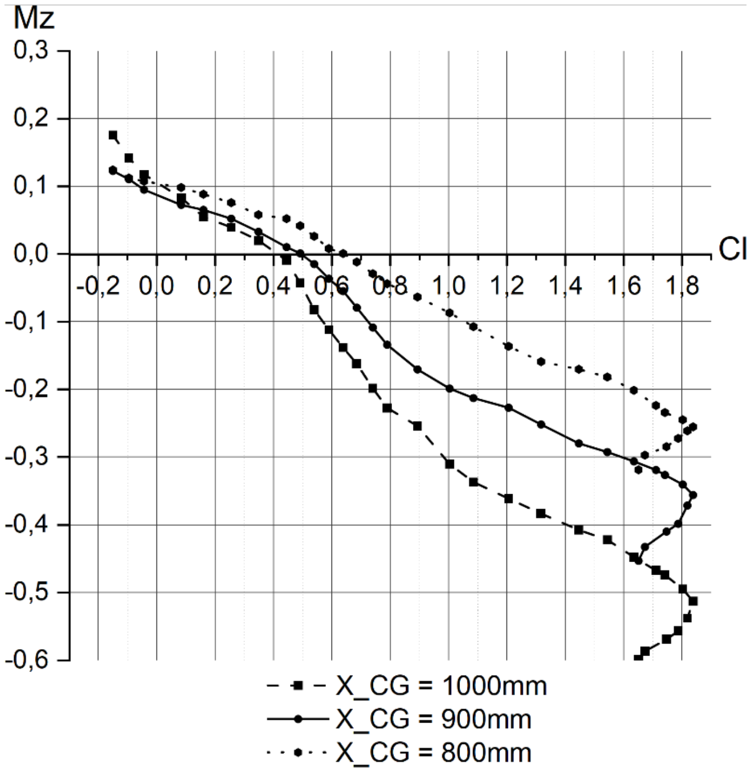

Fig. 5. Center of gravity distribution analysis for aircraft stability, longitudinal moment coefficient from lift coefficient

This position yielded a zero pitching moment with undeflected elevons and a lift coefficient of 0,5, corresponding to a design point airspeed of 15 m/s. This outcome validates the correctness of the defined wing twist during optimization.

A pivotal aspect of this exploration is the assessment of aerodynamic drag in the context of rotary propulsion. The objective is to reduce drag while maintaining comparable or slightly elevated coefficients of lift. This approach ensures that integrating rotary propulsion systems doesn't compromise overall aircraft performance.

The culmination of these efforts leads to the concept of aerodynamic excellence. This concept encompasses the harmonization of the aforementioned elements, aiming to minimize compromises between safety, handling, and other essential aircraft attributes. The goal is to achieve prototype aircraft values that match or even surpass the current aerodynamic performance, thereby enhancing safety, handling capabilities, and other crucial characteristics.

The foundation of assessing the stability of the aircraft's duck scheme lies in the $mz(Cl)$ parameter, representing longitudinal stability. Precise control of this parameter, with the aim to keep it below 0 (approximately $mz(Cl) \approx -0,25$), is vital to ensure stable flight dynamics. This equilibrium revolves around mz, ideally maintained at 0, and Cl, the lift coefficient. Skillful manipulation of these variables aims for the utmost aerodynamic excellence, enhancing the overall efficiency of the aircraft's design.

In conclusion, this study synergizes numerical simulations with meticulous calculations to optimize the aerodynamic attributes of an aircraft model. By scrutinizing the frontal provisions, investigating angle of attack behavior, devising drag reduction strategies, and harmonizing multiple crucial characteristics, the research aims to achieve a well-rounded and efficient aircraft design that excels in terms of safety, handling, and performance.

The comprehensive calculations unveil a promising avenue for developing stable horizontal flight aircraft. Notably, unlike conventional aircraft designs that often require a stability parameter of -0,25, this study reveals additional stability contributions from a rotating gyroscopic moment, acting as a counterforce against orientation deviations.

In addition to the previously outlined analyses, our study delved into the intricate relationship between the rotational speed of the propulsion wing's rotor and the aircraft's longitudinal stability. This exploration aimed to comprehensively understand the interplay of rotor speed with the aircraft's stability characteristics, shedding light on a crucial aspect of its overall aerodynamic performance.

To conduct these investigations, a range of rotational speeds for the propulsion wing's rotor was simulated using our computational fluid dynamics (CFD) framework. These simulations involved altering the rotor speed while keeping other parameters constant, allowing us to isolate the effects of rotation on the aircraft's behavior. The resulting data was then meticulously analyzed to ascertain the precise impact of varying rotor speeds on longitudinal stability.

Our findings revealed a nuanced relationship between rotor speed and longitudinal stability. At lower rotor speeds, we observed a discernible influence on the aircraft's longitudinal moment and stability margin. As the rotor speed increased, the aircraft exhibited specific alterations in its longitudinal behavior, indicating a direct correlation between rotation and stability, fig. 6.

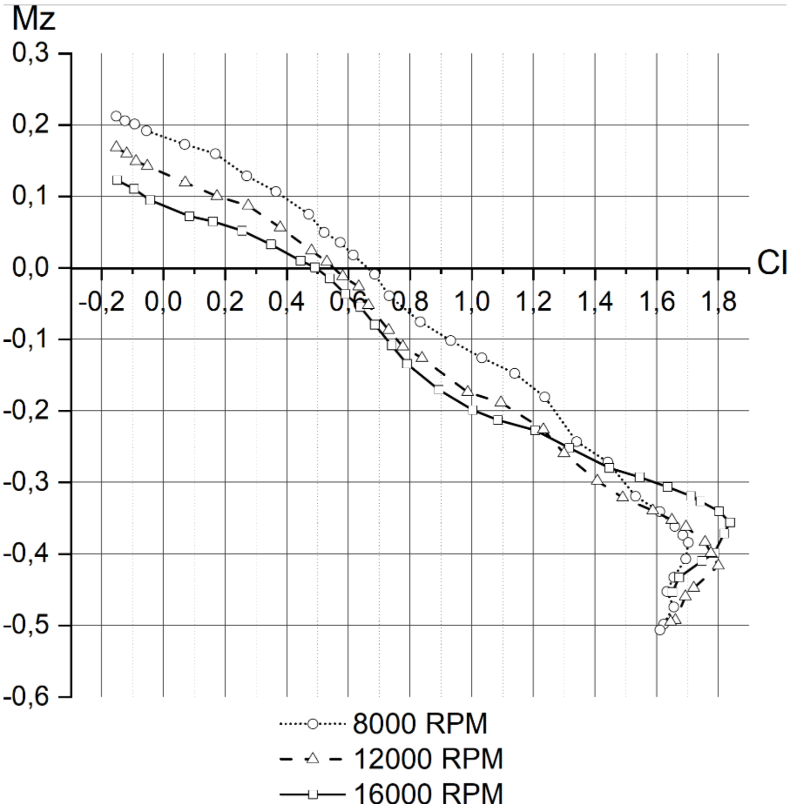

Fig. 6. Propulsion rotation speed distribution analysis for aircraft stability, longitudinal moment coefficient from lift coefficient

Interestingly, certain rotor speed ranges led to pronounced changes in the aircraft's stability margin, suggesting that the choice of rotor speed can be strategically leveraged to optimize the aircraft's overall stability profile. Furthermore, the data indicated that specific rotor speed configurations could potentially enhance the aircraft's resistance to deviations in orientation, contributing to its overall flight stability.

These insights not only broaden our understanding of the intricate dynamics governing the aircraft's longitudinal stability but also offer practical implications for aircraft design and operation. By carefully selecting rotor speed parameters, it is conceivable to enhance the aircraft's stability during various flight scenarios, thereby augmenting its operational safety and reliability.

Fig. 7 and Fig. 8 shows polar curve of lift and drag coefficient of the aircraft and aerodynamic efficiency from lift coefficient. The polar curve is very smooth. Drag coefficient Cx_0 = 0,04 provides an illuminating depiction of the variation in the lift-to-drag ratio concerning the coefficient of lift. Notably, the graph unveils a peak value of maximum aerodynamic efficiency 18 between lift coefficient of 0,4 – 1. The aircraft design point is for lift coefficient equal to 0,5 – 0,65, what is in the middle of the optimum lift coefficient section. This finding underscores the critical importance of this coefficient in achieving optimal lift-to-drag performance, thus influencing the aircraft's overall aerodynamic efficiency. Elucidates a linear reduction in the longitudinal moment until it reaches a *Cl* (coefficient of lift) value of 1,8. This observed trend aligns harmoniously with the requirements for normal mode flight. This longitudinal moment reduction ensures the aircraft's stability and control during different phases of flight, contributing to its reliable and predictable behavior.

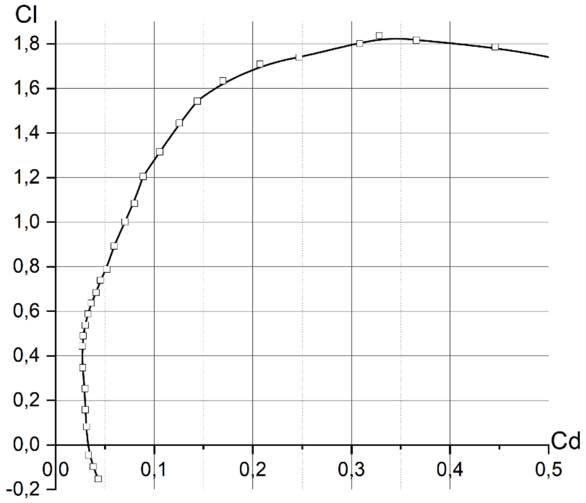

Fig. 7. Polar curve

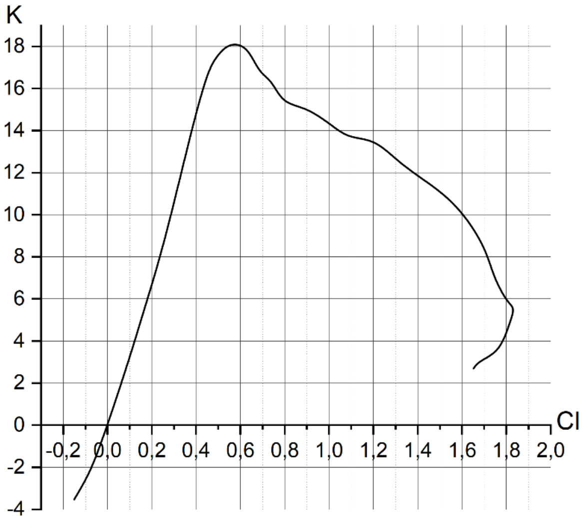

Fig. 8. Aerodynamic efficiency from lift coefficient

In conclusion, our rigorous calculations not only underscore the feasibility of crafting an aircraft with stable horizontal flight characteristics but also elucidate the interplay of multiple factors in achieving this stability. The synergy of the calculated stability parameter, the counteracting gyroscopic moment, and the critical coefficients of lift and drag all converge to demonstrate the potential for an aircraft design that excels in stability, aerodynamic performance, and controllability. The insights garnered from these calculations pave the way for further refinement and optimization in the pursuit of a safer, more efficient, and high-performing aircraft design.

Discussion

The utilization of empirical experimentation remains paramount in providing a comprehensive understanding of the model's developmental intricacies. The formidable challenge posed by the complex nature of high rotational speeds in rotary motion underscores the limitations of computational modeling, thereby elevating the indispensability of physical experiments in parameter determination and complexity revelation.

Zooming out to a broader context, the innovation within this novel aircraft design has orchestrated a striking amalgamation of attributes, seamlessly fusing the canard configuration with the integration of a crossflow fan. This harmonious symbiosis has not only unveiled exceptional flight performance in computational fluid dynamics (CFD) studies but has also yielded an extraordinarily high coefficient of efficiency within the framework of aircraft of this scheme. The anticipated level of aerodynamic efficiency surpassed the notable threshold of 18, thus accentuating the profound aerodynamic refinement embedded in the design.

The conclusions drawn from this study compellingly advocate for the integration of propulsive wing structures in "canard" aircraft, demonstrating a surplus of advantages over drawbacks. A pronounced merit manifests in the form of diminished takeoff distance, coupled with the unique ability to generate both lift and thrust during takeoff. Additionally, this innovation effectively mitigates challenges associated with bounced landings, as engine speed regulation facilitates controlled reduction of lift, resulting in a more controlled descent.

Empirical experiments resoundingly underscore the merits of adopting a rotary engine at the aircraft's rear. Conversely, the strategic placement of a small forewing or nose section ahead of the primary fixed wing ushers in unadulterated airflow, unleashing a cascade of aerodynamic benefits. This strategic arrangement effectively avoids turbulent vortices, thereby heightening aerodynamic qualities and control efficiency, given that all vortex-induced disturbances occur well behind the aircraft's wake.

In summation, the judicious amalgamation of empirical experiments and innovative design has unfurled a panorama of ideas for implementation. The fusion of "canard" architecture and propulsive wing technology not only highlights the mastery within this new aircraft but also underscores the symbiotic advantages of meticulously engineered structural solutions. This study resonates as a testament to the potential harnessed by empirical data in conducting experiments and unraveling the complexities inherent in contemporary aircraft design, thereby fostering a new era of aviation ingenuity.

Conclusion

In culmination, this article has brought to the forefront a paramount revelation that promises to reshape the very foundations of aircraft design. Embracing this innovative design paradigm, we can unveil a staggering reduction in takeoff distance by an impressive 30-40% in the future, a feat facilitated by the meticulous calculation of the coefficient of lift (Cl). This innovation brings with it an additional advantage – a reduction in takeoff and landing speeds. This reduction obviates the necessity for auxiliary mechanization to ensure safe landings, underscoring the ingenuity embedded within this new approach.

The elegance of the polar curve lies in its smooth progression, highlighting a remarkable minimum drag coefficient of $Cx0 = 0{,}04$. Yet, the true gem of the graph is the revelation of maximum aerodynamic efficiency, above 15 between lift coefficients of 0,4 – 0,9. This insight aligns harmoniously with the aircraft's design point, optimized for lift coefficients ranging from 0,5 to 0,65 – nestled perfectly within the realm of optimum.

Furthermore, the depiction of longitudinal moment reduction, coupled with a Cl value of 1,8, underscores the harmony between this trend and the requisites for normal mode flight. This meticulous calibration ensures the aircraft's stability and control, ushering reliability and predictability across diverse flight phases. In totality, these findings stand as a testament to the potential this new design paradigm holds, paving the way for safer, more efficient, and resolutely capable aircraft designs that herald a new era of aviation excellence.

In summary, the study's key revelation lies in the remarkable efficiency showcased across all flight phases. Looking ahead, a robust endorsement emerges for the incorporation of four motors, elevating reliability and overall performance. Additionally, the introduction of dual propulsion systems offers a unique avenue for manipulating aircraft roll through differential speed control. This enhancement, coupled with duplicated ailerons, promises a compelling synergy between performance optimization and heightened reliability.

Pushing boundaries further, the proposal to replace front canards with a rotary propulsion unit introduces a realm of novel possibilities for enhanced performance. This innovative concept holds the potential to redefine aircraft dynamics, prompting a fresh perspective on traditional configurations.

The amalgamation of visionary design, inventive manufacturing techniques, and rigorous experimentation lays a resilient foundation for aviation on the brink of transformation. With these insights and uncharted opportunities in hand, we stand poised to redefine the horizons of aeronautical potential.

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