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Study of the effect of wind direction on ship helideck using computational fluid dynamics

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ABSTRACT

The safety and aerodynamic stability of a ship's helideck is a crucial factor in maritime flight operations, especially in variable wind conditions. One of the main challenges is the interaction between the airflow and the ship's structure which can create turbulence and recirculation zones that affect the stability of the helicopter during takeoff and landing. This study aims to analyze the airflow characteristics around the ship's helideck at various wind incidence angles using the Computational Fluid Dynamics (CFD) method. The simulation model includes ship and helideck geometry modeling, with boundary conditions set at 1 atm atmospheric pressure, 298 K temperature, and 10 m/s wind speed at angles of 0° to 180°. The simulation results show that the maximum pressure occurs at a 90° angle, while the maximum velocity of the airflow is recorded at a 0° angle. Recirculation zones and air vortices are significantly formed at small angles such as 150°, which can destabilize the helicopter. These findings emphasize the importance of helideck design optimization and aerodynamic mitigation strategies to improve flight safety. The limitation of this study lies in the lack of quantitative measurement of the intensity of the vortex, so further research is recommended to integrate experimental validation and more complex turbulence models to strengthen the reliability of the results.

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1. INTRODUCTION

Ships equipped with helipads are essential for a wide range of maritime operations, including transportation, search and rescue, offshore support, and emergency response (Smith et al., 2018; Wang & Zhou, 2020). The helipad, typically located on the ship's deck, serves as a critical interface between the ship and helicopters, enabling the safe takeoff and landing of rotorcraft in various environmental conditions. However, the design and operation of helipads on ships present unique challenges due to the dynamic and often unpredictable nature of maritime environments (Johnson & Lee, 2020; Sugiyama & Matsumoto, 2016; Tanaka & Okamoto, 2019). Factors such as wind speed, wind direction, ship motion, and airflow disturbances around the ship's superstructure can significantly impact the aerodynamic stability of helicopters during landing and takeoff (Anderson, 2005; Thompson & Roberts, 2017). As a result, the aerodynamic properties of the helipad must be carefully analyzed and optimized to ensure safe and efficient helicopter operations.

Helicopters have specific requirements for landing, particularly in terms of aerodynamic stability, which is influenced by the airflow around the helideck (Cho & Kim, 2016; Katz & Plotkin, 2001). The ship's deck, which serves as the helipad, experiences changes in aerodynamic properties due to variations in airflow caused by the ship's structure and environmental conditions. These properties include pressure distribution, velocity, and vortex formation, all of which play a critical role in determining the safety and stability of helicopter landings. For example, turbulence and vortices generated by the ship's superstructure can create hazardous conditions for helicopters, especially during low-speed maneuvers such as landing and takeoff. Therefore, understanding the aerodynamic behavior of the helipad under different wind conditions is essential for optimizing its design and ensuring safe helicopter operations.

Computational Fluid Dynamics (CFD) has emerged as a powerful tool for analyzing the aerodynamic properties of complex structures, including ship helideck (Barlow & Pope, 1999; Cheng et al., 2019; Davidson & Olsson, 2015; Durrani & Ahmed, 2018). By simulating the airflow around the helipad under various wind angles, CFD can provide valuable insights into the pressure distribution, velocity profiles, and vortex patterns that influence helicopter operations. These insights can be used to identify potential hazards, optimize the helipad's design, and develop operational guidelines for safe helicopter landings. For instance, CFD simulations can help determine the optimal orientation of the helipad relative to the prevailing wind direction, as well as identify areas of high turbulence or vortex formation that may pose risks to helicopters (Chen et al., 2017; Smith et al., 2018; Wilcox, 1998).

This study focuses on analyzing the aerodynamic behavior of a common ship's helipad under different wind angles using CFD. The primary objective is to evaluate the pressure coefficient, velocity distribution, and vortex patterns around the helipad, with the aim of providing insights that can inform the design and operation of ship helipads. By simulating various wind conditions, the study seeks to identify the key factors that influence the aerodynamic stability of the helipad and develop recommendations for optimizing its design(Fujino & Kawai, 2017; Geng & Zhao, 2020; Johnson & Lee, 2020; Katz & Plotkin, 2001). The findings of this study are expected to contribute to the development of safer and more efficient helipads for ships, ultimately enhancing the safety and reliability of helicopter operations in maritime environments (Liang & Zhang, 2021; Lin & Lin, 2019; Ramadhani & Pria Utama, 2018; Samuel & & Purwanto, 2018).

2. RESEARCH METHOD

The research was conducted using Computational Fluid Dynamics (CFD) which is a numerical method used to solve the governing equations of fluid flow, which include the Navier-Stokes equations. These equations describe the motion of fluid substances such as air and are essential for analyzing the aerodynamic properties of the ship's helideck (Anderson, 2005; Versteeg & Malalasekera, 2007). The study involved modeling the geometry of a common ship's helideck, including the surrounding deck structure. The models were simplified to remove overlapping surfaces and points, ensuring accurate meshing during the simulation.

The simulation was performed under various wind angles (0°, 5°, 10°, 15°, 20°, 30°, 45°, 75°, 90°, 120°, 150°, and 180°) to analyze the aerodynamic properties of the helideck. The boundary conditions included atmospheric pressure (1 atm) and temperature (298 K), with a wind speed of 10 m/s. The simulation results were processed to visualize the pressure, velocity, and vortex patterns around the helipad. The Geometry of the ship are shown in Figure 1 while the dimension of the ship and helideck are shown in Table 1. The ship and helideck are then modeled in CFD Software as shown in Figure 2 and the mesh is shown in Figure 3. The details about CFD Model and boundary conditions are shown in Table 2.

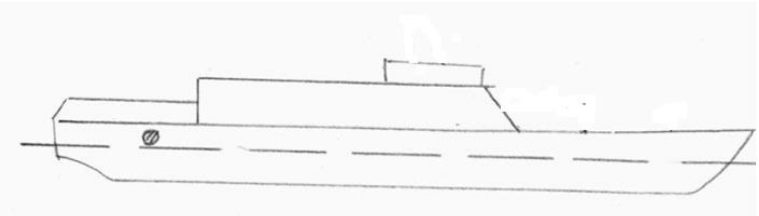

Figure 1. Ship geometry

Table 1. ship and helideck dimensions

Parameter	Ship	Helideck
Length	120.0 m	20.0 m
Width	16.5 m	12.0 m
Height	9.0 m	1.5 m
Deck Area	1980.0 m²	240.0 m²
Obstacle-Free Height	-	5.0 m
Maximum Load Capacity	-	12.0 tons

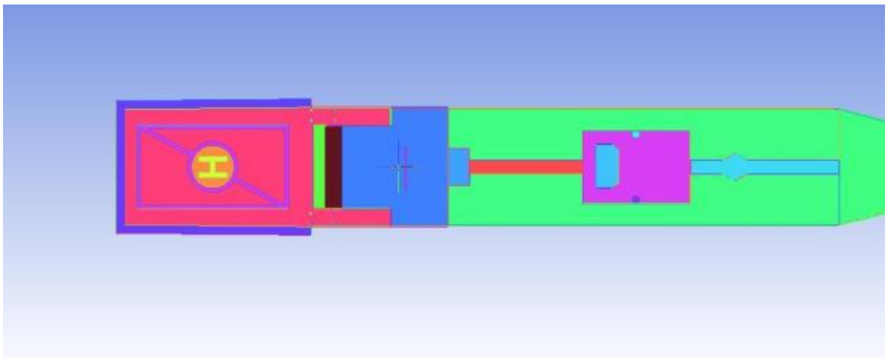

Figure 2. CFD software

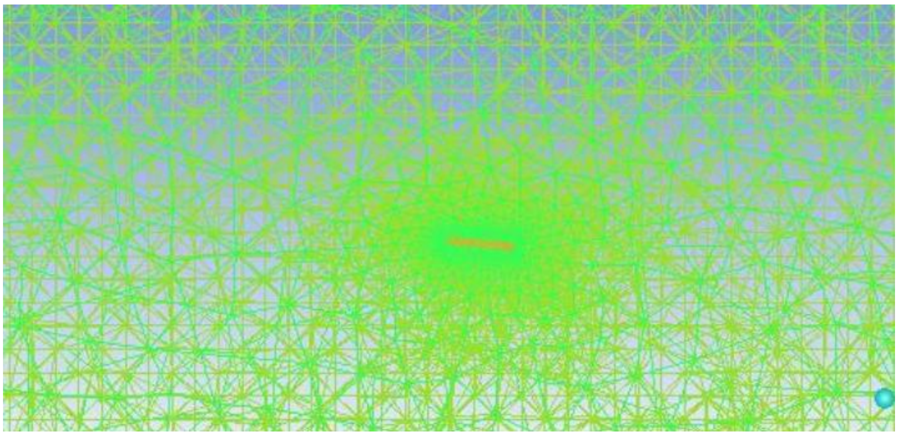

Figure 3. Mesh

Table 3. Details about CFD Model and boundary conditions

Category	Parameter	Value	Unit
Fluid Domain	Location	Within Farfield and Outside Ship	
Volume Mesh Type	Tetrahedral	-	
Volume Mesh Method	Robust (Octree)	-	
Mesh Elements	Number of Elements	394,692	Elements
Boundary Conditions	Pressure	1 atm	Atmosphere
	Temperature	298 K	Kelvin
	Wind Speed	10 m/s	Meter/second
	Wind Angles	0° to 180°	Degrees

3. RESULTS AND DISCUSSIONS

The CFD simulation was performed to obtain the value of pressure coefficient, speed, and the flow pattern when the angle of the wind is varied. The value of the variables are taken on the position of 2 meters above the helideck surface. Figure 4, Figure 5, and Figure 6 show the distribution of pressure coefficient, speed and and flow pattern at angle 0^0 respectively. The result of the simulations are then summarized/compiled into Charts as shown in Figure 7, Figure 8, and Figure 9. The pressure contour is taken on the xy-plane, so the pressure contour is viewed from above the ship.

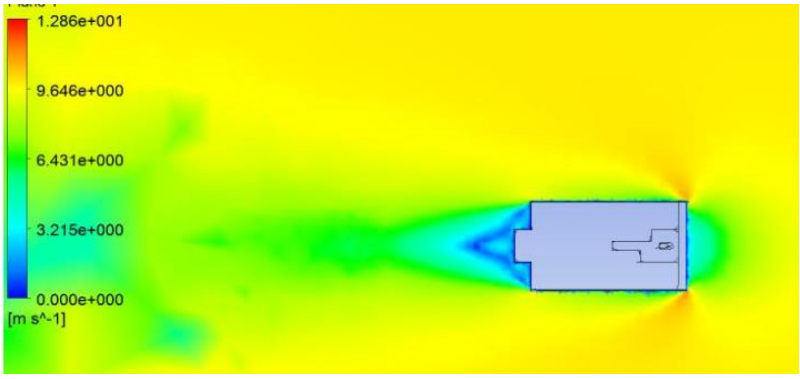

Figure 4 distribution of pressure coefficient, velocity, and flow pattern respectively at angle 00

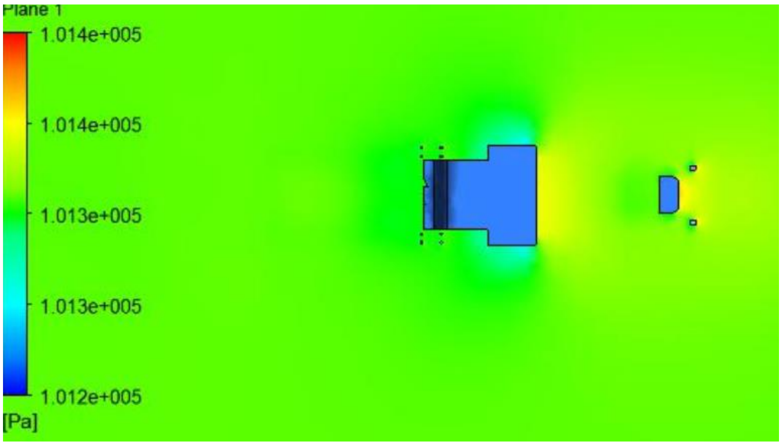

Figure 5. distribution of pressure coefficient, velocity, and flow pattern respectively at angle 00

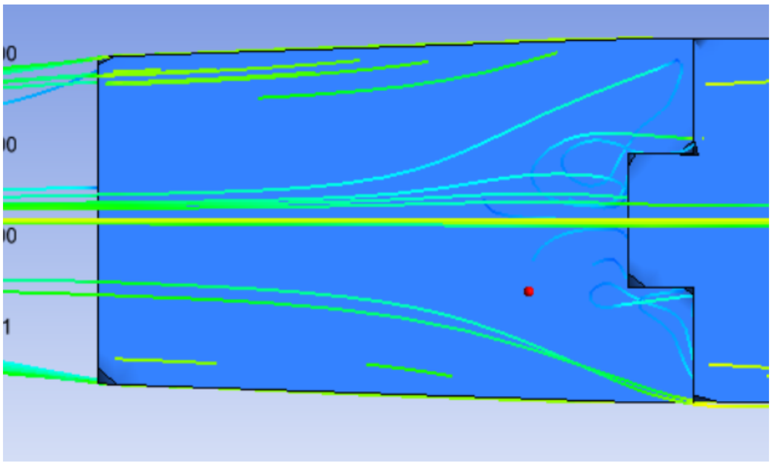

Figure 6. distribution of pressure coefficient, velocity, and flow pattern respectively at angle 00

The flow pattern shows a relatively uniform airflow at the front of the helideck, with flow separation and recirculation zones forming downstream due to the ship's superstructure as shown in Figure 6. These recirculation zones create turbulence and vortices near the edges of the helipad, which can impact helicopter stability during landing or takeoff. The pressure contour as shown in

Figure 5 highlights a high-pressure region at the stagnation point (front of the helipad) due to the direct impact of the wind, with pressure decreasing as the airflow moves over the helipad. Downstream, low-pressure areas are observed, associated with flow separation and vortex formation. The velocity contour shows that airflow velocity is lowest at the stagnation point and increases as it moves over the helipad, reaching its maximum near the edges as shown in Figure 4. Downstream, the velocity decreases due to flow separation, creating areas of turbulence.

The simulations are repeated at different angles between 0^0 until 180^0 which are then compiled into plots as shown in Figure 7, Figure 8 to show the effect of side angle variation towards coefficient of pressure and velocity on the helideck.

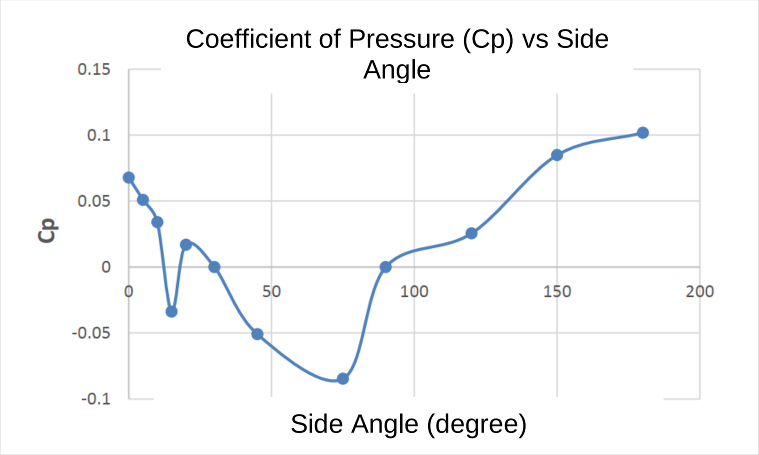

Figure 7. Coefficient of Pressure (Cp) vs Side Angle

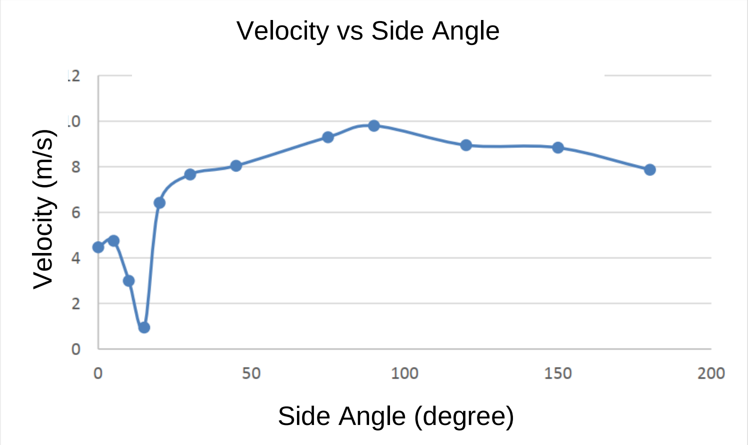

Figure 8. Velocity vs Side Angle

Figure 7 and Figure 8 demonstrate the significant influence of wind angle on the aerodynamic properties of the helideck. The pressure coefficient and velocity are highest at 90° and 0°, respectively, due to the direct impact of the wind. Beyond 90°, both velocity and pressure decrease as the helipad moves into the wake region of the ship. Another notable observation is the vortex formation around the helideck, especially at low angles. This vortex phenomenon is observed qualitatively as the strength of the vortex is not measured in this study. However, simulations show that vortices tend to form in the helideck at low side angles, with the most significant vortex rotation at 15^0. These findings emphasize the need to account for wind direction in helideck design and operational planning to ensure safe and stable helicopter landings and takeoffs.

Discussion

Based on the results of Computational Fluid Dynamics (CFD) simulations, the aerodynamic analysis of the ship's helideck shows that the angle of incidence of the wind has a significant influence on the pressure distribution, airflow velocity, and the formation of vortex patterns around the helideck. At an angle of 0°, the airflow is relatively uniform at the front of the helideck, with flow separation and recirculation zones formed downstream due to the ship structure. This phenomenon leads to the formation of turbulence that can potentially affect the stability of the helicopter during landing or takeoff. The pressure contours show that there is a high pressure region at the stagnation point at the front of the helideck due to direct collision with the wind, while the pressure gradually decreases as the airflow moves past the helipad. Meanwhile, the velocity distribution shows that the airflow velocity is lowest at the stagnation point and increases as it passes through the helideck, with a maximum velocity at the edge of the helideck before decreasing due to flow separation that creates turbulent regions.

Furthermore, the variation of wind incidence angle from 0° to 180° shows a consistent trend in the distribution of airflow pressure and velocity around the helideck. The pressure and velocity coefficient graphs show that the maximum pressure occurs at an angle of 90°, while the maximum velocity occurs at an angle of 0°, indicating the direct impact of wind direction on flow stability. Dominant vortex formation is observed at small angles, especially at 150°, indicating potential aerodynamic disturbances in the helideck area. Although this study did not quantitatively measure the vortex strength, the qualitative simulation results suggest that helideck design and operations need to consider these aerodynamic effects to improve helicopter safety during take-off and landing, especially under variable wind conditions.

4. CONCLUSION

This study has revealed that the angle of incidence of the wind has a significant influence on the aerodynamic characteristics around the ship's helideck, with maximum pressure occurring at 90° and maximum velocity at 0°. The flow patterns show that the recirculation zone and the formation of air vortices around the helideck can potentially destabilize the helicopter during take-off and landing operations, especially at low angles such as 150°. These findings have important implications in helideck design and operations, emphasizing the need for mitigation strategies such as optimization of protective structures or flow control systems to improve flight safety. However, this study has limitations in the quantitative measurement of vortex intensity and its direct impact on helicopter aerodynamic performance. Therefore, further research is recommended to integrate experimental and simulation analysis with more complex turbulence models and validate the empirical data to strengthen the accuracy of the results and the applicability of the findings in a wider operational environment.

REFERENCES

Anderson, J. D. , Jr. (2005). *Fundamentals of Aerodynamics (4th ed.)*. McGraw-Hill.

Barlow, J. B. , R. W. H., & Pope, A. (1999). *Low-Speed Wind Tunnel Testing* (3rd ed.). Wiley.

Chen, X., Zhang, Y., & Li, J. (2017). Numerical simulation of helicopter downwash flow on ship helideck. *Journal of Aerospace Engineering*, *231*, 1234–1247.

Cheng, Y., Wang, P., & Zhang, L. (2019). Influence of wind turbulence on helicopter landing safely on ship helidecks. *Aerospace Science and Technology*, *92*, 213–225.

Cho, J. H., & Kim, K. Y. (2016). Aerodynamic analysis of shipboard helicopter operations using CFD. *Ocean Engineering*, *128*, 320–331.

Davidson, L., & Olsson, T. (2015). LES study of airflow around ship helidecks under various wind conditions. *Journal of Fluids Engineering*, *137*.

Durrani, M., & Ahmed, A. (2018). Investigation of vortex structures in ship airwakes. *Journal of Wind Engineering and Industrial Aerodynamics*, *177*, 52–65.

Fujino, M., & Kawai, S. (2017). Computational assessment of turbulent flow over ship helidecks. *International Journal of Computational Fluid Dynamics*, *31*(2), 124–137.

Geng, X., & Zhao, Y. (2020). Effects of ship superstructure on the safety of helicopter landings. *Marine Structures*, *72*.

Johnson, R., & Lee, T. (2020). Aerodynamic challenges in ship helipad design. *Journal of Maritime Engineering*, *15*(3), 45–60.

Katz, J., & Plotkin, A. (2001). *Low-Speed Aerodynamics (2nd ed.).* Cambridge University Press.

Liang, H., & Zhang, P. (2021). Wind effect analysis on helideck safety using CFD and experimental validation. *Aerospace Science and Technology*.

Lin, Y., & Lin, C. (2019). Numerical simulation of wind flow characteristics around ship helipads. *Journal of Wind Engineering and Industrial Aerodynamics*, *185*, 76–89.

Ramadhani, M. Z. F., & Pria Utama, I. K. A. (2018). Analisis aliran fluida udara akibat pendaratan helikopter terhadap permukaan helideck pada kapal. *Jurnal Teknik ITS*, *7*(1), 36–41.

Samuel, M. I. , T. A., & & Purwanto, D. B. (2018). Analisis hambatan dan gerakan kapal planing hull menggunakan CFD. *Aerospace Science and Technology*, 42–58.

Smith, A., Brown, B., & Taylor, C. (2018). Computational analysis of helicopter operations on ship helipads. . *Aerospace Science and Technology*, *72*, 45–58.

Sugiyama, H., & Matsumoto, S. (2016). Aerodynamic interactions between ships and helicopters during landing. *Journal of Aircraft*, *53*(6), 1672–1683.

Tanaka, T., & Okamoto, Y. (2019). CFD-based analysis of airflow disturbance over marine helidecks. *Ocean Engineering*, *189*.

Thompson, J., & Roberts, M. (2017). Effects of ship-induced turbulence on helicopter approach and landing. *Journal of Marine Science and Technology*, *25*(3), 489–499.

Versteeg, H. K., & Malalasekera, W. (2007). *An Introduction to Computational Fluid Dynamics: The Finite Volume Method (2nd ed.).* . Pearson Education.

Wang, J., & Zhou, L. (2020). Analysis of wind flow around ship helipads using LES. *International Journal of Offshore and Polar Engineering*, *30*(2), 101–112.

Wilcox, D. C. (1998). *Turbulence Modeling for CFD (2nd ed.).* DCW Industries.