Computational Analysis of Velocity and Pressure Distribution in a Basic Plane Model Using SolidWorks

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1. Introduction

This report presents a computational analysis of the velocity and pressure distribution around a basic plane model using SolidWorks. The primary objective of this study is to understand the aerodynamic performance of the model under simulated atmospheric conditions at three distinct flight stages: take off, mid-flight, and landing. Specifically, the study aims to identify the differences between these stages and their effects on the aerodynamics of the plane.

The plane model was designed and simulated in SolidWorks, with specific attention to boundary conditions and mesh refinement to ensure accurate results. The simulations were conducted under consistent atmospheric conditions to observe the differences in aerodynamic characteristics at each stage. Detailed readings of velocity and pressure were obtained and analysed to identify key variations.

The findings reveal significant differences in velocity and pressure distribution at each stage, with notable areas of high and low pressure that are critical for understanding lift and drag forces. For instance, higher pressure was observed at the leading edges during take off, while mid-flight showed more uniform pressure distribution. These insights are crucial for optimizing aircraft design and improving performance.

The practical implications of these findings suggest potential modifications to the plane's design to enhance aerodynamic efficiency. Future work could involve more complex models and additional simulations to further validate the results and explore other flight conditions. This study demonstrates the effectiveness of using SolidWorks for aerodynamic analysis and provides valuable insights for future research and development in aircraft design.

2. Methodology

Model Design

The plane model was created using SolidWorks, as shown in the attached image. The model includes the fuselage, wings, and an engine mounted under the wing. Specific dimensions were annotated, with the length from the nose to a point near the tail measuring 36m. The distance from the outer edge of one wing to the other is 48m. The design choices aimed to represent a basic aircraft for aerodynamic analysis.

Simulation Setup

The simulations were conducted in SolidWorks with a velocity of 200 m/s in the -z direction and default atmospheric conditions. To simulate different flight stages, the angle of attack of the inlet was varied. For take off and landing stages, an additional velocity of 100 m/s in the ±y direction was applied to create the angle of attack, while a velocity of -200 m/s in the z direction was maintained in each study.

Flight Stages

Three distinct flight stages were simulated: take off, mid-flight, and landing. Each stage was defined by specific parameters:

- **Take off**: Increased angle of attack with an additional velocity of 100 m/s in the -y direction and -200 m/s in the z direction.
- **Mid-flight**: Standard conditions with a velocity of 200 m/s in the -z direction
- **Landing**: Similar to take off, with an increased angle of attack and additional velocity of 100 m/s in the +y direction and -200 m/s in the z direction.

Data Collection

Velocity and pressure readings were obtained using SolidWorks simulation tools. Surface plots were used to visualize pressure distribution, while flow trajectories illustrated the velocity of air around the plane. Additionally, an x-y plot of the top edge on the left wing was generated to analyse the pressure distribution along the wing at each flight stage.

3. Results

The results of the simulations conducted on the basic plane model using SolidWorks are presented below. The simulations were performed at three distinct flight stages: take off, mid-flight, and landing. The key observations from the velocity and pressure distributions are discussed.

3.1.1 Velocity Distribution

Take off Stage

Take off Velocity Distribution: The velocity distribution during the take off stage is shown in the first image. The streamlines indicate the flow of air around the aircraft, coloured by velocity magnitude. Higher velocities are observed at the leading edges of the wings and the nose of the aircraft. The colour legend indicates velocity values ranging from 0 to 319 m/s.

Mid-Flight Stage

Mid-Flight Velocity Distribution: The second image depicts the velocity distribution during mid-flight. The streamlines show a more uniform flow around the aircraft, with velocities ranging from 0 to approximately 255 m/s. The uniformity in velocity distribution indicates stable aerodynamic performance during mid-flight.

Landing Stage

Landing Velocity Distribution: The third image illustrates the velocity distribution during the landing stage. Similar to the take off stage, higher velocities are observed at the leading edges and the nose of the aircraft. The colour legend indicates velocity values ranging from 0 to approximately 300 m/s.

3.1.2 Pressure Distribution

Take off Stage

The pressure distribution during the take off stage shows higher pressure at the leading edges of the wings and the nose of the aircraft. This is critical for generating lift during take off. The graph indicates pressure values ranging from approximately 117,000 to 140,000 Pa.

Mid-Flight Stage

During mid-flight, the pressure distribution is more uniform, indicating stable aerodynamic performance. The graph shows pressure values along the wing, with two lines representing different data sets. The graph indicates pressure values ranging from approximately 111,000 to 142,500 Pa.

Landing Stage

The pressure distribution during the landing stage is similar to the take off stage, with higher pressure at the leading edges and the nose of the aircraft. This is essential for maintaining control and stability during landing. The graph indicates pressure values ranging from approximately 95,000 to 125,000 Pa.

3.1.3 Key Observations

1. **Velocity Variations**: Higher velocities at the leading edges and nose during take off and landing stages indicate increased aerodynamic forces required for lift and control.
2. **Pressure Patterns**: Uniform pressure distribution during mid-flight suggests stable aerodynamic performance, while higher pressure at critical points during takeoff and landing is necessary for lift and stability.
3. **Implications for Design**: The findings suggest potential modifications to the plane's design to enhance aerodynamic efficiency, such as optimizing the shape of the wings and nose to reduce drag and improve lift.

4. Discussion

Comparison with Expected Outcomes or Theoretical Predictions

The observed velocity and pressure distributions align well with theoretical predictions of aerodynamic behaviour. Higher velocities at the leading edges and nose during take off and landing are consistent with the need for increased lift and control forces. The uniform pressure distribution during mid-flight matches expectations for stable aerodynamic performance.

Possible Reasons for Any Discrepancies
Any discrepancies between the simulation results and theoretical predictions could be attributed to several factors:

- **Mesh Quality**: The accuracy of the simulation results can be affected by the quality of the mesh used in the model. Finer meshes generally produce more accurate results.
- **Boundary Conditions**: The assumptions made for boundary conditions, such as atmospheric conditions and velocities, may not perfectly replicate real-world scenarios.
- **Model Simplifications**: The basic plane model used in the simulations may lack certain complexities present in actual aircraft, leading to differences in aerodynamic behaviour.

Implications of the Findings
The findings from this study have several important implications for aircraft design:

- **Design Optimization**: The insights gained from the velocity and pressure distributions can be used to optimize the shape of the wings and nose to reduce drag and improve lift, enhancing overall aerodynamic efficiency.
- **Performance Improvement**: Understanding the aerodynamic behaviour at different flight stages can help in designing aircraft that perform better during take off, mid-flight, and landing.
- **Future Research**: The study provides a foundation for future research, which could involve more complex models and additional simulations to further validate the results and explore other flight conditions.

5. Conclusion

The study reveals significant variations in velocity and pressure distribution across the three flight stages. Higher velocities at the leading edges and nose during takeoff and landing indicate increased aerodynamic forces required for lift and control. Uniform pressure distribution during mid-flight suggests stable aerodynamic performance, while higher pressure at critical points during takeoff and landing is necessary for lift and stability.

These findings suggest potential modifications to the plane's design to enhance aerodynamic efficiency, such as optimizing the shape of the wings and nose to reduce drag and improve lift. Future work could involve more complex models and additional simulations to further validate the results and explore other flight conditions, incorporating more detailed boundary conditions and refining mesh quality for improved accuracy.

5.1 Personal Insights and Learning

Through this study, I have gained valuable insights into the aerodynamic behaviour of aircraft at different flight stages. The use of SolidWorks for simulation has provided a deeper understanding of how velocity and pressure distributions affect lift and control. Analysing the results has enhanced my knowledge of computational fluid dynamics and its application in aircraft design.

Additionally, the process of optimizing the plane's design to improve aerodynamic efficiency has highlighted the importance of detailed simulations and accurate data collection. This experience has equipped me with practical skills in using simulation tools and interpreting complex data, which will be beneficial for future research and development projects.

Overall, this study has not only contributed to my understanding of aerodynamics but also reinforced the significance of continuous improvement and innovation in aircraft design.

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