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Advanced Modelling of KF Implemented Flying Wing

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Abstract

This research carries out the advanced phase in correlation with the previous published design of KF Implemented Flying Wing. At the primary stage the basic design was considered under omission of non-static components and turbulent conditions. At this stage the simulations have taken a step ahead with improved flow conditions and advanced modeling of the design. As per the design aspects the engines, pylons, landing gears and shape improvements were done with solid modeling. Due to the computational limitations this was divided in to two phases as cruising conditions with non-static components and further studies to be carried out in Take-off and Landing conditions with extended landing gears. Under the stability and control conditions a separate research is being carried out in achieving the optimum capability. Propfan engine selected for extreme condition evaluations. The implementations were made without disrupting the base design which was presented in phase one basic simulation carried out prior to this. The simulation results deemed to be promising for the first stage as well as the effect of new components. The secondary target areas are to be carried out in further ongoing research as well.

Keywords: Flying Wing, Solid Modelling, Computational Fluid Dynamics, Kline Fogleman, Blended Wing

1. Introduction

Aircraft which are focused on blended wing designs are developed to undertake greater lift with least drag. The concept design of the first blended wing was dropped back with stalling. Flight control surfaces allow a pilot to adjust and control the aircraft's flight attitude. Which basically is a crucial factor in aircraft performance and safety. In early days even though the take-off was achieved the aircraft was uncontrollable in air. In order to achieve better controls there should be proper balancing of aircraft and perfect weight distribution.

The potential to achieve greater lift comes with the aircraft design ability to generate lift from the whole area of the aircraft including the unseparated fuselage area as well. The Westland Dreadnought was one of the earliest stages of BWB aircrafts. This design also suffered with the inability to prevent stall. An aircraft is free to rotate around three axes that are perpendicular to each other and intersect at its center of gravity (CG).

The second area of drawback is the total wetted area due to the enlarged wing space. The total skin drag increases with the area of contact to the external flow.

The advantages of significant increment in payload, increased fuel efficiency, improved lift to drag ratio provides the evolutionary edge to go through with the design concepts.

With the primary design of 'KF Implemented Flying Wing' the dimensions and design of conventional areas were kept at bay. To implant the blended win concepts the advanced designs are used at this stage. [1]

This stage was used to identify the areas of improvements to provide the advancements in achieving the full base of flying wing concept. Identifying the areas of

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implementing the control requirements and static components will be selected with simulative methods.

2. Literature review

The literature review under the topic of Advanced modelling of KF implemented flying wing design is correlated with the primary phase of the research; KF implemented Flying Wing. The amplification of properties and the effects of them are discussed comprehensively.

In this literature review it is discussed the design change requirements for advanced flow conditions and the property change requirements. The assumptions made in the primary stage have taken into consideration with practical conditions and its effects. [2]

These areas of change are divided as,

- Blended wing conditions
- Structural Design improvements
- Non - Static component implementations.
- Advanced flow conditions

In accordance with the reviewed research papers, the analytical facts were given as follows.

2.1. Blended wing conditions

The blended wing is achieved by the connection of wing to the fuselage body without having a clear division between the two. This aspect provide the aircraft with improved lift and efficient wide airfoil shaped body.

2.2. Structural Design improvements

Wing area was improved by implanting further complex component and shape changes to the body of the aircraft.

2.3. Non - Static component implementations

The primary simulations were run to the basic structure of the aircraft under the assumptions of avoiding Non – static components. (Landing Gears, Engines, etc.) In the advanced model the No – Static components are designated and have been taken into consideration in these simulations.

2.4. Advanced flow conditions

With the Non – Static components the flow conditions vary as well. Thus conducting the simulations under incompressible conditions are not of accuracy. In order to obtain far more accurate analysis the advanced flow conditions are taken into consideration as well.

3. Problem definition

In order to improve the basic design published under KF implemented Flying Wing the modifications need to be done to provide performance enhanced flow conditions and drag and lift components.

3.1. Implement the improvements using SolidWorks to the design.

The design will be rearranged and implemented further parts and smoothing to improve the found performance to be uplifted.

3.2. Re-run the simulations to identify further depth analysis.

The simulations will be rerun under the same previous conditions used in "KF implemented Flying Wing". The analysis will be provided with complimenting the new findings.

3.3. Compare with the previous design and recommend any further improvements.

The findings and analytical data will be used to be compared with the previous findings and publication.

The basic design was developed with the swift bird's analogy thus the improvements will be looked forward while keeping the same correlation as well. Refer Figure 1. [3]
Previous design will be improved to give out the higher safety and airworthy conditions. Which will bring out the better flow considerations.

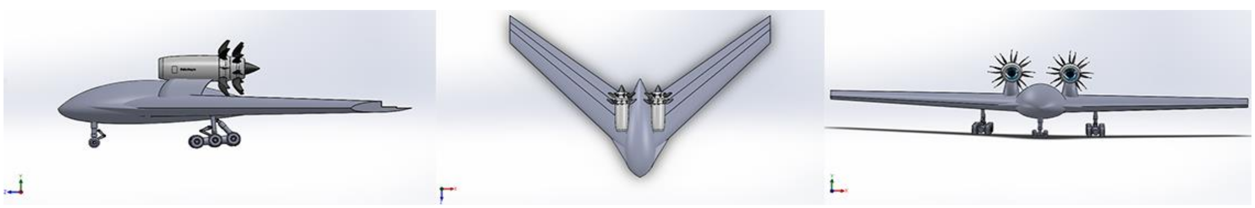

Figure 1: This figure describes the design improvements

4. Method of analysis (Numerical experiments)

With the available computational performance and to bring the final outcome nearest to the actual situational condition the following assumptions were made,

- Omit dynamic meshing for engine rotational part and consider as a static component.
- Consider compressible flow conditions.
- While considering the landing gears the flow velocity assumed to nearest for take-off and landing velocity.
- Consider sea level conditions to fulfil the above assumption is required, thus divided the simulation to two stages.
    - Cruising without landing gears
- Landing and Take-off with landing gears

The engine flow conditions can be considered in three different methods accordingly with the available computational power. [4]

4.1. Dynamic Meshing for Moving Parts and Flow Variations

Flow condition variations can be measured by implementing a dynamic mesh which can continuously calculate the flow variations.

4.2. Simultaneous Multiple Simulations

With the simultaneous simulations it can be adopted to different simulations which can run the same time laps in different iterations. For example a separate flow simulation implanted to full aircraft simulation with simultaneous iterations with similar time lapses.

4.3 Consider as a Static Component

Meshing the engine by considering component as a static component with zero displacement in flow. This require further simulation for flow variations in displacement flow as well.

With the available computational power and meshing capability the method was selected to be “Consider as a static component”. The advanced simulations will be carried out in further studies. Due to this condition the primary simulation is carried out with OpenFoam simulations with kωsst solver, this stage for omitted Landing gears with cruising conditions.

5. Results and discussion

With the solver properties the data was calculated with the use of following equations,

Turbulent Viscosity, $$\nu = \sqrt{\frac{3}{2}}\,(UIl) \quad (1)$$

Dynamic Viscosity, $$\mu = \rho \times \nu \quad (2)$$

Turbulent Energy, $$k = \frac{3}{2}\,(UI)^2 \quad (3)$$

Dissipation Rate, $$\epsilon = C_\mu \frac{k^{\frac{3}{2}}}{l} \qquad C_\mu = 0.09 \quad (4)$$

Specific Dissipation Rate, $$\omega = \frac{\sqrt{k}}{l} \quad (5)$$

Table 1: This table describes the simulation parameters

Property	Symbol	Calculated Value
Turbulent Viscosity	ν	1.46e-05 m^2s^{-1}
Turbulence Intensity	I	0.2
Turbulent length scale	l	0.3
Dynamic Viscosity	μ	1.789e-5 Nsm^{-2}
Density	ϱ	1.225 kgm^{-3}
Velocity	U	240 ms^{-1}
Static Pressure	P_{Static}	101325 Pa
Temperature	T	300 K
Angle of Attack	deg	3^0

The meshing for the simulation with Figure 2 was done with the use of SnappyHexMesh and with boundary mesh with Blockmesh properties. Table 1 presents the properties that was incorporated for the simulations. The conditions were considered as sea level.

With the use of Equation 3 and Equation 5 respectively, k =27.6021, Ꞷ = 17.6198.

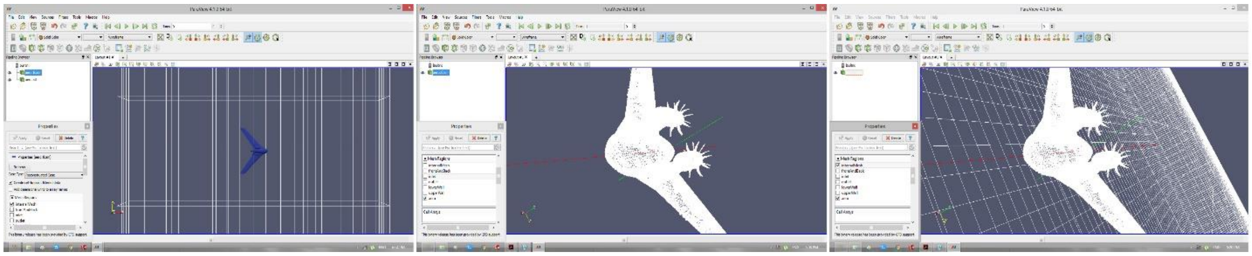

Figure 2: This figure describes the SnappyHexMesh output

With the completion of meshing the final output was with 2708750 cells, 8587101 faces and 3203925 node points. This was done with one major mesh and two separate refinements with higher local and global cells for the wings. With the available computational power a smoother mesh was made for the results to be as accurate as possible.

For the simulation the sonicFoam solver was taken as the velocity goes near transonic conditions. As per theoretical property behaviors in sonic conditions, each tend to change in shorter time range. Thus dT (0.25e-06) have been selected as the number of iterations to 25,000 increase accordingly to get accurate output.

Accordingly the C_l and C_d values were received as follows,

C_l	1.2122
C_d	1.0994

The study conducted with the basic design, the values were as at [5],

C_l	0.45608
C_d	0.18722

With the comparison alongside the basic design and the advanced model the lift and drag coefficients have increments. The variation of wing AoA and aircraft AoA has significant impact on the drag and lift of the aircraft. This will be addressed in further research, due to computational limitations.

6. Conclusion

With the final results of convergence in the simulations the improvements and the essential non-static components are able to keep the exceptional performance of the new design.

With this research the improvement with increased angle of attack was addressed as well. The primary research being completed proves the effectiveness of the design without the non-static components. With the outcomes of this the design has been proven to handle and provide better performance with the new inclusions as well.

The 3^0 AoA variations were able to provide further detailed progress for the designs capabilities. All implementations have proven to be improvement for the design whilst some percentage of drawbacks was seen as well. Such as the increment in skin friction drag due to area improvement and form drag due to the engine and pylon components.

The exceptional propagation alongside with the drawbacks the improvements have been able to stand out thus concluding as an effective design.

7. Future and ongoing studies

- The current study is extended to cruising conditions at 39,000 ft and the simulations are being carried out.
- C_l vs. AoA / C_d vs. AoA variation will be simulated.
- Enhanced simulation for landing and take-off are to be done.
- Structural and weight and balance analysis is to be carried out.
- Aircraft control system is to be implemented in further research.

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