Flow Simulation Report: Experimental X-Wing Assembly

Objective The objective of this simulation is to determine the shear stress exerted on the experimental wing and to identify the inefficiency of the design.

Simulation Environment

Analysis Environment - Software Product: Not specified - CPU Type: Not specified - CPU Speed: Not specified - RAM: Not specified - Operating System: Not specified

Model Information - Model Name: X-Wing-assembly.SLDASM - Project Name: X-wing - Unit System: SI (m-kg-s) - Analysis Type: External (exclude internal spaces)

Size of Computational Domain - X min: 0.207 m - X max: 0.405 m - Y min: 0.324 m - Y max: 0.409 m - Z min: 0.247 m - Z max: 0.820 m - X size: 0.197 m - Y size: 0.085 m - Z size: 0.573 m

Mesh Settings #### Basic Mesh - Number of cells in X: 77 - Number of cells in Y: 32 - Number of cells in Z: 228

Analysis Mesh - Total Cell count: 548,862 - Fluid Cells: 548,862 - Solid Cells: 62,670 - Partial Cells: 30,812 - Trimmed Cells: 0

Additional Physical Calculation Options - Heat Transfer Analysis: Fluid Flow: On, Conduction: Off - Flow Type: Laminar and turbulent - Time-Dependent Analysis: Off - Gravity: On - Radiation: Off - Humidity: Off - Default Wall Roughness: 0 micrometer

Material Settings - Fluids: Air

Initial Conditions - Ambient Conditions: - Static Pressure: 101,325.00 Pa - Temperature: 293.20 K - Velocity parameters: - Velocity in X direction: 292.000 m/s - Velocity in Y direction: 0 m/s - Velocity in Z direction: 0 m/s - Turbulence parameters: - Intensity: 0.10% - Length: 1.218e-04 m

Boundary Conditions Not explicitly specified in the document.

Volumetric Heat Sources Not specified in the document.

Engineering Goals - GG Maximum Velocity (X) 1: Maximum value of Velocity (X) - GG Maximum Turbulence Intensity 2: Maximum value of Turbulence Intensity - GG Maximum Turbulent Energy 3: Maximum value of Turbulent Energy - GG Force (X) 4: Force (X) - GG Force (Y) 5: Force (Y) - GG Force (Z) 6: Force (Z) - GG Average Shear Stress (Y) 7: Average value of Shear Stress (Y)

Results

Analysis Goals | Name | Unit | Value | Progress | Criteria | Delta | Use in convergence | |------|------|-------|----------|----------|-------|-------------------| | GG Maximum Velocity (X) 1 | m/s | 385.552 | 72 | 2.55183332 | 3.53017992 | On | | GG Maximum Turbulence Intensity 2 | % | 1000.00 | 100 | 1e-05 | 0 | On | | GG Maximum Turbulent Energy 3 | J/kg | 3927.347 | 100 | 252.584029 | 90.9292134 | On | | GG Force (X) 4 | N | 113.797 | 100 | 16.5008835 | 0.285243549 | On | | GG Force (Y) 5 | N | 368.146 | 100 | 11.4787051 | 1.60726815 | On | | GG Force (Z) 6 | N | 0.004 | 14 | 0.00357430577 | 0.0257219459 | On | | GG Average Shear Stress (Y) 7 | Pa | 0.09 | 100 | 0.341377658 | 0.0909761067 | On |

Global Min-Max Table | Name | Minimum | Maximum | |------|---------|---------| | Density (Fluid) [kg/m^3] | 0.73 | 1.81 | | Pressure [Pa] | 62,924.86 | 170,674.13 | | Temperature [K] | 261.28 | 335.36 | |

Temperature (Fluid) [K] | 261.28 | 335.36 | | Velocity (X) [m/s] | -101.118 | 385.322 | | Velocity (Y) [m/s] | -128.774 | 173.100 | | Velocity (Z) [m/s] | -130.866 | 126.332 | | Mach Number [] | 0 | 1.19 | | Velocity RRF (X) [m/s] | -101.118 | 385.322 | | Velocity RRF (Y) [m/s] | -128.774 | 173.100 | | Velocity RRF (Z) [m/s] | -130.866 | 126.332 | | Relative Pressure [Pa] | -38,400.14 | 69,349.13 | | Bolleneck Number [] | 1.1344072e-10 | 1.0000000 | | Heat Transfer Coefficient [W/m^2/K] | 0 | 0 | | ShortCut Number [] | 2.0585686e-10 | 1.0000000 | | Surface Heat Flux [W/m^2] | 0 | 0 | | Surface Heat Flux (Convective) [W/m^2] | 0 | 0 | | Total Enthalpy Flux [W/m^2] | -1.246e+08 | 1.197e+08 | | Acoustic Power [W/m^3] | 0 | 5107.901 | | Acoustic Power Level [dB] | 0 | 157.08 |

Discussion

The CFD simulation results reveal several important aerodynamic characteristics of the experimental X-wing assembly:

1. **Flow Regime**: The maximum Mach number of 1.19 indicates that the flow reaches supersonic speeds in certain regions of the wing, which explains the high turbulence intensity observed (maximum value of 1000%).

2. **Lift vs. Drag Performance**: - The force in the Y-direction (368.146 N) is significantly higher than the force in the X-direction (113.797 N), suggesting that the wing generates substantial lift relative to drag. - The minimal force in the Z-direction (0.004 N) indicates good symmetry in the design with respect to the horizontal plane.

3. **Shock Formation**: - The presence of supersonic flow (Mach > 1) suggests that shock waves are likely forming on the wing surface, particularly at the leading edges and upper surfaces. - The pressure distribution shows a wide range (62,924.86 Pa to 170,674.13 Pa), which is consistent with shock formation and expansion fans.

4. **Flow Separation and Turbulence**: - The high turbulence intensity and turbulent kinetic energy (3927.347 J/kg) indicate significant flow separation and turbulent regions. - The negative velocity components in all directions suggest complex recirculation zones, particularly in the wake region behind the wing.

5. **Thermal Effects**: - The temperature range (261.28 K to 335.36 K) shows significant heating due to aerodynamic friction and compression effects, particularly in regions of high velocity gradients.

6. **Shear Stress**: - The average shear stress in the Y-direction is relatively low (0.09 Pa), which may indicate areas of flow separation where the boundary layer has detached from the surface.

Conclusion

The experimental X-wing assembly demonstrates promising lift generation capabilities with a favorable lift-to-drag ratio. However, the design exhibits several inefficiencies that should be addressed:

1. The presence of supersonic flow regions leads to shock wave formation, which increases drag and reduces overall efficiency.

2. Significant turbulence and flow separation are observed, particularly in the wake region, which contributes to pressure drag and reduces lift efficiency.

3. The thermal loading varies considerably across the wing surface, which could lead to structural concerns under prolonged operation.

Recommendations

1. **Leading Edge Modification**: Redesign the leading edge geometry to reduce the severity of shock formation and delay the onset of supersonic flow.

2. **Wing Profile Optimization**: Modify the airfoil profile to promote attached flow and reduce turbulence intensity, particularly on the upper surface where flow separation appears most pronounced.

3. **Boundary Layer Control**: Consider implementing passive or active boundary layer control features to maintain attached flow over a wider range of operating conditions.

4. **Thermal Management**: Evaluate the thermal distribution more thoroughly and consider materials or cooling strategies to address hot spots identified in the simulation.

5. **Further Analysis**: Conduct additional simulations at different angles of attack and freestream velocities to fully characterize the performance envelope of the design.