An Experimental and Numerical Study to Analyse Mixed Convection Regime in a Fuselage Crown Compartment
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Overview

- MAAAXIMUS project
- Test Case Description
- Model description
  - Numerical
  - Experimental
- Numerical Results
- Numerical and experimental comparison
- Way forward
Overall Project Objectives:

**Weight Reduction** – replacing the number of parts with ‘one-shot’ technology

**Final Assembly Reduction** – adapt production lines for composites

**Simulation-based Design** – reduce dependence on physical testing

**Understanding Composite behaviour** – reliability and safety
MAAXIMUS-Thermal Activity

Improve thermo analysis

- Global Thermo Analysis at barrel scale
- Different Thermal behaviour of Composite Material
- Predict tools improvement
- More detailed thermal analysis
MAAXIMUS-Thermal Activity

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• Analysis and modelling
• of the thermal behaviour
• of fuselage
• confined compartments
• **Crown Compartment**

- Analysis and modelling
- of the thermal behaviour
- of fuselage
- confined compartments
- Complex compartment to model
- Solar Load
- Air Flow
  - Air condition
- Obstruction elements
  - Pipes

- Dissipating Elements
  - Lights
  - Electrical wires
  - Power supply
Drafting of 3D models and 2D working drawings:

- Width and height are kept same as an actual crown (2.45m x .4m)
- Depth reduced to 2 frames (1.17m)
- Air inlet = 40mm
- 2 x Air outlets = 20mm
- Material Used
  - Polycarbonate
  - Rockwool
  - Glass
- 1 layer insulation (50 mm)
Crown Compartment Rig Design

- Fuselage
- Ventilation Outlets
- Crown Floor
- Ventilation Inlet
Crown Compartment Rig Design

- Thermocouples
- Fuselage
- Ventilation Outlets
- Crown Floor
- Ventilation Inlet
Physical Model
Physical Model Detail
Boundary Conditions

- Experimental Rig
  - Fuselage Temperature
    - Temperature maintained constant by PID controller and 12 heater mats
  - Air flow
    - Mass flow supplied by 10 fans series 400F
- Numerical Set-up
  - Fuselage Temperature
  - Velocity inlet
  - Crown floor Temperature
• Convection Regime
  • Grashof Number $Gr = 6.5E+8$
    - Transition Flow
  • Reynolds Number $Re = 359.4$
    - Laminar Flow
  • Richardson Number
    - Forced convection negligible

\[ Ri = \frac{Gr}{Re^2} \approx 4680 \]

• Modelling
  • Laminar Navier-Stokes equations
  • Boussinesq Approx.

\[ g' = g \frac{\rho_2 - \rho_1}{\rho} \]
Numerical Method and Solution Strategy

- Spatial Discretization
  - Pressure based coupled algorithm
  - Second order upwind scheme
- Time Discretization
  - First Order Scheme
- Green Gauss cell based scheme

\[
\Delta t \approx \frac{\tau}{4} \approx \frac{L}{\sqrt{g\beta \Delta T L}} = 0.01s
\]

- Steady
  - 5000 time steps
  - Unsteady
  - Steady State
Domain and Mesh

- **Domain**
  - 2D
  - Symmetrical
  - Solid Zone
    - Insulation
  - Fluid Zone
    - Air

- **Mesh**
  - Multi-block
    - Structured
    - Unstructured
  - Wall mesh refinement
## Grid Independence Analysis

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<th>AVG Temp</th>
<th>Plume Height</th>
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Results: Temperature Iso-Lines

- $\Delta T$ (Ins.) = 50 K
- $\Delta T$ (Crown) = 30 K
- Temperature contours connected to flow features.
• Flow entering from inlet remains confined at the bottom of the compartment
Results: Buoyancy Driven Flow

- Three major recirculating zones are present due to buoyancy effects
- Unsteady behaviour of eddies
- Convergence problem
Unsteady Laminar Simulation

- Steady Solution utilised as initial solution
- Unsteady solution run
- Convergence reached
- but
- wrong solution
- Flow Visualization of inlet region and crown floor
- Numerical simulation
- (steady flow)
Insulation Temperature

- $T_{\text{End}} = 378 \text{ K}$
- $T_{\text{Floor}} = 298 \text{ K} - \text{Numerical}$
- Ambient Temperature $\approx 300 \text{ K}$
Vertical Temperature Profiles

• a) Mid-section (x=0)
• b) Section 2 (x=0.4)
• c) Section 3 (x=0.8)
Conclusion

• Crown Compartment has been studied both numerically and experimentally
• Only one configuration analysed
  • Necessity to expand the comparison
• Numerical results
  • Steady results needs to be achieved
  • Solution strategy seems to fail for this configuration
  • Turbulent flow should be investigated
• Experiments
  • Necessity to acknowledge flow structures
    – PIV measurements are necessary
THANK YOU FOR YOUR ATTENTION

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