Aircraft passenger cabin thermal comfort analysis by means of integrated mono dimensional CFD approach

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Virtual Prototyping in A&D PLM

Virtual Prototyping covers the full lifecycle development and the validation process.

Needs & Requirements → Concept & Definition → Assessment → Development → Production → Operation & Support

Full Lifecycle Validation

- SYSTEM
- SUB- SYSTEM
- EQUIPMENT

Operational Scenario

Performance Simulation

Concept Evaluation

Flight Test

Laboratory Test

Synthetic Environment

Decomposition & Design

Integration & Testing
Virtual Prototyping in A&D PLM

Virtual & Physical Prototyping & Simulation Extension and Coverage

Virtual Product

Virtual Laboratory

Virtual Manufacturing

Virtual Utilization

Concept

Performance

Industrialization

Operation

Vision

Concept

Experience

Definition

Synthesis

Manufacturing

Maintenance

Recycling

High Power Computing

Multi-disciplinary Simulation

Process, Data & Knowledge Management

Full Scale Testing

Creazione di un "Component"
ECS distribution design and integration – a process view

- Integrated 1D – CFD process view for the evaluation of thermal comfort in a passenger cabin environment
- Methodologies integration: taking the advantage of system-level and CFD methods to ensure that the simulation process is Fit For Purpose
- Parameters relevant for passenger thermal comfort:
  - outlets geometry, positioning and orientation (direct impinging air on the passengers)
  - ECS distribution system architecture (airflow splitting)
  - Thermo-acoustic configuration
** CAD models **

ECS distribution CAD model – input for ECS distribution system 1D model

Passenger Cabin interiors and ECS final distribution CAD model inputs for cabin outlets CFD model and cabin CFD model
** ECS distribution system and components models **

1D ECS distribution model

CFD ECS components model

Coupling between 1D ECS distribution system and CFD ECS components by means of components pneumatic characterization ($\sigma \Delta P - W$ curves)
Passenger cabin and thermal comfort models

Coupling between 1D passenger thermal model and cabin CFD model is performed by means of a Java routine, exchanging data (temperature and velocity distribution near the passenger, heat flux and humidity produced by the passenger) on the CFD model boundaries.

- Upper outlet – interface with ECS 1D model
- Lower outlet – interface with ECS 1D model
- Recirculation grid
- Human surface – interface with passenger thermal model (Gagge 2 node human thermal model)
Passenger thermal model – as is

The model considers the control of body temperature to be accomplished by means of skin temperature and central core body temperature.

**Inputs to the model:**
- Metabolic rate
- Work rate
- Intrinsic clothing insulation
- Velocity of air around body
- Barometric pressure
- Ambient air temperature
- Mean radiant temperature (in first approximation considered equal to ambient air temperature)
- Ambient vapour pressure

**Other parameters:**
- Body weight
- Body surface
- Ratio of body's radiating area to total surface area
- Minimum skin conductance
- Specific heat of blood
- Latent heat of water
- Specific heat of body
- Stefan-Boltzmann Costant
- Lewis Relation at sea level

**Model outputs:**
- Temperature of skin shell
- Central core temperature
- Total heat power from the human body to the environment
- Respired Convective Heat Loss
- Respired Evaporative Heat Loss
- Heat Loss for skin diffusion
- Total evaporative heat loss
- Ratio of mass skin shell to mass central core
- Skin blood flow
- Unevaporated sweat
- Rate total water evaporated (by respiration, perspiration, sweat)
- ASHRAE Effective Temperature

**Inputs from CFD model**

**Outputs to the CFD model**
Passenger thermal model – to be

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Inputs from CFD model

Outputs to the CFD model
ECS distribution design and integration – preliminary results

Mesh model (approx $10^7$ cells)

Temperature pattern

Velocity streamlines
ECS distribution design and integration – next steps

Cabin air distribution system thermo-fluid dynamic and acoustic optimization

Low Pressure Distribution System Optimization
Parametric 1D models and analyses with integrated 1D/CFD methodology (optimization on parametric models)
1. Design Parameters: length and diameter for risers, manifolds
2. Objectives: pressure losses, noise and weight minimization

Cabin Air Outlets Optimization (1)
Non-parametric air outlets CAD models with CatiaV5, CFD analyses (optimization using morphing technique)
1. Design Parameters: air outlets geometry
2. Objectives: pressure losses and noise minimization

Cabin Air Outlets Optimization (2)
Parametric Passenger Cabin CAD models with CatiaV5, CFD analyses (optimization on parametric models)
1. Design Parameters: air outlets location and orientation
2. Objectives: air velocity field in the allowed range (max. 70 fpm at head level in seated position, minimum 10 fpm), minimization of the mean velocity differences among each passenger, head-foot temperature difference minimization
Thank you!