Fraunhofer IBP

FRAUNHOFER INSTITUTE FOR BUILDING PHYSICS IBP

IBP REPORT 516

38 (2011) NEW RESEARCH RESULTS IN BRIEF

Sandeep Rao Bolineni,
Christoph van Treeck

CFD MODELING AND SIMULATION OF AIRCRAFT CABIN

USING PARAMETRIC HUMAN MANIKIN MODELING

BACKGROUND

Thermal comfort studies are relevant for several areas of application such as in the aircraft and automotive areas as well as in building HVAC design. We demonstrate the integration of parametric multi-segmented human manikin models into an aircraft cabin for predicting the thermal comfort of passengers to heterogeneous thermal environments. The geometric model of a virtual human is derived from an ergonomic model which parametrically defines the armature model. Computational Fluid Dynamics (CFD) is used for modeling fluid flow and for predicting local heat transfer between manikin surface elements and the environment. Quantitative evaluation is made through comparison of the obtained numerical results with internally available measurement data of former projects.

PARAMETRIC HUMAN MANIKIN MODELING

A multi-segmented thermo physiological manikin model is used in order to predict the response of the human body to varying environmental conditions. The segmentation of the underlying geometric model follows the specific settings of the thermo physiological model which consists of a concentric layer structure. For example, the upper arm is divided into three segments (interior, posterior and inferior), the model on a whole consists of 48 segments (Figure 1). Both male and female models are derived from an ergonomic RAMSIS model, which provides access to anthropometric data and is a widely accepted industry standard. Transforming body parts according to an ergonomic model which relates topological dependencies is also allowed. Surfaces considered as artificial skin thereby follow posture changes due to geometric constraints of the applied CAD model, respectively.

PARAMETRIC AIRCRAFT CABIN MODEL

A parametric interior aircraft cabin model is developed providing a common geometric base for different configurations. Following the parameterization methodology within the CAD system Catia V5, the interior model can be changed into different configurations ranging from business class to economy class seats.

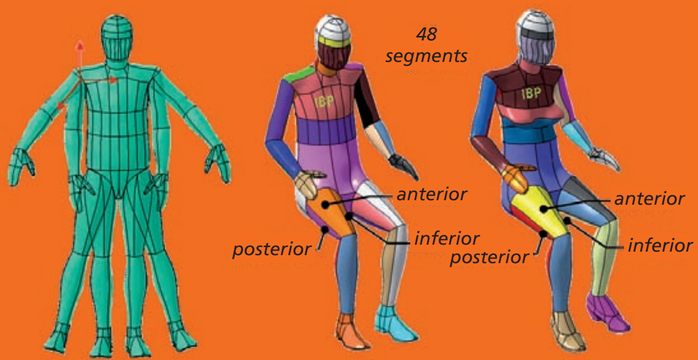
Fraunhofer Institute for Building Physics IBP

Nobelstrasse 12, 70569 Stuttgart, Germany
Phone +49 711 970-00
info@ibp.fraunhofer.de

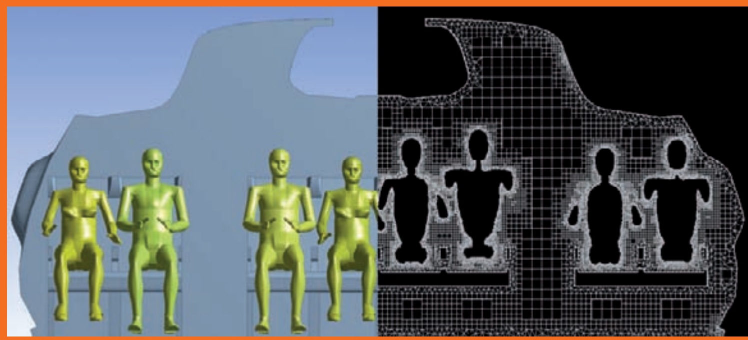
Holzkirchen Branch
Fraunhoferstr. 10, 83626 Valley, Germany
Phone +49 8024 643-0
info@hoki.ibp.fraunhofer.de

Kassel Branch
Gottschalkstr. 28a, 34127 Kassel, Germany
Phone +49 561 804-1870
info-ks@ibp.fraunhofer.de

www.ibp.fraunhofer.de



1 *Parametric human manikin model*



2 *Geometric aircraft model and mesh model.*

INTEGRATED MESH MODEL

In the shown example, eight different sized manikins (male and female) are integrated into the aircraft cabin model which consists of nine rows configured in 2-4-2 economy class seats; the model on a whole consists of 72 manikins. To resolve the boundary layer around the human body, five layers of extruded triangular prisms are created at the surface of the manikin as shown in Figure 2. A typical hexacore mesh of the computational domain consists of about 20 million cells. The meshes are generated using the commercial meshing tools ANSYS ICEM CFD and TGrid.

BOUNDARY CONDITIONS

The physical parameters are taken from real scale experiments conducted at the Flight Test Facility (FTF) of Fraunhofer IBP. In this configuration, the air which is blown from the inlets into the cabin has a velocity of approx. 0.5 m/s and temperature of approx. 8 °C. The surface temperatures of the cabin walls and seats are set to 22 °C and 28 °C, respectively. The initial temperature inside the cabin was taken as 24 °C. Manikin skin temperatures, the dynamic response of an individual to changes of the thermal environment are adapted from a thermoregulation model. The airflow is modeled using the Reynolds averaged Navier Stokes equations (RANS) with a SST-kω Turbulence model using the commercial software ANSYS Fluent.

Diagram 1: Temperature plot at cabin cross section

Diagram 2: Visualization of air flow velocity at cabin cross section

RESULTS

The temperatures of the flow field and manikin skin temperatures are analyzed inside the aircraft cabin. As shown in Diagram 1 the temperatures range from 8 to 32.5 °C observed asymmetrical inside the aircraft cabin, which is mainly due to variable manikin sizes. The air blown from the inlets with a velocity of 0.5 m/s increases smoothly, reaching 1.7 m/s at the outlets (Diagram 2). Further comparison of numerical and experimental results is made in terms of temperature and velocity. First results show satisfactory agreement between CFD and experimental results.

ONGOING DEVELOPMENTS

We currently develop a parametric convective heat transfer coefficient model database based on a series of such CFD simulations for well-defined flow configurations. The data base will be made available as part of our co-simulation middleware developments in the future in order to parametrically assess heat transfer between thermal manikin surface elements and the surrounding micro climate in coupled transient simulations.