Low-Cost Thermal Manikin – A Competitive Instrument to Simulate Thermal Loads and to Determine Thermal Passenger Comfort

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Introduction

The German Aerospace Center (DLR) is a research institute with a plethora of research areas. One of them is the development of novel concepts for air-conditioning in passenger compartments of aircraft, trains and cars. With the objective to determine thermal comfort, ventilation efficiency and energy efficiency under realistic boundary conditions, thermal manikins (TMs) are used to simulate the impact of the passengers and their obstruction. Furthermore, they serve as a measurement tool to determine local equivalent temperatures. The main features of our TMs are a simple design (also available for competitive CFD simulations) and easy handling (TMs are lighter than 4 kg). Moreover, they are technically suitable for flight tests (certified TMs) and easily contactable by means of a power supply pin (direct connection to standard lab power supply possible).

Thermal Manikins As Heat Loads and Obstruction

The core of the TM consists of flame-retardant foam, equipped with heating wire and a thin layer of black heat-conductive aluminum. By varying the spatial density of the wrapped wire in the head region, a higher heat flux density is realized. Each TM, with a volume of 50 l and a surface of 1.52 m^2, can be heated by an external power supply to provide a constant sensible heat release in a range of 0 to about 150 W. Since we need the manikins in large quantities to equip whole aircraft or train compartments, a low-cost system with simple handling and commissioning characteristics is important. The application of our TMs in test facilities within an Airbus A320 [1], in a train laboratory [2] and a generic car [3] is depicted in Figure 1.

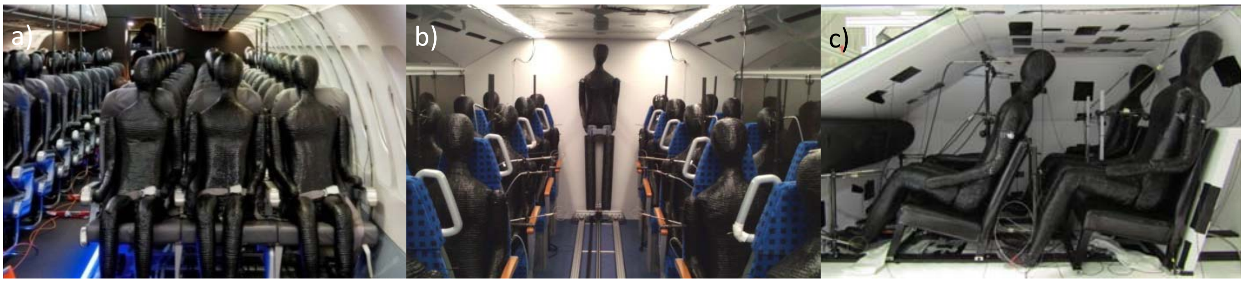

Figure 1: Thermal manikins. a) during flight tests with an A320 b) in a generic train laboratory c) in a generic car mock-up.

Besides their use as stationary, sitting passengers, the TMs are also applied in experimental set-ups to investigate the influence of moving heat loads in a train passenger compartment. The system comprises a 6 m long traverse stage with additional load bearing capacity, a pre-configured control system for the stepping motor and a TM in an upright position [4]. A photo of this standing TM is shown in Figure 1b).

Human Comfort Manikin

Apart from being used as heat loads and obstruction, the TMs are utilized to determine and to evaluate thermal comfort. Commonly, thermal comfort is quantified based on the equivalent temperature (T_{eq}) combining all effects of comfort-relevant influences into a single quantity. According to [5], the TM is calibrated in a dedicated temperature-controlled box (see Figure 2a)) providing isothermal conditions. The boundary conditions, like fluid and surface temperature are monitored by 25 resistance temperature detectors. In addition, the surface temperatures are recorded by an infrared (IR) camera. Based on these data, the mean temperatures of different body parts are calculated. Consequently, we obtain a linear relation between the mean surface temperature of the body part and the mean air temperature within the box. The latter corresponds to the equivalent temperature. By means of this relation we are able to rate the thermal comfort using the evaluation criteria specified in [5].

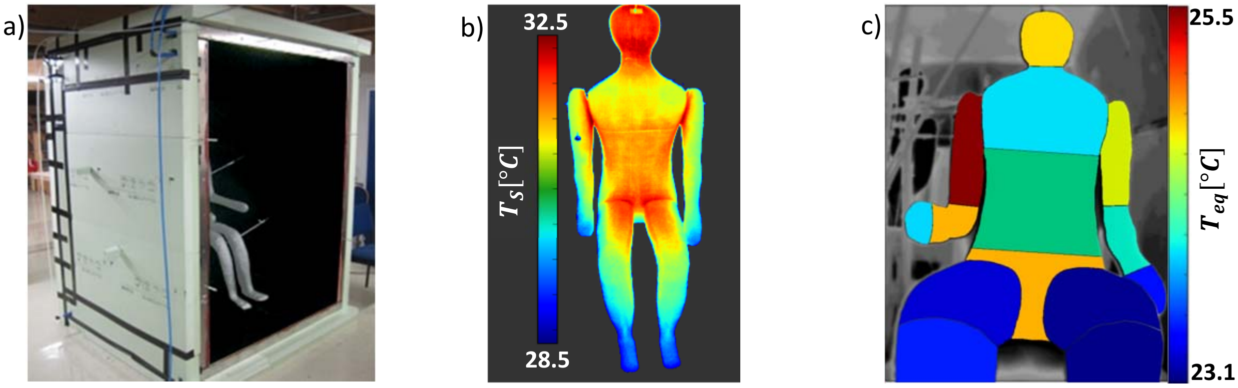

Figure 2: a) calibration box (without front section) and the TM. b) IR view of the TM to determine the surface temperatures. c) local equivalent temperatures of the TM calculated based on the calibration data.

A sample result of the application of the method is revealed in Figure 2). It shows the equivalent temperature for the different body parts of a TM in the generic car mock-up in the case of cabin displacement ventilation.

Additionally, a self-controlled TM is developed with the aim to simulate the human metabolism by automatically adjusting its heating power as a function of the global equivalent temperature.

Conclusion

A low-cost and practicable measurement instrument which allows the simulation of the heat loads and the obstruction of a human passenger, while simultaneously determining the thermal comfort, is highly desirable. At the DLR, a TM was developed which meets these requirements. The TM reveals a simplified, however, realistic shape and heat load of a human body. Furthermore, we defined a process chain to calibrate the TM in order to use it as an instrument for evaluating the thermal passenger comfort. However, the TM is continuously being developed further. Current projects address the topics of dimensionless characterization of the TM with the objective to identify the physical quantities which determine thermal comfort.

References

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