Acta Tecnología - International Scientific Journal about Technologies
Volume: 9 2023 Issue: 1 Pages: 19-23 ISSN 2453-675X


*https://doi.org/10.22306/atec.v9i1.163* *Received: 28 Nov. 2022; Revised: 31 Jan. 2023; Accepted: 20 Feb. 2023*

# Thermal sensation models for environmental parameters testing

**Ruzena Kralikova**
Technical University of Kosice, Faculty of Mechanical Engineering, Department of Environmental Engineering, Park Komenskeho 5, 042 00 Kosice, Slovak Republic, EU, ruzena.kralikova@tuke.sk (corresponding author)
**Ervin Lumnitzer**
Technical University of Kosice, Faculty of Mechanical Engineering, Department of Environmental Engineering, Park Komenskeho 5, 042 00 Kosice, Slovak Republic, EU, ervin.lumnitzer@tuke.sk

***Keywords:*** microclimate, thermal stress, thermal comfort, environment, thermal manikin.
***Abstract:*** Currently, there are various complex models that are used to predict the thermal load, or thermal comfort of the employee with different scales for evaluating the feeling of warmth or of cold, with the help of which it is possible not only to speed up the evaluation of the thermal load but also to make it more precise. With the help of thermal manikins, it is possible to simulate human reactions to heat and humidity conditions. The article deals with the possibilities of using thermal manikins as a useful aid in measuring heat exchange between the environment and the human body, testing thermal stress, etc. These tools will then be available for use by the industry to develop more efficient thermal comfort systems.

## 1 Introduction

The text of the article is font type Times New Roman. The human body is surrounded by a microclimate, which is the result of its convective release of heat in the environment. In industrial operations, workers are exposed to various extreme microclimatic conditions. Currently, there are various complex models that serve to predict the employee's thermal comfort with different scales for evaluating the sensation of heat/cold. Because these models work with different parameters, there is no uniform model that can contain all types of activities and clothing that directly impact thermal well-being.

The real conditions affecting people at the workplace can be simulated in thermal chambers. These climatic chambers are specially designed and equipped for this method of simulation. Human reactions can be simulated using thermal manikins, which are a useful aid in measuring the heat exchange between the environment and the human body, testing thermal stress, etc. Several methods and calculation models are used to assess thermal comfort. Models of the human body are so-called thermal manikins. These devices can be applied primarily when testing the properties of clothing or the safety of specific products such as protective equipment and clothing for extreme conditions, but also in the design and applications of HVAC systems, etc.

Using thermal manikin in climate chambers with different air temperatures, it is possible to simulate the release of heat from the human body. Various techniques are used for measurement and visualization (monitoring of airflow, thermography, anemometry, etc.).

## 2 History of thermal manikins

In 1939, General Electric built the first-ever thermal manikin made of copper to test an electric blanket. Subsequently, figures were produced with the main purpose of testing the protective clothing used by the US military (Figure 1, Figure 2). In 1941, researchers - Gagge, Burton and Bazett developed a unit of thermal resistance that is used to describe the insulating value of clothing (clo). Since then, instrumental studies of man, clothing and his environment have been used more and more.

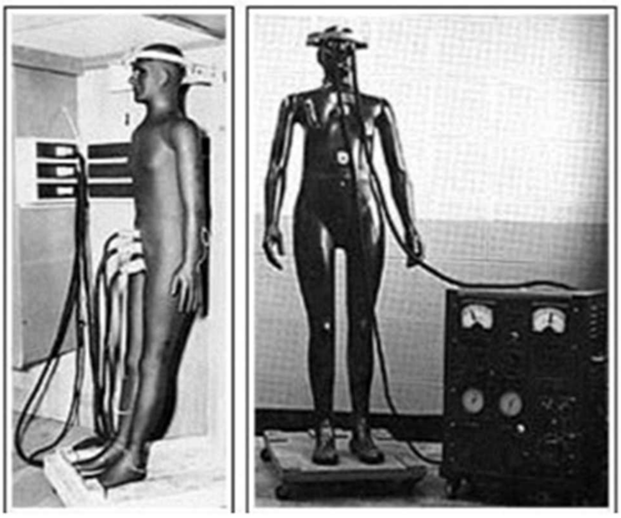

*Figure 1 First models of thermal manikins [1]*

Copper was the material used to make the manikin. The prototype of the manikin still had limited mobility [1,4]. The subsequent development changed not only the appearance but also the type and material of the manikin. From one segment it gradually became a multi-segment. Elements such as a manikin with a sweating system, a breathing system, etc. were gradually added.

In 1964, copper was abandoned and manikins began to be constructed from aluminium. Next, in 1967 were made the first manikins from plastic materials in Denmark. In 1973 there was a manikin that could move and in 1996 it could even breathe. Later, he also performed realistic movements that employees perform during work.

*Figure 2 Thermal test protective clothing manikin [1]*

The material from which the manikin was made also changed. The breakthrough occurred during the millennium when manikins made of porous materials and metals began to appear. The type of regulation has also undergone progress, while the first such manikin worked on analogue regulation, currently, digital transmission of the obtained data is used [1,6].

Currently a thermoregulation manikin with a sweating system is used in the industry. The automotive application, thermal manikins appeared in the 1980s, and they have been in constant development ever since [10].

In addition to experimental methods, numerical methods are also used for indoor microclimate research. These are usually Computational fluid dynamic (CFD) techniques. In both experimental and numerical methods, thermal conditions must be related to the thermal sensations of the interior space user [8,11].

## 3 Models of the thermal manikins

The thermal manikin is a special device that matches a person's appearance and is used to evaluate the thermal load, the so-called thermal comfort or discomfort. With the help of these manikins, it is possible to simulate the transfer of heat between the human body and the working environment. There are different types of human models or models of parts of the human body with different uses [1,2,7]. To a certain limited extent, they can also be used for the purpose of testing human physiological reactions. Among the most famous models used to determine the thermal comfort of a person are:

- Fanger's model,
- Wissler's dynamic model,
- Stolwijk's model,
- Gagg's 2-node model,
- Fiala's model,
- Tanabeh's dynamic model,
- Kohri and Mochid model,
- Fiala's multi-node model etc.

Currently, there are approximately 100 manikin models that are used in determining the thermal-humidity microclimate, for environmental and clothing testing (Figure 3).

*Figure 3 ANDI manikin for clothing testing [13]*

The most frequently used manikin is the Newton model [9]. This model consists of 34 heated 34 zones and is made up of parts such as the head face, chest, abdomen, arms, forearms, hands, hips, calves and feet (Figure 4).

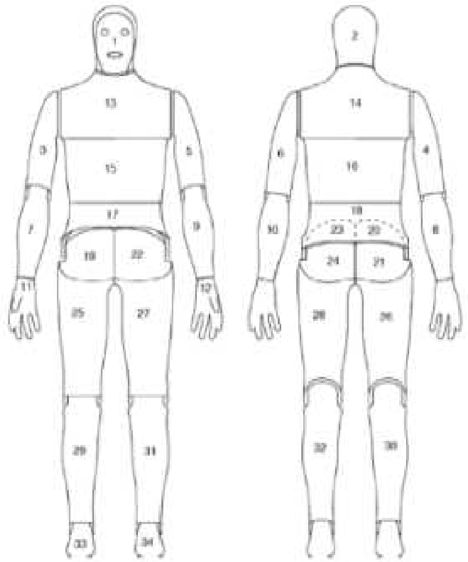

*Figure 4 Newton model with parts of the human body [13]*

The Newton model is interconnected with software, which includes physiological models of thermal comfort. The systems that the manikin contains make it able to simulate a person, i.e., j. sweating, walking, breathing. The manikin even has an adjustable breathing system. These conveniences cause more efficient monitoring of thermal comfort. The data obtained from the manikin is evaluated using special software. System innovations are becoming more and more evident not only in software but also in manikin models. Future software variants will also enable the connection of the classic model of Newton's manikin with virtual reality. This connection will allow any simulations to be performed [13].

### *3.1 HVAC automotive manikins*

The use of thermal manikin is very broad. However, it is mostly used in testing the thermal insulation of protective clothing. When determining the insulation of clothing, the main monitored parameters are moisture evaporation resistance and thermal insulation.

The above-mentioned factors form the basis for the thermal insulation of clothing and are influenced not only by the type of material used but also by the heat and humidity of the environment. The requirements for measurements of thermal insulation of clothing, resistance to moisture evaporation is established by the relevant stan. Advanced thermal manikins for seat testing are shown Newton manikin model and ADAM manikin (ADvanced Automotive Manikin). The values that are obtained are subsequently used for the optimization and modeling of ventilation and air conditioning devices in the interior spaces of buildings.

The danger of heat also often arises in cases of fire. Since a human cannot be used for tests or measurements in these conditions due to the potential risk, manikins are used which are designed to replace humans. Because the surfaces of the manikins (shells) are significantly different compared to human skin, sensors are implanted in the manikins and a related mathematical model is built to simulate the skin.

Thermal manikins are also a key element in the development of technologies based on the Heating, Ventilation and Air-Conditioning system (HVAC) to achieve a safer and more comfortable working environment. In uncomfortable hot ambient, thanks to the thermoregulation system, the human body starts with vasodilatation and sweating, trying to prevent a rise in internal body temperature. Since these mechanisms are of limited capabilities, to prevent the further rise of body temperature and to avoid the risk of hyperthermia, it is necessary to make the ambient comfortable by cooling or to ensure the way to release the heat from the body.

The manikins are available in different materials and designs. Thermal manikin is often used in the automotive industry. Since they help in the development of HVAC technologies, they find their use for the evaluation of heating/air-conditioning equipment in passenger cars, trucks and various other means of transport.

The automotive HVAC manikin features a system that includes a carbon epoxy body mould with surface-mounted sensors that measure air velocity, temperature, radiant heat flux, and relative humidity. The sensors are protected to ensure that the manikin is not damaged during loading and positioning [3,4,10]. The HVAC manikin for automobiles ("Automotive HVAC Manikin") is designed so that it can be easily inserted into any vehicle. The hands are in the shape of gloves with a curved grip, the design of which allows for proper positioning on the steering wheel. Their shape does not affect air movement but allows airflow similar to a human grip/fist. The back of the thighs is flattened to simulate realistic airflow [2,4,5].

The microclimate conditions and thus human thermal sensation as well, are dependent on air temperature, air velocity, relative humidity and mean radiant temperature. Automotive manikins are used to test the thermal comfort of passengers and the thermal and humidity parameters in the cabins of vehicles HVAC systems (Figure 5).

*Figure 5 Newton automotive HVAC manikin [12]*

Any improvement of the HVAC system and optimization of the thermal environment in the cabin are potentially associated with an increase in thermal comfort in the vehicle and a reduction in heat load and greenhouse gas emissions, including the total energy consumption of the vehicle [2,12].

The requirement to provide a comfortable interior space in the vehicle is often met at the expense of energy requirements. The energy demand of the air conditioning unit requires a lot of attention, especially in the case of electric cars and hybrids, when saving electricity affects the range of the vehicle. Among the biggest challenges of the HVAC system of vehicles and car cabins is quickly and efficiently cooling the interior of a vehicle parked in the sun on sunny summer days. Incorporating the solar load as a source of heat into the CFD analysis was difficult until recently, but there has been a shift in this direction and many current CFD software allows calculations taking the solar load into account.

## 4 Conclusion

Today's applications of thermal manikins primarily consisting of the thermal insulation properties of clothing or thermal conditions in building interiors. The use of climatic test chambers with thermal manikins is one of the new trends in HVAC design. By applying these modern technologies, it is currently possible to create a complex model of thermal comfort in the interior of buildings or the interior of the driver's cabin even before the actual HVAC installation takes place. Human thermal manikins with a high degree of sensory spatial resolution, local thermoregulatory responses including sweating, fast time response and feedback for continuous response and adaptation to the thermal environment like a human will be increasingly available for industrial use as well as for the development of more efficient thermal management systems. comfort. Numerical thermal comfort models and thermal manikin are becoming thermal comfort assessment tools that can accurately predict human physiological and psychological responses in real and simulated non-uniform transient thermal environments.

Analytical and simulation computer programs in connection with mathematical models of thermal comfort and human thermal models allow, compared to experimental methods, to provide a more complex picture of microclimate conditions with the possibility of quick and inexpensive solution design.

**Acknowledgment**

The paper is part of a research agency project: APVV-21-0120 " Research of an innovative method of monitoring the noise load generated by overhead power lines" (50%). In addition, the paper is part of the solution of the project KEGA 011TUKE-4/2021 " Implementation of current scientific-research, technical and methodological solutions in the environmental engineering field into the educational process at universities” (50%).

## References

[1] FANGER, P.: *Thermal Comfort-Analysis and Applications in Environmental Engineering*, Thermal Comfort-Analysis and Applications in Environ, Engineering, Danish Technical Press, Denmark, 1970.

[2] KHATOON, S., KIM, M.H.: Thermal Comfort in the Passenger Compartment Using a 3D Num. Analysis and Comparison with Fanger’s Comfort Models, *Energies*, Vol. 13, No. 3, pp. 1-15, 2020. https://doi.org/10.3390/en13030690

[3] KLIMENT, M., PEKARCIKOVA, M., TREBUNA, P., TREBUNA, M.: Application of TestBed 4.0 Technology within the Implementation of Industry 4.0 in Teaching Methods of Industrial Engineering as Well as Industrial Practice, *Sustainability*, Vol. 13, No. 6, pp. 1-16, 2021. https://doi.org/10.3390/su13168963

[4] KOELBLEN, B.: Thermal sensation models: Validation and sensitivity towards thermo-physiological parameters, *Building and Environ*, Vol. 12, pp. 200-211, 2018.

[5] MATSUNAGA, K., SUDO, F., TANABE, S., MADSEN, T.L.: Evaluation and Measurement of Thermal Comfort in the Vehicles with a New Thermal Manikin, *SAE Technical Paper*, 931958, 1993. https://doi.org/10.4271/931958

[6] PSIKUTA, A., ALLEGRINI, J., KOELBLEN, B., BOGDAN, A., ANNAHEIM, S., MARTÍNEZ, N., DEROME, D., CARMELIET, J., ROSSI, R.M.: Thermal manikins controlled by human thermoregulation models for energy efficiency and thermal comfort research – A review, *Renewable and Sustainable Energy Reviews*, Vol. 78, pp. 1315-1330, 2017.

[7] SCHAUDIENST, F., VOGDT, F.U.: Fanger’s model of thermal comfort: a model suitable just for men?, *Energy Procedia*, Vol. 132, pp. 129-134, 2017.

[8] TREBUNA, P., PETRIKOVÁ, A., PEKARČÍKOVÁ, M.: Influence of physical factors of working environment on worker's performance from the ergonomic point of view, *Acta Simulatio*, Vol. 3, No. 3, pp. 1-9, 2017.

[9] VOELKER, C., MAEMPEL, S., KORNADT, O.: Measuring the human body's microclimate using a thermal manikin, *Indoor Air*, Vol. 24, No. 6, pp. 567-79, 2014. https://doi.org/10.1111/ina.12112

[10] RUZIC, D., BIKIC, S.: An approach to the modeling of a virtual thermal manikin, *Thermal Science*, Vol. 18, No. 4, pp. 1413-1423, 2014. https://doi.org/10.2298/TSCI130115115R

[11] VARGA, G., FERENCSIK, V.: Analysis of Cylindricity Error of High and Low Temperature Storage Tested Alternator Stators, *International Journal of Automotive Technology*, Vol. 21, No. 6, pp. 1519-1526, 2020. https://doi.org/10.1007/s12239-020-0143-3

[12] Automotive HVAC Manikin: Measure passenger comfort and environmental conditions in automobile

and transit cabins, [Online], Available: http://thermetrics.com/products/manikin/automotive-hvac-manikin [05 Jun 2022], 2022.

[13] Newton Thermal Manikin: Thermal manikin designed for clothing and environmental testing, [Online], Available: http://thermetrics.com/products/manikin/automotive-hvac-manikin [05 Feb 2022], 2022.

**Review process**

Single-blind peer review process.