Project POLARBEAR BUILDING

Technologies GmbH

Computational analysis of bio inspired thermal absorber systems made of textile fabrics

Introduction

Textile fabrics are characterized by a large surface, a low weight and a high mechanical stability. Therefore, they are suitable for various applications in the field of bionics. The present work deals with the use of textile fabrics in thermal absorber systems. Thermal absorber systems heat up by incoming solar radiation and the heat is transferred to air flowing through the textile structure. At the same time, they can act as thermal insulation. For the evaluation and interpretation of these systems numerical investigations are performed.

Thermal absorber system

Fig. 1: *Polarbear (© A. Walker)*

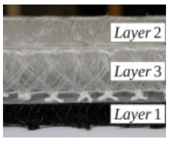

Fig. 2: *Thermal collector*

Thermal absorber systems made of textile fabrics are inspired by the icebear (Fig. 1). They can utilised as self-supporting or on existings roofs. The used thermal collector (Fig. 2) consists of three different textile fabrics. It was developed at the Institute of Textile Technology and Process Engineering Denkendorf (ITV).

The decisive physical processes for the function of thermal absorber systems are (Fig. 3):

- Solar radiation is transmitted.
- Heat radiation produced by the roof and the heated structure is reflected by layer 2 and 3.
- The thermal collector has a low thermal diffusivity.
- Flowing through air absorbs heat from the textile fabric.
- Pressure loss of the flowing through air is low.

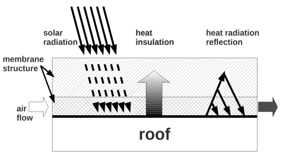

Fig. 3: *Design and principle*

Preprocessing

Due to their porous structure, textile fabrics have a large heat-exchanging surface. If they are handled as homogenized porous structures, the heat transfer processes can not be described in a correct way. Therefore a microstructure model locally resolving all filaments of the three-dimensional fabrics has been formulated using the Pace3D-Software.

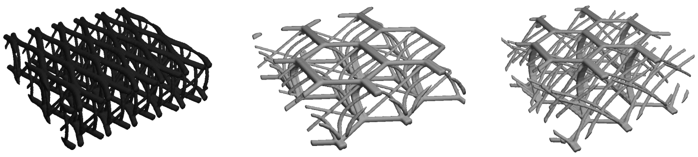

Fig. 4: *Modeled layers of the thermal collector*

Simplified radiation model

To analyze the heat transfer processes inside the three-dimensional fabrics, numerical imulations have been performed using the phase-field solver Pace3D and the commercial CFD-Solver StarCCM+.

LC1 - pressure loss and heat transfer on a simplified geometry

In the first loadcase the convective heat transfer and the pressure loss in a section of layer 1 is computed using a simplified radiation model based on the Stefan–Boltzmann law.

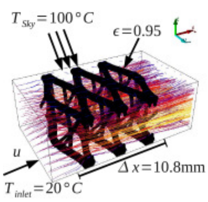

Fig. 5: *BC LC1*

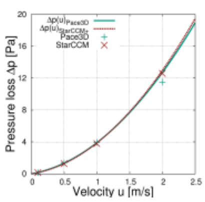

Fig. 6: *Pressure loss*

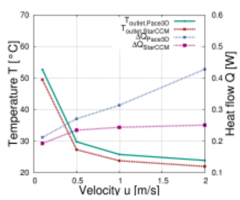

Fig. 7: *Temperature*

Solar radiation model

Simulating the same section of layer 1 as in Load Case 1 (LC 1) with a solar radiation model in StarCCM+, lower outlet temperatures are achieved. This makes the use of the solar radiation model for further investigations obligatory.

LC2 – heat transfer on a simplified model

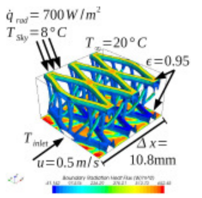

Fig. 8: *BC LC2*

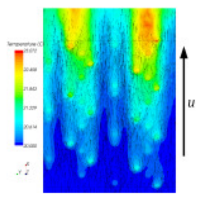

Fig. 9: *Temperature*

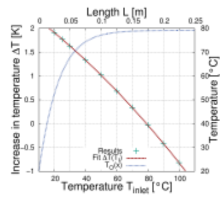

Fig. 10: *Temperature*

LC2 includes a heat sink above the structure (Fig. 8). By variation the inlet temperature, the maximum outlet temperature is computed with 80 ℃. This study allows to estimate the outlet temperature as a function of the length of a thermal absorber system (Fig. 10).

LC3 – heat transfer on a complex model

To achieve higher output temperatures than 80 ℃ (compare LC2), the layer 1 must be insulated from the surrounding air and the losses by heat radiation must be reduced. This leads to the complex collector structure in figure 2.

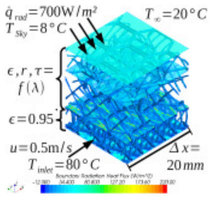

Fig. 11: *BC LC3*

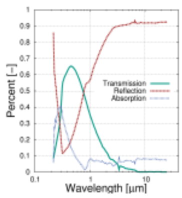

Fig. 12: *Radiation properties*

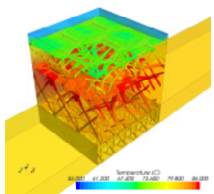

Fig. 13: *Temperature*

Layer 2, 3 and the intermediate films have well-defined radiation properties (Fig. 12). They not only reflect IR radiation produced by the roof and the heated structure, but also reflect and absorb most of the incoming UV radiation to protect the underlying layers. The simulation (Fig. 11) has demonstrated a temperature increase (Toutlet = 80.6 ℃) and a reduced proportion of the incident UV radiation in the lower region of the collector.

Conclusion

The results show that the advanced simulation techniques allow to analyse the rate of convective heat transfer, radiation and pressure loss in three-dimensional fabrics. With the help of a simulation study of microstructure models of the textile fabrics, dimensioning of large-scale applications can be made. In future, additional effects e.g. free convection in the layers or different solar altitudes should be taken into account improving the quality of the results. A comparison with experimental investigations is intended.

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