however, it seems not to be necessary with respect to satisfactory precision of calculations for a number of Gauss points equal to 2.

Conclusion remark

In the paper, a simple way of average thermal conductivity calculation of FGM filled with long parallely-arranged fibres was presented. Next the effective thermal conductivity for a layer of fibre FGM was determined in the gradient direction of fibre diameter changes. Numerical calculations were carried out for a material of linear variability of fibre diameter, assuming different velocity of fibre radius changes across the thickness of the material sample.

Additionally it was shown that in the case of thermal properties, lamina consisting of three or more layers can be treated as continuous with good accuracy. Consequently there is no need to consider all layers of lamina because we can homogenise them in one structure with the prescribed function defining the variability of the fibre diameter, and then treat it as continuous.

The effectiveness of the proposed method of calculation of effective thermal conductivities of fibre FGM is defined by the number of elementary mathematical operations which have to be done to calculate proper integrals. Assuming numerical integration using five Gauss points to calculate the average thermal conductivity at a given point and two Gauss points to calculate the effective thermal coefficient of the whole layer of fibre FGM, we need a little more then one hundred elementary mathematical operations. In the real world of numerical calculations, the time of execution of this number of calculations is negligibly small.

To verify the accuracy of this approach we need practical tests. In the case of insufficient compatibility of practical test results with numerical calculations, the method proposed should be revised taking into account the stochastic approach to fibre arrangements in the unit cell.

References

1. Latha PK, Darshana Y, Venugopal V. Role of building material in thermal comfort in tropical climates – A review. *Journal of Building Engineering* 2015; 3: 104–113.
2. Mlakar J, Štrancar J. Temperature and humidity profiles in passive-house building blocks. *Build Environ* 2013; 60: 185–193.
3. Song G, Paskaluk S, Sati R, Crown EM, Dale JD, Ackerman M. Thermal protective performance of protective clothing used for low radiant heat protection. *Text Res J* 2011; 81(3): 311-323.
4. Yu S, Warren JJ. Numerical modeling of heat and moisture transfer in a wearable convective cooling system for human comfort. *Build Environ* 2015; 93(2): 50–62.
5. Korycki R. Two-dimensional shape identification for the unsteady con-duction problem. *Struct Multidiscip O* 2001; 21(3): 229-238.
6. Zucca S. Identification of a low-order model for thermal stress monitoring. *J Therm Stresses* 2005; 28(3): 301-315.
7. Kodur VKR, Naser M, Pakala P, Varma A. Modeling the response of composite beam–slab assemblies exposed to fire. *J Constr Steel Res* 2013; 80: 163-173.
8. Korycki R. Modeling of transient heat transfer within bounded seams. *Fibres Text East Eur* 2011; 88(5): 112-116.
9. Padture NP, Gell M, Jordan EH. Thermal Barrier Coatings for Gas-Turbine Engine Applications. *Science* Journals 2002; 296(5566): 280-284.
10. Koizumi M. FGM activities in Japan. *Compos Part B-Eng* 1997; 28(1-2): 1-4.
11. Shabana YM, Noda N. Numerical evaluation of the thermomechanical effective properties of a functionally graded material using the homogenization method. *Int J Solids Struct* 2008; 45: 3494-3506.
12. Yin HM, Paulino GH, Buttlar WG, Sun LZ. Effective Thermal Conductivity of Two-Phase Functionally Graded Particulate Composites. *J Appl Phys* 2005; 98(6): 063704-063704-9.
13. Giunta G, Crisafulli D, Belouettar S, Carrera E. A thermo-mechanical analysis of functionally graded beams via hierarchical modelling. *Compos Struct* 2013; 95: 676-690.
14. Loja MAR, Barbosa JI, Mota Soares CM. A study on the modeling of sandwich functionally graded particulate composites. *Compos Struct* 2012; 94(7): 2209–2217.
15. Huu-Tai T, Seung-Eock K. A review of theories for the modeling and analysis of functionally graded plates and shells 2015. *Compos Struct*; 128: 70–86.
16. Kelly A. *Concise Encyclopedia of Composite Materials*. Pergamon, 1994.
17. Olatunji AO, Boetcher SKS, Cundari TR. Thermal conduction analysis layered functionally graded materials. *Comp Mater Sci* 2012; 54: 329-335.
18. Ghoshdastidar PS. *Heat Transfer*. Oxford University Press, 2004.
19. Dems K, Radaszewska E, Turant J. Modeling of Fibre-Reinforced Composite Material Subjected to Thermal Load. *J Therm Stresses* 2012; 35: 579-595.

Received 15.12.2015 Reviewed 02.02.2016