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Thermodynamic Processes in Nanostructured Thermocoatings

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1 Introduction

In the 21st century, humanity has faced serious problems of energy and environmental aspects. Reducing energy consumption is fundamental tools in order to slow the degradation of our environment. Because of these reasons regulations relating to thermal insulation performance of buildings are getting more and more rigorous nowadays. The appearance of nanotechnology-based thermal insulation materials in building industry opened several possibilities in the 1990s for designers because of their high-performance thermal insulating quality (Leydecker, 2008) from which nano-ceramic thermocoatings are generally considered to be the most critical because of the contradictory technical data about their thermal insulating mechanism.

The most paint-on insulation products contain microscopic vacuum-hollow ceramic microspheres with a diameter of 20-120 μm and with a cellular wall thickness of 50-200 nm. These microspheres are mixed with synthetic binging materials (styrene and acryl latex). They are typically used for exterior and interior wall insulation, but they are also suitable for pipe insulation and protection against fire and corrosion. (Lan *et al.*, 2014).

2 Aims, Methods and Results

Special literature provides different data about thermal insulation quality about nano-ceramic thermocoatings (Chukhlanov *et al.*, 2017; Lakatos, 2016; Orbán, 2015) Therefore, thermodynamic tests with nano-ceramic thermocoatings became the main focus of this paper and the main research task was to clear and describe the thermophysical processes inside nano-ceramic thermocoatings. After studying the special literature six experiments were made.

The first two experiments were conducted to find out that the materials really has heat reflective ability (heat mirror effect) and to check whether it has an extremely low thermal conductivity claimed by some special literature references and the manufacturer's handouts. Results of Experiment 1 seemed to show a minor negative effect of nano-ceramic coating to thermal insulation quality. During Experiment 2 thermal conductivity of the pure nano-ceramic coating was tested directly and in air-dry condition it was measured to be 0.0690 W/mK. It was also declared that thermal conductivity of this material has the same thermal conductivity if it is used as a very thin membrane (Bozsaky, 2017).

Based on former experiments it was concluded that insulating effect of nano-ceramic thermocoatings is probably not caused by its extremely low thermal conductivity but their high surface heat transfer resistance. Considering it as a basic concept four more experiments (Experiments 3-6) were conducted in 2016-2018. For these experiments 6 different sample

configurations were constructed containing traditional thermal insulation materials (EPS, XPS, OSB). An additional air gap was included into the construction with different sizes. There were configurations, which contained nano-ceramic coated and uncoated samples as well.

Because of the inhomogeneous sample configurations effective thermal conductivity (λ_{eff}) was able to be measured. Air gap had the same position and the same size in each sample so the conduction and convection inside air gap should be also the same in each case. This is why difference between effective thermal conductivity of coated and uncoated samples could be attributed only to the coating. From these tests is was expected that there will be significant differences in effective thermal conductivity between coated and uncoated samples and the increasing size of air gap should cause higher changes.

3 Conclusions

Due to the fact that test results of EPS and XPS samples were consistent with preliminary expectations, Experiments 3-6 confirmed the previously raised theory that because of their special nanostructure, insulating effect of nano-ceramic thermocoatings lies in their significantly higher surface heat transfer resistance than traditional, macro-structured thermal insulation materials. It can be declared that in case of using nano-structured thermocoatings on the surfaces of building structures convective heat transfer coefficient (h_i or h_e, according to the location of the coating) might be taken account in different way than in case of traditional macro-structured thermal insulation materials. New results also showed that the effectiveness of nano-ceramic thermocoatings is more intensive using it on the cold side of the structure. It can also be stated that the application of nano-ceramic thermocoatings between two structural layers is the least effective method from thermal insulating point of view. Test results of OSB samples showed that the same material quality, composition and application technology may not be suitable for insulating different kind of surfaces.

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