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Condensation tests on glass samples for energy efficient windows

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Abstract

This article presents results from a pilot study comparing condensation patterns on small glass samples with different surface properties. Experiments were carried out on three commercial glass samples (clear float, TiO_2-coated and SnO_2-coated) to see how water condensed on the different surfaces. The experiments were carried out under a clear night sky in Uppsala, Sweden. It was found that the pane with the low-emittance coating stayed clean of condensation longer than the other two. In the morning, the water layer on the TiO_2-coated sample was smeared out so that it was possible to see through that pane, while the view through the other two was still blurred. The TiO_2 coating does not prevent condensation, but makes it easier to see through the water layer. These simple tests indicate noticeable differences between different surface materials and also that these effects can be studied by exposing small samples to a clear night sky without having to perform full scale tests.

Keywords: External water condensation; Energy efficient windows

1. Introduction

Most of us have experienced water condensation on windows, either between the window panes or on the inside [1]. In both cases, the condensation indicates that the window is of poor quality or has a high *U*-value. In the former case, humid air leaks into a space that is supposed to be closed or properly ventilated and in the latter case water condenses on the inner window surface because the window is considerably colder than the room [2]. That means that heat leaks out from the room through the window. The phenomenon of interest in this article, external condensation on windows, is experienced when the temperature of the external glass pane of a window goes below the outside dew point due to radiative cooling [3–5]. This is a relatively new phenomenon and appears during clear nights on well-insulated windows for which the thermal losses do not balance the radiative cooling of the external glass surface. Such a decrease in pane temperature is desirable when a radiative cooling system is designed and has, therefore, been studied for that application [6–10], but not in relation to well-insulated windows.

Condensation happens during clear nights when radiation from the window towards the sky is large. The scope of condensation depends on the environment, the building and the climate (weather). The characteristics of the outer surface also affects how fast condensation appears and how it is distributed across the surface [11,12]. Often small droplets are formed and they cause light scattering which obstructs the view through the window.

A general resistance against using well-insulated windows because of this phenomenon can be noticed [13]. In order to avoid, or at least reduce, the problem with external water condensation on windows, thin film glass coating technology can be utilized. Especially two concepts are of interest here, low-emissivity coatings and hydrophilic coatings. A low-emissivity coating will decrease the occurrence of condensation, whereas a hydrophilic surface will help smearing out the water on the surface so that the view through the window is less obstructed.

Many factors, both surface properties and environmental conditions, affect the process of water vapour condensation on a solid surface. There are broadly speaking two types of condensation: dropwise condensation and film

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condensation. In the former case, the condensate is created in the form of individual drops and, in the latter case, the condensate forms a continuous layer on the surface [14]. Mixed types of condensation also exist. Our work presented here is a first attempt to evaluate how different coatings on the outer surface affect the condensation process. The aim is to evaluate different ways of avoiding the problem of obstructed view through a window due to external water condensation and to develop a technique to monitor the occurrence of condensation.

Since the perceived problem of external condensation on well-insulated windows in cold climates is relatively new, only few observations and simulations have been carried out [15–17], but no systematic study of the actual process. Experiments have not been undertaken, since the night sky is difficult to simulate in a laboratory. A more investigated problem is external condensation on poorly insulated windows in hot climates in air-conditioned buildings [18]. Then, dew on the window is a sign of poor thermal insulation, whereas in our case, dew on the window is a sign of excellent thermal quality. Well-insulated windows constitute a way to save energy [19,20], and it is therefore, important to find a way to make the view through these windows less obstructed by possible condensation.

We decided to study three glazing products (see Table 1); uncoated clear float glass (surface emissivity 0.84) as a reference since most windows of today do not have any external coating, a low-emissivity fluorine-doped tin dioxide hard coating (surface emissivity 0.15) since it is often used on internal surfaces and, therefore, commercially available, and a titanium dioxide coated self-cleaning glazing product (surface emissivity 0.84) since it has the desired hydrophilic properties and is expected to gain a larger market share. Both coated products are well known for their durability and can, therefore, be used with the coating on the external surface. Most other low-emissivity products can only be used in a sealed insulated glass unit and are, therefore, not feasible for this possible future application.

The solar optical properties, such as the reduction of the solar factor (g), must be considered when external coatings are applied on windows. This was, however, beyond the scope of the present study. The object of this work was primarily to perform a feasibility study to see to which extent simple tests with only visible inspection of small samples can provide information about the formation of condensation on different glass coatings.

2. Experimental setup

Our experiments, accounted for here, were not carried out on real, installed windows, but on small test samples. The sample size was not regarded as being critical since edge effects were expected to be small also for small samples because of the low heat conductivity of glass. For the first experiment, we used smaller, 5 cm × 10 cm, samples simply to test the feasibility of the methodology. In the two following experiments, larger, 30 cm × 30 cm, samples were used to get a better visual impression of the condensation.

The glass samples were left facing the night sky as described in Sections 2.1–2.3. In two of our experiments, the test panes were placed horizontally and in a third experiment they were put in an almost upright position to better simulate a real window situation. Since the panes were tilted instead of vertical, condensation would occur more often than on a real window. For a vertical window, the surface normal points in the direction of the horizon and the sky only covers the upper half of the hemisphere seen by the glass surface. For a tilted window, the sky covers more than half of the hemisphere (the view factor is larger than 0.5) and hence the radiative cooling from the sky is higher [21]. The inclination of the glass pane was not expected to affect the formation of condensation in any other way than changing the time of the onset of condensation, i.e., it was not expected to affect the structure of the condensation. When much condensation has formed the inclination will affect how easily the drops run down the pane, but in our experiments that latter part of the condensation process was not primarily studied.

All tests were performed during clear summer nights, with almost no wind, since condensation is more likely to occur under these conditions [16]. We did not measure the relative humidity or calculate the dew point, since we were primarily interested in monitoring differences between the samples. The pane temperature was measured with thermocouples. For upcoming experiments, an IR-camera could give additional information. These initial experiments were not undertaken to verify any models when condensation occurs. We used visual inspection, but for future experiments, we have developed a testing equipment that can

Table 1
Our samples

Called here	Description
Clear float glass	Traditional commercial clear float glass with no coatings
Low-emissivity coated glass	Commercial pane with a low-emissivity coating with a surface resistivity of about 20 Ω/□. This pane is today used in well-insulated windows with the coating either on the outer side of the innermost pane or on the inner side of the external pane, i.e., the coated side is not turned outside as in our experiments and measurements
Self-cleaning glass	Commercial pane with a titanium dioxide, "titania", coating with self-cleaning properties. This pane is relatively new. It has been sold for only a couple of years and stands for a very small part of the world float glass pane market

The three glass samples tested in our experiments.