Thermal Deformation of Window for Climatic Conditions of Russia

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Abstract. During the last decades in Russia new designs of window found wide application. As a rule, modern designs of window are made of combinations of materials with different thermal characteristics. Most of them are designed for European climatic conditions. Operation in climatic conditions of Russia can lead to essential thermal deformations of elements of a design of window. It is necessary to consider that thermal deformations of various elements of window (a frame, a shutter, an impost) can lead to change of the main operational parameters of a design. Current regulations this parameter is not currently normalized. The authors conducted a large volume of experimental studies of window blocks made of PVC, aluminum alloys and other materials in order to assess the impact of thermal deformation on the characteristics of window blocks. On the basis of the conducted studies revealed a significant influence of thermal deformation of structures on thermal performance, the minimum temperature on the inner surface, the change of air permeability through the window unit, reducing the insulation of window units. Thus, the revealed physical process directly influences maintenance of comfort, an internal microclimate, costs of heating, ventilation and conditioning of buildings. Taking into account the diversity of climatic regions of Russia, there is a need for a comprehensive assessment of the main performance characteristics of window units, the development of measures to reduce the impact of thermal deformation on the performance of window units and the selection of optimal technical solutions for a given region of construction.

1. Thermal deformations of windows as a physical process

With the effect of thermal deformations of windows, domestic specialists collided in the mid-1990s, when the products of foreign companies from PVC profiles and combined aluminum profiles with thermal inserts began to be supplied to the Russian market. Over the past decade, the design of windows has been generally adapted to the climatic conditions of Russia, the problems of selecting the chemical composition of the main components of the structure have been solved, their durability and frost resistance.

From the system of rationing and description of physical processes occurring in translucent structures, such an important physical indicator as the thermal deformation of the profile system constantly falls out. As shown by the conducted studies, windows from PVC and aluminum with thermoinserts are to a greater extent subjected to thermal deformations. For wooden windows and
window made of fiberglass, this effect is insignificant. Windows from other materials (steel, aluminum, without thermal breaks and others) are used much less often.

In general, the physical effect of the thermal deformation of the profile of the window arises from the difference between the external and internal air temperature and, respectively, between the external and internal surfaces of the structure during the cold period of the year. In this case, due to the effect of temperature linear expansion, the outer side of the structure is compressed relative to the internal one, which leads to the appearance of deflection. But even more important problem in this case is the unevenness of temperature deformations in adjacent structural elements having different thickness, thermal conductivity and / or consisting of materials with different coefficients of temperature linear expansion (CTLE). The most pronounced effect is for combinations of materials with significantly different values of the CTLE - a profile of PVC and steel reinforcement, aluminum profile, glass and thermal inserts. According to the terminology of colleagues from Germany, this physical process was called "bimetallic effect".

Thus, thermal deformations of the window block profile have a complex nonlinear dependence on a complex of various physical effects and design parameters of the window unit. This is the temperature of the outside and inside air, the width of the profile system and the thermal insert, the type and depth of the installation of the insulating glass unit, the number and location of the locking systems, the type of installation, the location and the number of installed fasteners.

In Fig.1 the schemes of possible deflections of the window profiles relative to each other caused by thermal deformations are given.

\[ f = \frac{L^2K \Delta t}{8B} \]  

Fig. 1. The scheme of possible deflections of profiles relative to each other.

I - impost; S - sash; F - frame;

f_S - deflection of the sash of the window; f_I - deflection of the window impost; f_F - deflection of the window frame; f_I-S - relative deformation of the impost and sash; f_F-S - relative deformation of the frame and sash.

In a simplified form, the value of the thermal deformation of the profile depends on its design length (L), width (B), temperature difference (\(\Delta t\)), and the coefficient of linear thermal expansion of the material (K).

\[ f = \frac{L^2K \Delta t}{8B} \]  

This formula, given in [1], is valid for a uniform temperature gradient over the section and depth of the profile, which can be observed, for example, in a PVC profile (without reinforcement). For windows made of aluminum and PVC profiles with a large width, the structure of the deformations can differ significantly from the proposed physical model. Increasing the profile width in some cases can even increase the degree of thermal deformation. In this case, in order to obtain accurate values, it is necessary to calculate the temperature fields and to estimate the thermal deformations on their basis.
This physical process is difficult to be mathematically and computer simulated. There are some publications on the results of the study of thermal deformations using the calculation method [2], but there is no information on the comparison of the results with experimental data, except for a separate test of PVC windows [3].

Foreign developers of profile systems from PVC and aluminum profiles also take steps towards studying this physical process. The main vector of their research is the creation of similar temperature differences by heating the inner surface of the window. The results of the research are used in the development of new profile systems.

2. Effect of thermal deformation on the indoor microclimate

The effect of thermal deformation can influence the microclimate in the room. In addition to a significant decrease in temperature on the inner surface of the window, the effect of thermal deformation leads to increased infiltration / exfiltration through a window that significantly exceeds the declared operational characteristics of the window [4]. Thus, the air permeability of a window made of aluminum alloys changed during the tests at various external temperatures by 7 times.

In addition to the thermal engineering component, which influences the microclimate and the comfort of staying indoors, a decrease in the sound insulation of the window subjected to thermal deformations was revealed.

3. Experimental studies of thermal deformations of windows

In the laboratory "Enclosing structures of high-rise and unique buildings" NIISF RAABS in recent years carried out a large complex of studies of thermal deformations of the window as a physical process and its influence on various operational characteristics of this class of structures. To conduct research, a methodology and unique experimental equipment, protected by patents for inventions and utility models [5, 6], was developed. Selected results have been published in Russian and foreign publications [4, 7]. The work on the study of thermal deformation of windows made of PVC, aluminum and wood with various types of filling (single, double glass unit, glued-in double glass unit) has been performed.

In Fig. 3 shows the results of measurements of thermal deformations of various types of windows, when conducting thermal tests.

![Fig. 3. Comparison of deformations of various types of windows.](image_url)

Fig. 2. Comparison of deflections of the impost of various types of windows from PVC profile under the same conditions.
In all cases, with large differences in the temperatures of the internal and external air, strong and uneven deformations of the window elements occurred.

In all the examined test results, large deformations were observed in the impost (Fig. 2). Also, in most cases, the deformations of the frame and the flaps on the loop side were approximately equal, although in the aluminum profile [4] the deformation of the frame was much larger than that of the leaf (Fig. 3). The deflections of the sash from the side of the impost coincided with the deflections of either the flaps from the loop side or the impost. In general, it has not been possible to identify a single scheme for window deformation until now, even for structures of the same type of materials and components. At the same time, it was revealed that there is a direct relationship between the magnitude of mutual deformations of a combination of profiles (frame-impost, frame-wing) from the temperature difference.

Comparison of the values of thermal deformation with the values of deflections arising due to the effect of wind load, showed that the values of the deflections of the window elements due to these physical processes are comparable. While the value of the maximum deflection due to the effect of the wind load is normalized [8] as 1/300 or 6 mm (recommended values of deflections according to [9]), the value of a comparable but not less important parameter remains beyond the standard performance characteristics.

The most interesting is to estimate the mutual influence of the impact of wind load and thermal deformations on the window. To solve this problem, it is necessary to develop a new generation of experimental equipment.

4. Effect of thermal deformations of window blocks on their sound insulation

During the thermotechnical testing of windows and balcony doors of profiles from aluminum alloys with a triple glass unit SPD 6I-14Ar-4-14Ar-I4, the size of 2600x2740 mm. At the same time, thermal deformation tests of the design and insulation of airborne noise were performed.

The results of measuring thermal deformation in the range of external temperatures text = 0 ÷ -40°C are shown in Fig. 4. The obtained values of the relative deflection of the combination of the frame-wing profiles are well comparable with the results of Fig. The scheme of action as a whole coincides with type 2 in Fig. 1.

In Fig.5, the graph of the influence of insulation of air noise of a balcony door from profiles from aluminum alloys with a triple glass unit SPD 6I-14Ar-4-14Ar-I4 under the influence of thermal deformation is given.

As can be seen from the analysis of the obtained data (Fig.4 and Fig.5), the increase in thermal deformations leads to a decrease in sound insulation by 2-3 dB. When testing a similar window in
accordance with GOST 27296-12 in the absence of temperature difference, the value of sound insulation is 41 dB.

Of course, in order to obtain reliable dependencies, it is necessary to carry out a much larger amount of experimental data and to develop a specialized experimental procedure. In general, the reduction of sound insulation through windows with a large difference in outdoor and indoor temperatures is confirmed by the large volume of field surveys.

![Graph showing thermal deformations of a window from profiles from aluminum alloys.](image1)

**Fig. 4.** Values of thermal deformations of a window from profiles from aluminum alloys.

![Graph showing insulation of air noise of the balcony door from the profiles of aluminum alloys with a triple glass unit SPD 6I-14Ar-4-14Ar-14 under the influence of thermal deformation.](image2)

**Fig. 5.** Insulation of air noise of the balcony door from the profiles of aluminum alloys with a triple glass unit SPD 6I-14Ar-4-14Ar-14 under the influence of thermal deformation.

5. **Conclusions**

Thermal deformations have a significant effect both on the performance characteristics of this class of enclosing structures of buildings and structures, and on the microclimate in the room, and, consequently, on the heat loss and energy efficiency of the building. Studies of the effect of thermal deformation of windows will allow us to more fully formulate the principle of climatic applicability of windows for different regions of our country.
The works on the assessment of the climatic applicability of external enclosing structures [10] should form new principles for the use of modern building materials in the territory of Russia. Work on the study of thermal deformations is planned to be completed by the development of a standard for determining the set of operational characteristics of windows changing under the influence of this physical effect and introducing the concept of "thermal deformation" of a window as a normalized parameter.

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