Mathematical methods of glazing designing

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Abstract

System for mathematical modeling of glazing functioning during operation is considered in the paper. This system takes into account operational loads, climatic effects and influence of building structures. It is destined for calculation of glazing performance and generating of glazing variant which meets prescribed requirements.

Large number of effects acts together on glazing of building or installation during their operation, especially in regions with inclement climate. These factors must be considered during projection of glazing. There are snow and wind loads, possible impacts of mans or objects, low and high temperatures, oscillations of temperature and humidity, chemical substances, variations of atmospheric pressure, solar radiation. Effect of these factors results in fluctuation of glazing performance in comparison with normal conditions. Moreover, fluctuations of glazing characteristics influence on each over. For example, high atmospheric pressure or wind load can cause sag of glass and this sag leads to heat transfer resistance lowering. As a consequence, sag can increase more because of lowering of temperature in inner gas space. Therefore it is necessary to discover glazing characteristics in all range of actions. Strength and security properties must be determined under the most unfavorable combination of extreme action values.

Developed mathematical models of glazing and software system on their basis allow solving such problems. This system is successfully used in the Glass Research Institute.

Introduction

This paper we devote to hard problem of mathematical modeling of glazing functioning during its exploitation. We plan to take into account maximum of the possible real factors: operational loads, climatic effects and influence of building structures. As a result of our investigations we want to develop system that will be destined for calculation of glazing performance and generating of glazing variant which meets prescribed requirements.

When glazing operates in the building or construction especially in regions with inclement climate it is affected by a lot of factors which acts together and must be considering during designing of glazing and planning of its maintenance as well. There are snow and wind loads, possible impacts of mans or objects, low and high temperatures, oscillations of temperature and humidity, chemical substances, variations of atmospheric pressure, solar radiation. Effect of these factors results in fluctuation of glazing performance in comparison with normal conditions. Moreover, fluctuations of glazing characteristics influence on each over. For example, high atmospheric pressure or wind load can cause sag of glass and this sag leads to heat transfer resistance lowering. As a consequence, sag can increase more because of lowering of temperature in inner gas space. Therefore it is necessary to discover glazing characteristics in all range of actions. Strength and security properties must be determined under the most unfavorable combination of extreme action values.

The problem of glazing parameters calculation solves for a long time. There are standards ISO 9050:1990 “Glass in building - Determination of light transmittance, solar direct transmittance, total solar energy transmittance and ultraviolet transmittance, and related glazing factors” and ISO 10292:1994 “Glass in building - Calculation of steady-state U values (thermal transmittance) of multiple glazing”. With the help of these standards it is possible to calculate supposed optical and thermal parameters of the glazing based on characteristics of glasses included in it. In the most cases such calculation would be sufficiently accurate to estimate optical performance of the glazing and heat loss throw it. But these simple methods don’t include any geometrical calculations or connections between optical, geometry and thermal characteristics.

Now also a set of standards dedicated to calculation of glazing behavior under mechanical loads are under development. This set includes prEN 13474 “Glass in building - Design of glass panes”. It is very useful in practical work but it has some imperfections too. Specifically, at the present there is no straight connection

between thermal loads on the glazing and its possible breakage. On the other hand this calculation is soundly simplified and originates from presence in the system specific well-described type of environmental stress (for example, it can be uniform or linear).

The main text

We bring a new challenge before ourselves. The challenge is to realize complete to the maximum accounting of all physical factors affected on glazing and develop full as much as possible model of its behavior in the network of one program complex suitable to permanent use in the work of our Center.

Starting from examinations of existed techniques we didn't found them fully satisfactory. Furthermore they are not match for the using under Russian conditions and virtually haven't joint with local normative documents. Therefore we decided to start from the problem with the most general conditions.

Hence we work in three dimensional coordinate system and need to take into consideration following physical processes which proceed in the glazing during its exploitation at the same time:

- Direct heat transmission;
- Convective heat transmission and convective pressure oscillations in the gas spaces;
- Radiance heat transfer;
- Thermal expansion and shrinking of solid materials (glass and enclosure structures) and pressure oscillations of the gas;
- Heating of solid materials (glass and enclosure structures) and gases under the influence of solar radiation;
- Glass and enclosures deformations under the influence of external loads both conditionally steady (self weight, atmospheric pressure alterations, snow and application loads) and temporary (as wind pressure);
- Glazing support conditions and method of edge fixation;
- Particularities of surroundings where the glazing is installed (for example, glazing can be segment of pool or aquarium enclosure).

This entire physical environment in general case is described by known differential equations (mostly, equations of the second degree). Of cause, equations must be supplemented with boundary and initial conditions. Obtained equation system can be substantially simplified in the case of the glazing subject to following assumptions:

- All processes in the glazing occur sufficiently slowly therefore we can make calculation in quasistationary state;
- In most cases it is admittedly enough to consider only the most general cases of loads distribution and standard support conditions;
- In practice nature of filling gas is not noticed for multiplicity and represent combination of well-known gases in some proportion;
- All functions describing proceeded processes are continuous and differentiable functions (at least, this is more than admissible assumption).

Particularities of solving problem are also following:

- For the every specific project (building or construction glazing) we know limiting values and ranges for the all influenced parameters (temperatures indoor and outdoor, atmospheric pressure, solar radiation intensity, wind force, blanket of snow thickness, maximum of operational loads etc);
- There is initial condition (usually it is temperature equal to 20 C indoor and outdoor, normal pressure and absence of others loads to the glazing), and we know all geometry, optical and thermal parameters of glazing under this condition;
- Preliminary analysis allows choosing the most dangerous combinations of external factors effects and the calculations must be taken under that conditions. There is no necessity to make calculations with all possible initial conditions.

During mathematical models elaboration and program complex development it is necessary to consider following:

- Insulated glass unit can contain decorative window sashes. Those partitions make difficulties to gas convection and may result in separation of the inner gas space on isolated zones;

- Glazing can include many different types of glasses. Glass can be with different thickness, optical, heat insulating, mechanical properties or composition. We try to include into consideration also laminated glass, glass with affixed film, coated glass, strengthened types of glass;
- Glazing may have fastening of the different construction. Constructional elements and spacers can be carried out from different materials;

Conclusions

Our work is not ended yet but we done a lot of work and have some plans. Finally calculation must give following results in the form of report:

- Energy balance of the glazing (heat loss or income to the indoor) during different seasons;
- Light transmission of the glazing;
- Possibility of condensation or freezing of the glazing from inner side during winter period;
- Capabilities of every glass in glazing to sustain without breakage all affecting loads and stresses;
- Limits of the deformation of the glasses in glazing.

Analysis of the calculations result allows determining way to enhancement of the glazing in the case then it didn't comply with given requirements. After redevelopment such calculations can be repeated.

Problem put by are solving by numerical methods of mathematical physics using complicated mathematical apparatus. During these researches we developed several methods for numerical solving of particular problems. Large amount of comparative and final numerical experiments was carried out.

Developed mathematical models of the glazing and program complex prototypes allow solving of described problem and successfully used in the Glass Research Institute.

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