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Thermal distributions through profiled aluminum fire-resistant doors depending on the side of the fire exposure

Rozkłady termiczne przez aluminiowe, profilowe drzwi przeciwpożarowe w zależności od strony ekspozycji pożarowej

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Abstract. Fire doors play a key role in the fulfilment of the requirement for ensuring efficient and safe evacuation in case of fire. In fire conditions, they are to form a barrier to fire, smoke and heat. Therefore, this type of items should be appropriately fire-rated with respect to fire integrity, fire insulation and smoke control. This article discusses the main aspects of heat flow stopping, i.e. fire insulation of hinged aluminum, profiled fire doors depending on the fire exposure side. The results were compared of temperature increase on aluminum profiles in the case of several types of fire doors with symmetrical cross-sections of the profiles (two possible cases of fire exposure) and fire doors with asymmetrical cross-sections of the profiles (four fire cases possible). The items selected for each comparison were made in the same way in all respects, with the fire direction being the only difference.

Keywords: fire resistance; fire doors; insulation; glass panes; aluminum profiles.

Streszczenie. Drzwi przeciwpożarowe odgrywają kluczową rolę w spełnieniu wymagania dotyczącego zapewnienia sprawnej i bezpiecznej ewakuacji w przypadku pożaru. W warunkach pożaru powinny stanowić barierę dla ognia, dymu i ciepła. Muszą więc mieć odpowiednią odporność pod względem szczelności ogniowej, izolacyjności ogniowej i dymoszczelności. W artykule omówiono główne aspekty wpływające na przepływ ciepła, tj. izolację ogniową aluminiowych, uchylnych, profilowych drzwi przeciwpożarowych w zależności od strony narażenia na ogień. Porównano wyniki wzrostu temperatury na profilach aluminiowych w przypadku kilku typów drzwi przeciwpożarowych o symetrycznych przekrojach profili (dwa możliwe przypadki narażenia na ogień) oraz drzwi przeciwpożarowych o niesymetrycznych przekrojach profili (cztery przypadki możliwego pożaru). Badane elementy do każdego porównania zostały wykonane w ten sam sposób, a jedyną różnicą był kierunek oddziaływania ognia.

Słowa kluczowe: odporność ogniowa; drzwi przeciwpożarowe; izolacja; szyby; profile aluminiowe.

Fire doors are used as closures for openings in horizontal fire partitions found usually in public buildings including hospitals, cinemas, schools, shopping malls, high-rise buildings [1, 2] and special-purpose structures, such as e. g. tunnels. This type of buildings and structures must ensure efficient and safe evacuation of occupants in case of fire. Fire door plays the key role in meeting the fire safety regulations concerning building structures. Their main task is to close the openings in vertical fire partitions and to separate fire zones during fire. In case of fire, doors are supposed to provide a barrier for fire, smoke and high temperature. That is why such items should be of relevant fire rating, related to fire integrity and insulating properties, and the appropriate smoke control grade. There are many producers of fire doors worldwide, and consequently the range of available products is highly diversified. In spite of the fact that each producer uses their individual structural solutions, some common features can be found in the majority of cases. Everything depends on the door material – wood [3, 4] or metal [5, 6] usually aluminium or steel. Doors can also be divided according to their opening method (swing, sliding, folding etc.) or the number of door leaves (single-leaf, double-leaf, etc.). Glazed closures [7] using special glazing with fire protection function [8 ÷ 14] constitute a special group. Among many structures of a similar kind there are also aluminium profile doors, being the main subject matter of this paper.

The reference doors are made of special aluminium profiles. The structure of the leaf frame is similar to profiles used as the frame structure of glazed partitions [15]. The space between the profiles is filled with special glazing or opaque panels, usually made of plasterboard seated in steel or aluminium sheet cladding. The filling is fixed with steel angles. The items are fixed to the aluminium or steel profile with screws or rivets. The fixing is hidden under the beading which is fastened or screwed to the metal profile. The space between the beading and the glass pane is sealed with gaskets, usually made of EPDS, whereas intumescent gaskets [16] are placed along the glass pane circumference. The profiles are made of angles connected by thermal spacers (e.g. made of glass fibre reinforced polyamide). As a result of such combination, chambers are formed in the profiles, which are filled with special fire-protection filling to ensure their insulation and limitation of adver-

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se thermal impact (e.g. plasterboard, silicate and cement board, silicate-calcium boards or boards made of mineral wool or wooden slats). Using chamber profiles is a good solution from the economic point of view. By changing the kind or degree of filling with fire protection inserts or the size of the thermal spacer and using the same angles, different fire rating values can be achieved.

The use of appropriate hardware also matters in the case of fire doors. The hardware needs to match the heavy weight of fire doors and not deteriorate the door structure (for its fire protection characteristics). One should remember that fire door fulfils its function only when it is closed. That is why when this kind of closure is placed in an evacuation route, it needs to be featured with a self-closing device, such as a self-closing mechanism or spring hinge.

This paper presents the aspects related to the profiled aluminium door capability to stop the heat flow, namely to their fire insulating properties. The influence was verified of the direction of fire affecting the door on the temperatures recorded on the non-heated surface of aluminium profiles making the leaf and door frame structure.

Methods and materials

Eight different single-leaf profiled aluminiumfully-glazed door sets were tested. There were 7 different aluminium profiles used in the tests (door sets 7 and 8 were featured with the same aluminium profile but had different dimensions and different kind of glazing). All the profiles were 3-chamber ones having two aluminium shapes with a thermal spacer. Three of the tested profiles had an unsymmetrical section (two shapes with different chamber size combined), while the other ones were symmetrical (two shapes with the same chamber size combined). The details concerning the tested items are summarised in Table.

The structure of the door sets 1 and 2 allowed for mounting the hinges both on the side of the profile small chamber and big chamber, and so the door sets were tested in 4 different cases. Door set 3 was made in such a way that despite its being non-symmetrical it was possible to use hinges only on the smaller chamber side, and that is why similarly to doors 4 – 8 where both chambers were symmetrical, the test was carried out only for 2 cases. All the samples were tested in the same test chamber and subjected to heating according to the standard temperature-time curve determined by formula (1).

Tested door sets

Testowane zestawy drzwiowe

Door set No.	Dimensions (width× height) [mm]	Profile type	Profile dimensions (width× depth) [mm]	Insulation insert	Glass pane type	Glass pane thickness [mm]
1	1398 x 2359	3-chamber unsymmetrical	69.0 x 75.0	cement based	single	16
2	1293 x 2254	3-chamber unsymmetrical	63.0 x 60.0	plasterboard type F	single	22
3	1406 x 2806	3-chamber unsymmetrical	68.0 x 68.0	plasterboard type F	single	22
4	1500 x 2700	3-chamber symmetrical	70.5 x 60.0	mineral wool density of 150 kg/m^3	single	17
5	1400 x 2500	3-chamber symmetrical	65.0 x 65.0	plasterboard type F	single	21
6	1400 x 2500	3-chamber symmetrical	67.0 x 78.0	plasterboard type F	single	15
7	1320 x 3110	3-chamber symmetrical	46.0 x 80.0	plasterboard type F	single	17
8	1420 x 2522	3-chamber symmetrical	46.0 x 80.0	mineral wool density of 150 kg/m^3 (inside the chamber) + plasterboard type F (outside chambers)	2-chamber glass unit	60

$$T = 345 \log_{10} (8t + 1) + 20 \qquad (1)$$

where:

T – means temperature [°C];

t – stands for the test duration [mm].

The temperature gain was measured during each test on the door frame profiles and door leaf profiles. For the door leaf the temperatures were measured in places marked from 1 to 5 in Figure 1, while for the door frame they were marked in places 6 to 10 shown in Figure 1.

The results for temperature gains on the non-heated surface of the door leaf profiles are presented in Figure 2, while Figure 3 applies to the door frame profiles.

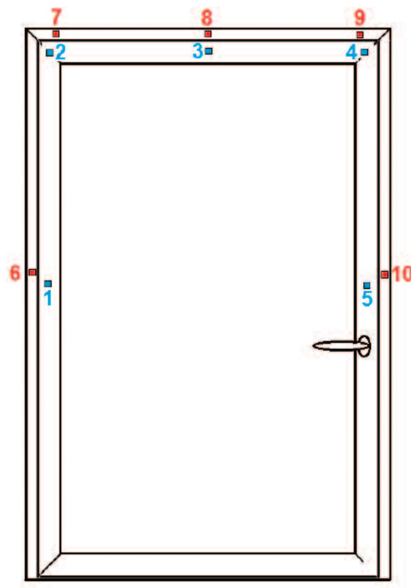

Fig. 1. Places where temperature gain is measured on the non-heated surface of the sample item

Rys. 1. Miejsca pomiaru przyrostu temperatury na nienagrzewanej powierzchni elementu próbnego

Discussion

Analysing the diagrams presented in the previous section it can be concluded that for a door leaf profile the mean temperature gains on the door surface are similar, regardless of the direction of the fire impact. Taking into consideration only the result in the 30th minute of the test, in most cases a higher temperature could be observed for the door opening towards the test chamber interior, i.e. when it was heated on the hinge side. In the case of non-symmetrical door it can be observed that the hinge installation side was of low significance, while the door opening direction against the test chamber mattered more.

For temperatures recorded on the door frame, an opposite tendency can be

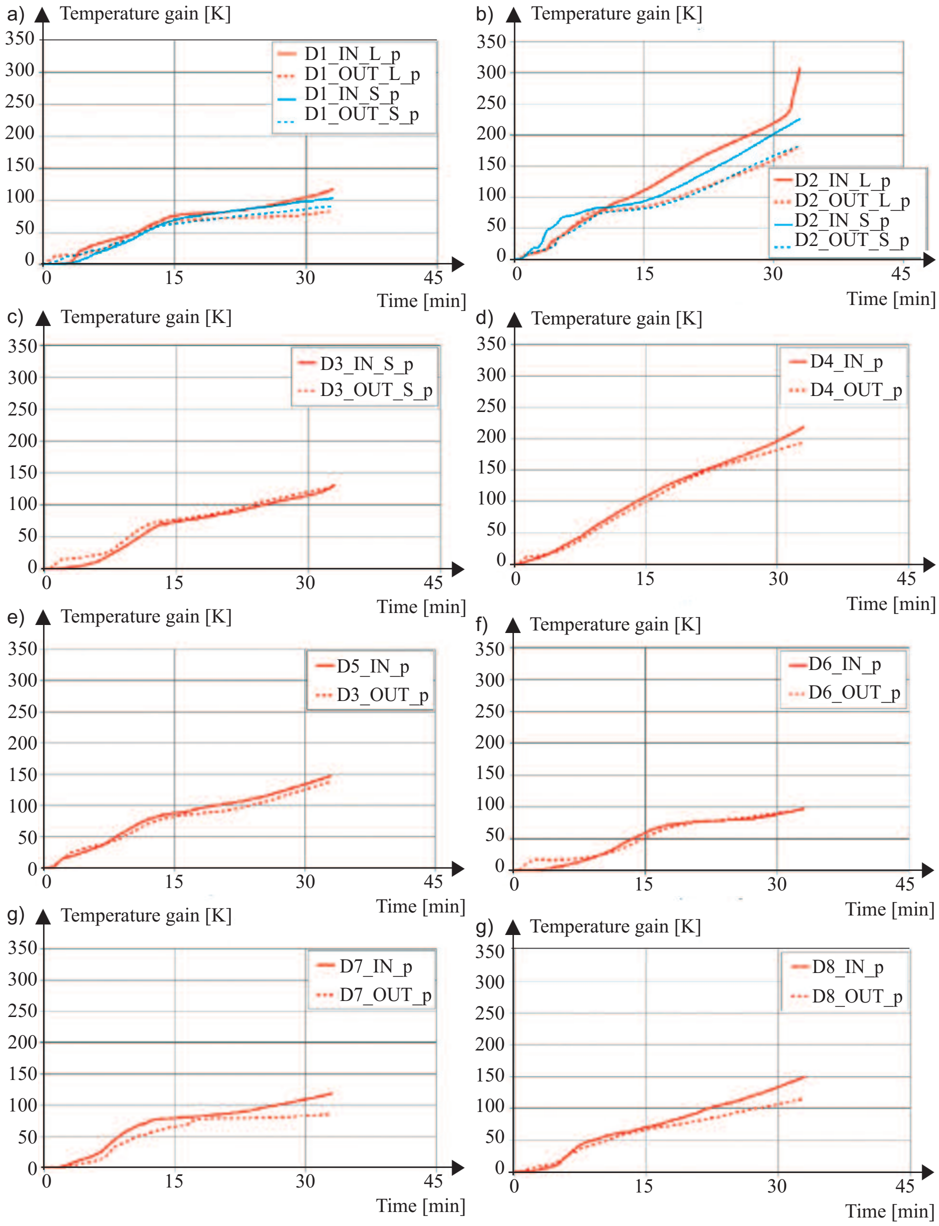

Fig. 2. The mean temperature gain on the door leaf profiles depending on the fire impact direction (D1 ÷ D8 – numbering of door sets corresponding with table; IN – door leaf opening direction inside the furnace; OUT – door leaf opening direction outside the furnace; L – hinge placed on the side of the large profile chamber in case of unsymmetrical profiles; S – hinge placed on the side of the small profile chamber in case of unsymmetrical profiles; p – temperature on the door leaf profiles – average temperature rise calculated from thermocouples No. 1 ÷ 5 in figure 1)

Rys. 2. Średni przyrost temperatury na profilach skrzydeł drzwiowych w zależności od kierunku oddziaływania ognia (D1 ÷ D8 – numeracja drzwi odpowiadająca numeracji przedstawionej w tabeli; IN – skrzydło drzwiowe otwierane w kierunku wnętrza pieca; OUT – skrzydło drzwiowe otwierane w kierunku na zewnątrz pieca; L – zawias umieszczony po stronie większej komory profilu, w przypadku profili niesymetrycznych; S – zawias umieszczony po stronie mniejszej komory profilu, w przypadku profili niesymetrycznych; p – przyrost temperatury na profilach skrzydeł drzwiowych – średnia z pomiarów uzyskanych w punktach 1 ÷ 5 przedstawionych na rysunku 1)

observed in the majority of cases, i.e. higher temperature for the door sets opening to the outside of the test chamber. In the case of the first two door sets (non-symmetrical) for which the test was carried out in 4 different cases, it can be observed that the highest temperatures were recorded for the door frames where the hinges were installed on the smaller chamber side.

Both for the door leaf profile and the door frame it can be observed how the profile insulation method affects its heat flow. In most cases, a much higher temperature gain was observed for gypsum inserts and cement-based inserts in the initial 15 minutes of the test, followed by much smaller temperature gain in the second half of the test. In the case of mineral wool, the mean temperature increase was stable throughout the test. If high temperature reaches the profiles with cement and plasterboard inserts, they start to evaporate and cool the profile, which is represented by a „shelf" effect on the diagram, lasting several minutes, where the gain recorded on the profile surface is either stable or increases insignificantly. The shelf length depends on the kind of insert and the size of the chamber and the whole profile. For mineral wool such phenomena practically do not occur, which means it insulates the profile in the same way during the whole test. It needs to be emphasised that regardless of the profile size, much higher temperatures were recorded for the profiles insulated with mineral wool than for the other ones.

Conclusions

The flow of heat through profiled aluminum fire doors depends on a number of factors related both to the structure of the whole set and its fixing method or carefulness of the sample preparation. The fire insulation characteristics of this door type are affected by such factors as the profile size and its insulation methods, type of applied glazing and intumescent sealing along its circumference.

The presented test results show the significance of the door leaf opening direction influence on the temperature recorded on aluminum profiles. For some cases it can be considered negligible while for other it is extremely important, which clearly indicates the need to verify fire resistance of profiled aluminum single-leaf glazed doors in two versions for symmetrical sections and in four ver-

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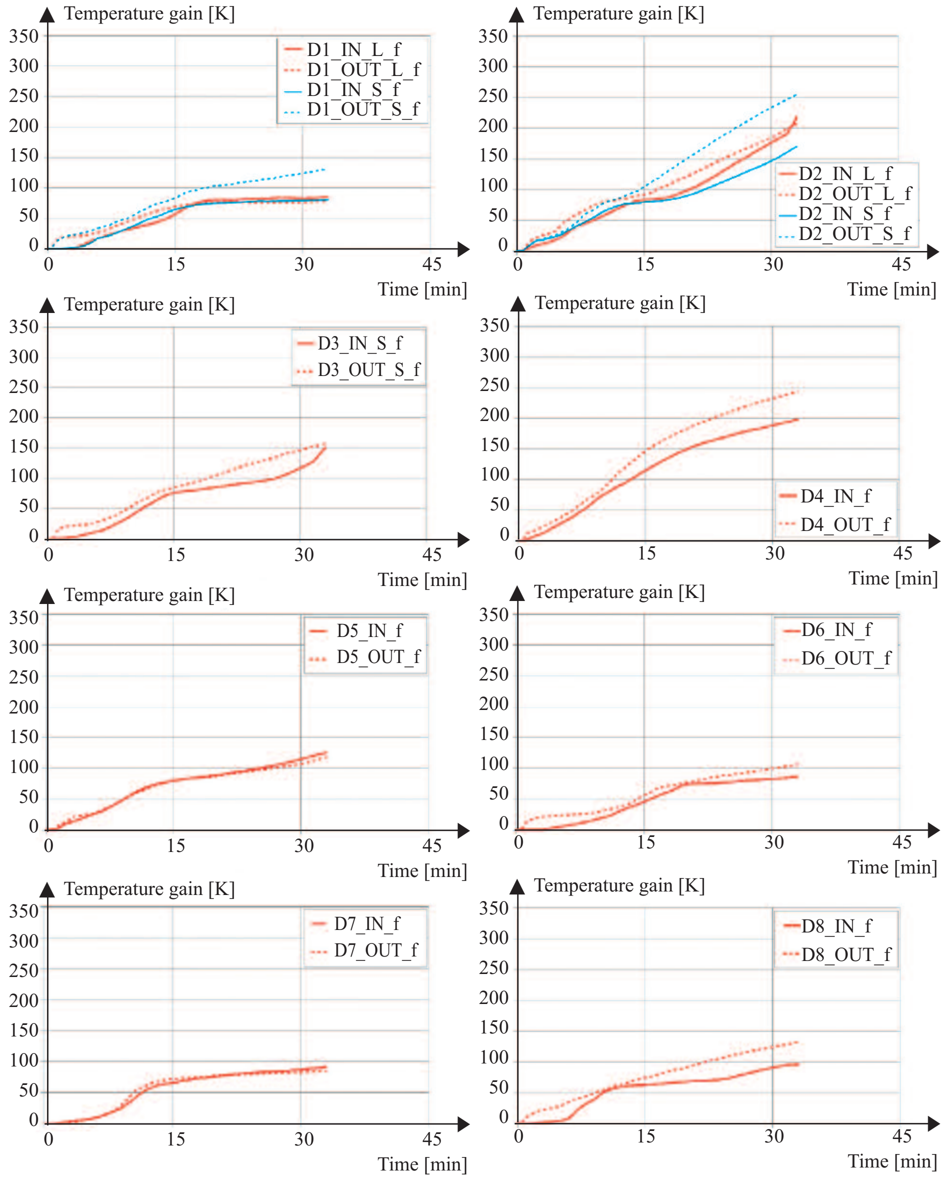

Fig. 3. The mean temperature gain on the door frame profile depending on the fire impact direction (D1 ÷ D8 – numbering of door sets corresponding with table; IN – door leaf opening direction inside the furnace; OUT – door leaf opening direction outside the furnace; L – hinge placed on the side of the large profile chamber in case of unsymmetrical profiles; S – hinge placed on the side of the small profile chamber in case of unsymmetrical profiles; f – temperature on the frame profiles – average temperature rise calculated from thermocouples No. 6 ÷ 10 in figure 1)

Rys. 3. Średni przyrost temperatury na profilu ościeżnicy w zależności od kierunku oddziaływania ognia (D1 ÷ D8 – numeracja drzwi odpowiadająca numeracji przedstawionej w tabeli; IN – skrzydło drzwiowe otwierane w kierunku wnętrza pieca; OUT – skrzydło drzwiowe otwierane w kierunku na zewnątrz pieca; L – zawias umieszczony po stronie większej komory profilu, w przypadku profili niesymetrycznych; S – zawias umieszczony po stronie mniejszej komory profilu, w przypadku profili niesymetrycznych; f – przyrost temperatury na profilach ościeżnicy – średnia z pomiarów uzyskanych w punktach 6 ÷ 10 przedstawionych na rysunku 1)

sions for door sets made of profiles with an unsymmetrical section, where it is possible to fix a hinge on each side of the profile. It is not possible to evaluate fire resistance rating or insulating performance of fire doors based on their design or specifications of components.

Even a minor change in the construction or fixing method can greatly affect the fire resistance characteristics and so the only way to determine the actual fire rating is to carry out a relevant test. It needs to be emphasised that fire insulationrating is always connected with fire integrity. It is not possible to classify doors only for their fire insulationand so a loss of fire integrity also means a loss of fire insulation rating.

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