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Features of fire and explosion safety of buildings from a sandwich of panels

Eugenia Salymova [1,*]

[1]Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

Abstract. Recently in Russia about 100% of buildings of an oil and gas complex are built with use triplex a sandwich of panels (S.P). Almost all these buildings are explosive and increase in their exploisure-resistance requires application of easily thrown off or safety designs. A sandwich of the panel is an ideal applicant for a role of safety designs according to the weight characteristics. Except inertial properties extremely important characteristic is opening pressure. This size remains acritical in view of a variety of their sizes, thickness of metal sheets, a variety of their fastening to metal designs. In work opening pressure at explosion for a sandwich of panels of 2x1,2 m in size for various options of fastening is experimentally received. We suspect that load of one knot of fastening does not depend on the panel sizes, only on the knot device. For various ways of fastening design pressure of opening in case of a normal distribution of durability of clusters is defined. The criterion for assessment of effectiveness of the panels used as safety designs is received. This criterion determines the maximal pressure upon dive during opening. The received criterion confirms effectiveness a sandwich of panels as a safety design.

1 Introduction

A large number of the buildings and constructions with use a sandwich of panels have been built recently. Most often the sandwich of the panel is used at construction of warehouse and production rooms, and also offices, shops, supermarkets.

Most often buildings from panels are built at the enterprises of oil, gas and oil and gas branches. These buildings are at a fire risk. Our task is to find the ways to make them safe. We recommend applying easily thrown off or safety designs.

The easily thrown off designs is the most widespread a glazing, its effectiveness can change depending on the sizes, thickness, and also frequency rate of a glazing (unary, double or troyenny).

Triplex panels according to the weight characteristics can serve as efficient safety designs if to provide their reliable opening (destruction of fastenings) with pressure below admissible (ΔPd). Admissible pressure is defined from conditions of inadmissibility of the collapses leading to loss of life and unacceptable material damage.

Indeterminacy of process of opening of the apertures blocked by panels does not allow using reasonably them as safety designs. The area of the easily thrown off designs and their

*Corresponding author: ICA_kbs@mgsu.ru

characteristic are defined by calculations. However their carrying out it is impossible owing to obscurity of process of opening of safety designs from a sandwich of panels.

2 Materials and Methods

Change of pressure indoors at explosion. It is necessary to watch dynamics of change of pressure taking into account development of the center of explosion and the expiration of gases through apertures in the protecting designs. There is a speech about quasistatic development of process of the explosion caused by deflagration combustion of combustible gas system. Pressure at such explosion is identical in all points of the room and changes in time. Wave effects are absent. At flame propagations of W< 30 m/s explosion quasistatic. Many works as domestic and foreign experts are devoted to this problem [1-15].

The processes happening at internal explosion are represented by means of Figure 1.

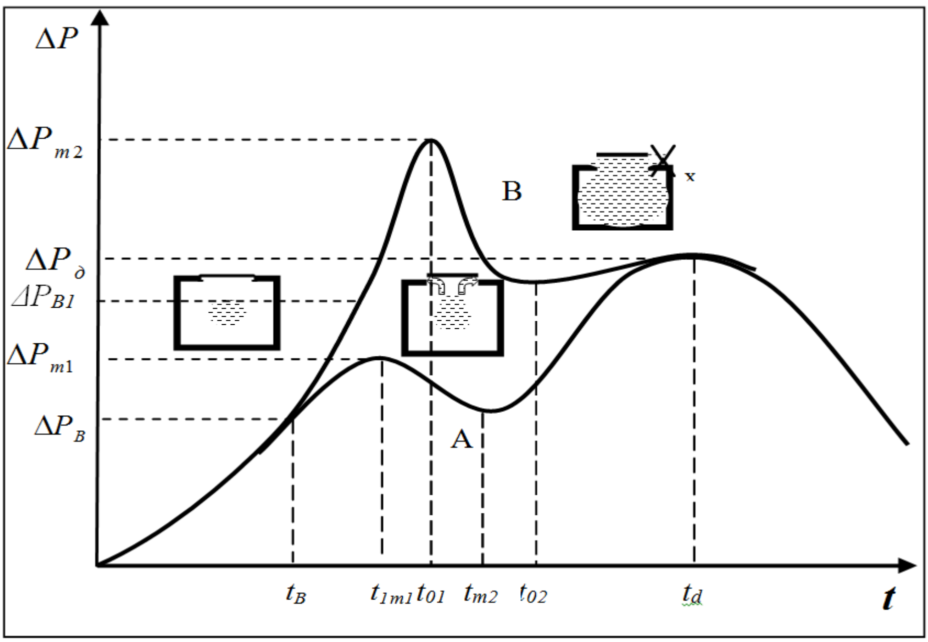

Fig. 1. The processes happening at internal explosion.

In an instant "0" there is an initiation and the flame extends in the form of the sphere in self contained volume (a shot 1). By the time of «t_v» time pressure reaches size ΔP_v – opening pressure. Safety designs start moving and gradually open space for the expiration of gases. At first cold gases expire, and then because of deformation of the combustion zone hot gases expire.

The quick-response safety design moves rather quickly and by the time of «t_{m1}» time pressure reaches ΔP_{m1} (a curve «A»).

More inertial safety designs the (a curve «B») less aggressively opens an aperture for a depressurization and by the time of time ΔP_{m2}>ΔP_{m1}. To instants of «t_{01}» and «t_{02}» of armholes opened completely and pressure minima were implemented. The moments of «t_{01}» and «t_{02}» are characterized by a condition: ΠX=a*b, when the area of the expiration through lateral areas is compared to the area of an aperture, Π – aperture perimeter, X – the shift of the personal computer, «a*b» – the area of an aperture. Since the moments of «t_{01}» and «t_{02}» when the area of the expiration to become maximal, pressure begins to grow in system as the area of the center of explosion continues to grow at the invariable area of the expiration.

In «t_d» instant burning area reaches a maximum, as determines pressure ΔP_d (admissible pressure). From explained above follows that the open space of apertures of «S_0» by the time of time of «t_d» has to meet a condition:

$$S_0 \geq \frac{(\sigma-1)U_{g2}{}^2 K_f V_0{}^{2/3} \rho_0{}^{1/2}\left[\xi+(1-\xi)\sigma^{1/2}\right]}{\nu_g (2\Delta P_g)^{1/2}} \tag{1}$$

Here U_{g2} – the speed of explosive combustion by the time of td, σ – expansion ratio at combustion, $K_f = \frac{A_f}{V_0^{2/3}}$ - a crest factor of the room, «A_f» – the area of a flame by the time of «t_d», ΔP_d – the allowed pressure at explosion, ν_g – a coefficient of discharge, V_0 – room volume, ξ – a share of the open space of apertures through which expires cold mix.

The allowed pressure at explosion is defined by calculation on a carrying capacity for the corresponding limiting condition. [15-19]. After definition of «S_0» it is necessary to make so that at the time of opening of the easily thrown off designs pressure does not exceed ΔP_d, that is the case $\Delta P_{m2} > \Delta P_d$ (a curve «B» fig. 1) does not provide a building explosion resistance. From Figure 1 it is visible that if ΔP_v on a curve «A» to increase opening pressure to ΔP_{v1}, then the condition of a explosion resistance is not satisfied also at quick-response by the easily thrown off designs. According to the weight characteristics, the sandwich panel is quick-response and can have easily thrown off designs if its reliable opening is provided. Reliable opening is characterized by a condition that at ΔP_v the opening peak ΔP_m is less ΔP_d, and itself the easily thrown off designs at the same time is effective.

3 Results

Opening a panel sandwich at explosion. Analysis and experiment. The personal computer equation of motion after opening is described by the equation: $m_{PK} \frac{d^2}{dt^2}(X(t)) = \Delta P(t) ab$,

m_{pk} - the mass of the easily thrown off designs, X (t) – the distance passed by the easily thrown off designs after opening, ΔP(t) – the changing pressure upon the easily thrown off designs. In the analysis of an equation of motion we assume:

1. Only cold gases expire;
2. $\Delta P(t) = \frac{\Delta P_v + \Delta P_m}{2} = \Delta \overline{P}$
3. Overpressures at which outlet velocity of gases through apertures can be presented as are considered: $\sqrt{\frac{2\Delta \overline{P}}{\rho_0}}$

The last assumption is accepted only for simplification. Pressure indoors during explosion taking into account the expiration of gases and shift of the personal computer has an appearance [20]:

$$\frac{d\Delta P(t)}{dt} = \gamma(\sigma-1)\sigma^2 4\pi U_g t^2 - \upsilon_g \Pi X N \left(\frac{2\Delta P(t)}{\rho_0}\right)^{1/2} \tag{2}$$

From the assumptions made above and a condition $\frac{d\Delta P(t)}{dt} = 0$, but $\Delta P(t) = \Delta P_1$ at the time of a maximum ΔP(t) peak size ΔP_1 is determined.

$$\Delta P_1 = \Delta P_v \frac{A}{\left(A^{1/2} - 1\right)^2},$$

$$A = \frac{\nu_g (a+b) ab \Delta P_v^{3/2} N}{2^{3/2} \pi m_{PK} \rho_0^{1/2} U_{g1}^{3} (\sigma - 1)\sigma^2} \quad (3)$$

Where N – number of the opened easily thrown off designs. U_{g1} – burning rate at the first peak, П=2 (a+b).

Separately the opened safety designs are considered the safety designs which do not have the common borders. The having common borders are united in one safety designs. For ΔP_1 follows from the analysis of expression that ΔP_1 grows with body height ΔP_v, but the relation $\Delta P_1/\Delta P_v$ decreases with body height ΔP_V.

Problem of the pilot study was assessment of tension failure load of fastening a sandwich of the panel and determination of pressure of opening a panel sandwich (P.S.) as safety designs.

The pilot study was conducted on the pilot units which main part was made by cameras of 10 m^3 and 1 m^3. For the whole SP fastening to the camera of 10 m^3 the diffuser fastened. A narrow part of the diffuser fastened to an outlet opening of the camera, and to a wide part S.P. of 2x1.2 m in size fastened.

Explosive cameras were equipped with system of ignition and filing of pressure. Disconnection of contacts on the diffuser and S.P. allowed fixing a start of motion (openings) of S.P. During experiences, high-speed video filming on which it was possible to duplicate the moment of opening was carried out and to control the movement safety designs. On the camera of 1 m^3 S.P. of 0.4x0.4 m in size fragments were tested. Details of carrying out experiments are explained in [21].

In the first series of experiments the joint ventures of 2x1.2 m at nominal fastening were tested four self-tapping screws to a metal profile thickness 0.005m. In total 4 self-tapping screws were slightly deformed, but remained in a metal profile, having broken through S.P. a washer and a head of the self-tapping screw. Middle pressure of opening ΔP_v=3.34 kPa, σ=0.06, K_v = 0.02

The second series of experiences differed lack of washers under heads of self-tapping screws. In total 4 self-tapping screws were slightly deformed, but remained in a metal profile, having broken through a sandwich the panel a self-tapping screw head a leaf of S.P. Middle pressure of opening ΔP_v=2.18 kPa, σ=0.088, S_t = 2.35, K_v = 0.04.

In the third series of experiences in the sheet S.P. in the place of fastening under a washer cruciform cuts to border of washers became. In total 4 self-tapping screws were slightly deformed, but remained in a metal profile, having broken through a sandwich the panel a self-tapping screw head a leaf of S.P. Middle pressure of opening ΔP_v=1.28 kPa, σ=0.11, S_t = 2.35, K_v = 0.086.

The fourth series of experiments was conducted on the explosive camera 1 m^3. Of 0.4x0.4 m in size fragment of S.P. as the easily thrown off designs at nominal fastening was tested – 2 self-tapping screws with washers to a metal profile 0.002 m thick. Destruction of fastenings came at the expense of a vyryv of self-tapping screws from a metal profile. Middle pressure of opening ΔP_v=15.16 kPa, σ=0.18, S_t = 2.35, K_v = 0.12.

More complete data including tension failure load on one self-tapping screw is presented in the Table 1.

Table 1. Results of the pilot study a sandwich panels, as easily thrown off designs**.**

No. of a Series of experim ents	The tested design	Thickness of a metal profile, mm	Number of self tapping screws	Nature of destructi on	Pressure of opening, kPa.	Load of one self-tapping screw, kN	Note
1	sandwich panels, 1200x2000x 50mm	5	4	The self tapping screw in a metal profile	3,2 3,38 3,45	1,92 2,03 2,07	-
2	sandwich panels, 1200x2000x 50mm	5	4	The self tapping screw in a metal profile	2,4 2,03 2,2	1,44 1,20 1,32	Without washers
3	sandwich panels 1200x2000x 50mm	5	4	The self tapping screw in a metal profile	1,2 1,55 1,1	0,72 0,93 0,66	Cut of a metal leaf
4	Fragment panel sandwich,40 0x400x50 mm	2	2	The self-tapping screw in the panel	11,28 18,8 15,40	0,90 1,50 1,23	Thickn ess of a design is 2 mm

The necessary number of self-tapping screws used at nominal fastening depends from S.P. In to the Table 2 are long the nominal number of self-tapping screws and recommended for S.P. used as the easily thrown off designs for opening pressure decrease is specified. Self-tapping screws fasten with washers and destruction of fastening happens on the mechanism of break of a leaf (the first series of experiments).

Table 2. Dependence of pressure of opening on a way of fastening of safety designs.

Length of the panel, m	Number of self-tapping screws	Pressure of opening, kPa	The recommended number of self-tapping screws	Middle pressure of opening, at the recommended fastening of self-tapping screws, kPa	The recommended pressure of opening, kPa
2	4	3.34	4 Without washers	2.18	3.1
2	4	3.34	4 Cut of a metal leaf	1.28	2.0
3	6	3.34	4 nominal	2.23	3.0
3	6	3.34	4 Without washers	1.45	2.24
4.5	8	3	4 nominal	2.25	2.1
4.5	8	3	4 Without washers	1.45	1.6
6	10	2.8	4 nominal	2.24	1.63
6	10	2.8	6 nominal	1.7	2.3

At construction Table 2 it was supposed that average load of 1 screw remains for the corresponding way of fastening.

Assuming that distribution of destructive deformations submits to the normal law to distribution, it turns out the following design pressure of opening (last table column 2). At the same time reliability of opening more than 99% is provided. In to the Table 2 data on design pressure of opening for various options of fastening of the safety designs.

4 Discussion

Design of the safety designs and determination of the area of the safety designs. At installation a sandwich of the panel fasten screws to metal designs. Besides for ensuring safety designs of the panel connect to a solid heater among themselves the "ledge-a groove" system. Such padding communication between panels complicates opening of the safety designs therefore individual panels will be opened with a larger pressure, than in experiments where the panel fastened without the side system "ledge-a groove". For elimination and minimizing of influence of communication between panels when opening, it is offered:

1. To unite panels with the weakened fastenings in one card consisting of several panels so that at edges of the panel there was no communication "a ledge - a groove";
2. To delete ledges, and to fill grooves with the weak sealants;
3. As the safety designs to use panels with the weak heater (a mineral wool and so on) which connection among themselves has no communication "a ledge - a groove";
4. As the safety designs to use panels with minimum thickness of metal sheet of 0,5 mm;
5. To reduce designs for fastening of the panels used as the safety designs to thickness of 2 mm in the place of fastening.

For the determination of the area of the safety designs, it is necessary to determine first of all the size of the allowed pressure ΔP_d. As a rule, the allowed pressure is defined by calculation on a carrying capacity for the first group of the limiting conditions [19]. About use of the equivalent statistical loading [19,22]. Further on expression (1) to be the required area of open apertures. The sizes of cards get out of design reasons. The card consists of safety designs, which are in contact with each other. It is necessary to remember that the safety design is a sandwich panel with the weakened fastening. Let «a»– length of the safety designs, «b» - safety design width, b=1.2 m is routine.

The area of the card is equal: $S_k = a*b*n$ where n – number of panels in the card.

The number of cards is equal: $N = S_0 / S_k$

This «N» value should be substituted in expression (2-3), and instead of (a*b) it is necessary to substitute S_k, instead of (a+b) → (a+n*b), pressure of opening undertakes calculated.

Further on expressions (3) the condition ΔP_1 is checked$\Delta P_1 < \Delta P_d$. If this condition is satisfied, then calculation comes to an end. If it is not carried out, then it is possible to take also measures: 1 – to increase S_0, 2 – to reduce design pressure of opening, 3 – to increase number of cards.

5 Conclusion

According to the weight characteristics, a sandwich of the panel is an ideal safety designs. It is necessary to weaken fastening clusters to designs to make them safe.

It is possible to provide stability not only for load-bearing frames, but also for sandwich of panels, which are used as the protecting designs. It is necessary to use as the protecting designs smaller panels with the larger thickness of a leaf, in comparison with safety designs which fastening is weakened.

For example, when using as safety designs the 6th meter panels with fastening – 4 nominal self-tapping screws, it is possible to provide protection of less than 50% of the protecting designs from panels whose values in the Table 3 are highlighted in red color; from 50% and to 100% - black and 100% - green.

Table 3. Dependence of change of reliability a panel sandwich from its sizes.

Thickness of the panel, mm	Carrying capacity of panels at evenly distributed load, kg/m^2													
	Length of flight, m													
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0	9.0
60	180	135	105	85	70	50	30							
100	336	246	198	165	142	128	110	90	75	60	48	38	27	
120		340	238	196	170	152	130	110	90	78	68	56	40	28
150			325	255	212	185	168	145	108	98	84	70	50	35
200				340	386	250	212	190	152	122	105	90	68	52
250					370	315	270	229	186	150	128	110	82	65

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