Use of rotary safety structures for internal explosions

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Abstract. The article examines methods for protecting buildings against internal explosions through the implementation of safety rotary structures. The study analyzes various approaches to structural safeguarding during internal blast events, with particular focus on different types of safety structures and their operational parameters. The research investigates the determination of gas venting areas in buildings using rotary mechanisms designed to ensure occupant safety. Key parameters such as the sealing depth and flap thickness of safety structures are evaluated for their role in forming effective gas outflow zones. The work establishes a functional relationship between the dimensions of the safety structure flap and the resulting area for primary gas venting and pressure relief. Additionally, the study comprehensively considers the influence of safety structure embedment depth and material thickness on blast mitigation performance. These findings provide valuable insights for optimizing building safety systems in explosion-prone environments.

1 Introduction

In the modern world, one of the most demanded industries is construction.

Every day, hundreds of buildings and structures appear in the world, reconstructed and repaired. These facilities must meet some criteria, the most important of which is safety.

The issue of explosion safety applies not only to industrial facilities on the territory of which explosive and flammable substances can be stored, but also to mass development facilities, as well as individual construction, which often use household gas for heating and cooking.If the rules for storage, use of potentially hazardous substances were violated, or an accident or leak occurred, there is a high probability of accumulation of a combustible mixture in the volume of the room and its subsequent explosive combustion. During an explosion, a large amount of energy is released in a short period of time, which forms an increased overpressure. Excessive pressure can disrupt the integrity of the building, as well as lead to its complete destruction.There are many ways to protect buildings and structures from the effects of an explosion. One of the design solutions that can help partially or completely avoid the consequences of an internal explosion is safety structures (SS), which allow you to free the discharge opening before the overpressure reaches the maximum permissible.The relevance of the topic of this work is the need for the effective use of safety

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structures, the influence of the depth of sealing on the action of rotary safety structures has never been taken into account before, which implies the purpose of this work: to analyze the effectiveness of the action of rotary safety structures in internal explosions and to determine the effect of the parameters of safety structures, including the depth of sealing, on their effect.

Determination of the nature and magnitude of loads that affect the enclosing structures during internal explosions developing in a confined room was presented in work

In order to correctly select the safety structures, it is necessary to calculate the value at the first and second pressure peaks, to conduct a comparative analysis of the pressure value at the first pressure peak depending on the dimensionless area. Such calculations are carried out in the work [1].

As a result, it turns out that the process of opening easily removable structures, namely the process of relieving excess pressure, is a complex process that depends on many parameters that reduce or increase its efficiency. The introduction of additional conditions in the mount, changes in physical and geometric parameters immediately affect the opening process.

2 Methodology

Safety structures are external enclosing structures of the building intended for overpressure relief. The principle of operation is that with an increase in excess pressure, the fasteners are destroyed and the discharge opening opens, through which gases flow out and the pressure is released. The main task of easily removable structures is to free the discharge opening before the overpressure reaches the maximum permissible (permissible). [2] (according to L.P. Pilyugin. Structures of explosive production facilities (theoretical basis of design). (M.: Stroyizdat, 1988)). There are several types of easily expandable structures, differing in several ways. safety structures classifications should be considered.
Classifications of safety structures (GOST R 56288-2014 Window structures with double-glazed windows easily expandable for buildings)

1) Inertial (opened gradually)
2) Non-inertial (open instantly).

Types of of safety structures:

1) Collapsible of safety structures (window cover of blind glazing);
2) Rotating of safety structures (window sash with rotating flaps);
3) Shifting of safety structures (lightweight roof slabs and wall panels);

Depending on the location of the axis of rotation, the rotating glazing elements are divided into:

1) Upperparts;
2) Lower hanging;
3) Medium-weight.

Classification of safety window structures by the type of rotary sash:

1) With vertical hinge;
2) With horizontal hinge.

Classification of safety window window structures by application:

1) Industrial buildings and structures;
2) Residential buildings.

To give a full description of the safety structures, you need to know their parameters.
The main parameters of the safety structures include:

1) Inertia;
2) Fastening method;
3) Embedment depth.

The effectiveness of pressure reduction is influenced by factors such as:

1) Explosion parameters;
2) Safety structures parameters;
3) Design features of the room;
4) Cluttering of premises with building structures and equipment.

Factors that affect the efficiency of opening rotating safety structures can be divided into two groups. The first group includes factors reflecting the design features of safety structures. For example, their geometric dimensions, mass, method of attachment to the outer fence, position relative to the ground, and so on. The second group includes factors reflecting the features of the placement of safety structures, such as the distance between the safety structures, the distance from the safety structures to the ground surface.

Fasteners holding the rotating safety structures in the closed state must ensure the reliability of their opening when the overpressure reaches the opening pressure of the safety structures. However, the strength of such fasteners should be sufficient so that they do not collapse under wind load. Accordingly, it is necessary that the opening pressure of easily jettison structures be much higher than the calculated wind load. Unforeseen impacts that may lead to opening of openings shall also be considered.

It is important to note that rotating safety structures, in comparison with moving ones, are safer during operation, since after opening, moving structures in case of a fall can cause material damage or damage to human health if measures are not provided for them to prevent their fall (according to GOST R 56288-2014 Window structures with double-glazed windows easily expandable for buildings, MGSU) [3].

For the effective use of safety structures in practice and solving various tasks in the field of explosion protection, it is necessary to correctly calculate and select the area of safety structures, the characteristics of safety structures to timely reduce the loads that pose a danger to building structures and humans.

In order to correctly select the safety structures, it is necessary to calculate the value at the first and second pressure peaks, to conduct a comparative analysis of the pressure value at the first pressure peak depending on the dimensionless area. Such calculations are carried out in the work.

As a result of the analysis, it became clear that: the process of opening safety structures, namely the process of relieving excess pressure, is a complex process that depends on many parameters that reduce or increase its effectiveness. The introduction of additional conditions in the mount, changes in physical and geometric parameters immediately affect the opening process.

In the methods for calculating the parameters of safety structures [4,5] (According to Manual for inspection and design of buildings and structures, exposure to explosive loads. (JSC TsNIIPromzdaniy, Moscow, 2000) and SP 56.13330.2021. Code of practice. Manufacturing buildings. SNiP 31-03-200), the area of openings is repeatedly mentioned, but in reality we are interested in the area of outflow.

The device of rotary safety structures: one side of the "weld" is fixed "stationary" on hinges or hinges, and the other is fixed with easily destructible fasteners, which, when destroyed, allow the structure to make a rotary movement, thereby freeing the discharge opening, so the area of gas outflow and pressure relief varies depending on the degree of "opening," that is, depends on the angle of rotation of the sash. The diagram of this design is shown in Fig. 1:

 https://doi.org/10.1051/e3sconf/202564600012

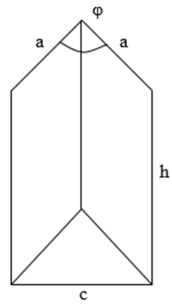

Fig.1. Scheme of rotary safety structure

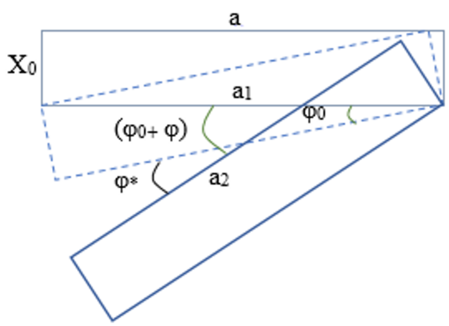

Fig.2. Scheme of rotary safety structure, top view.

It is necessary to find the outflow area. It is important to take into account not only the length and height of the structure itself, but also the depth of sealing, as well as the thickness of the "flap," since the lengths of the inner surfaces of the flaps α_1 and α_2 change depending on the opening angle of the easily flapped structure.
The outflow area consists of the area of three sections: a rectangular section and two triangular sections.

$$S_{is} = 2 * 0{,}5\left(\mathrm{a} - \mathrm{x}_0 \frac{1}{tg(\varphi_0+\varphi)}\right)\left(a - \frac{\mathrm{x}_0}{\sin(\varphi_0+\varphi)}\right) sin(\varphi_0+\varphi) + \frac{}{} h\sqrt{\left(a - \mathrm{x}_0 \frac{1}{tg(\varphi_0+\varphi)}\right)^2 + \left(a - \mathrm{x}_0 \frac{1}{sin(\varphi_0+\varphi)}\right)^2 - 2\left(\mathrm{a} - \mathrm{x}_0 \frac{1}{tg(\varphi_0+\varphi)}\right)\left(a - \mathrm{x}_0 \frac{1}{sin(\varphi_0+\varphi)}\right) cos(\varphi_0+\varphi)}$$
(1)

where φ_0 - no-load angle;
X_0 – depth of sealing of safety structure equal to its thickness;
$\varphi *$ – door turn angle;
a – width of safety structure;
h – height of safety structure.

The angle of φ_0 – is considered - the maximum angle of opening of the safety structure, at which the outflow area is still zero.

$$\varphi_0 = arctg\left(\frac{X_0}{\alpha}\right) \cdot \frac{180}{\pi}. \quad (2)$$

The discharge area of a fully open safety structure, that is, the area of the free discharge opening:

$$S_0 = h \cdot (a - X_0) \quad (3)$$

Determining the angle at which the outflow area is equal to the maximum opening area φ*:

$$S_{is} = S_0 \tag{4}$$

Let's represent (4) in expanded form and define the angle φ*. The meaning of determining this angle is that at some point in time, further movement of the structure does not increase the outflow area, since the outflow area has already reached the area of the full open opening.

3 Results

It is necessary to consider the ratios of geometric parameters and their effect on the action of easily removable structures.

Expression (2) has a ratio of X_0/a. To study the effect of this ratio on the φ angle. To do this, the X_0 value is changed and the angle φ* is determined by the successive approximation method in MathCad. Tables 1-4 show the calculation results for the various widths (a) and heights (h) of the safety structure.

Table 1. Dependence of angle φ* on the ratio X_0/a (a = 2 m, h = 3,5 m)

X_0, м	*a*, м	h, м	X_0/a,	φ*,°	φ_0, °
0,02	2	3,5	0,01	37,8	0,573
0,05	2	3,5	0,025	37,4	1,432
0,08	2	3,5	0,04	37,3	2,292
0,1	2	3,5	0,05	37,1	2,865
0,15	2	3,5	0,075	36,3	4,297
0,2	2	3,5	0,1	35,7	5,73
0,25	2	3,5	0,125	35,1	7,162

As can be seen from the data (Table 1), as the value of the ratio X_0/a increases, the value of the angle φ* decreases, so the area S_0 (3) decreases.

Table 2. Dependence of angle φ* on the ratio X0 /a (a = 3 m, h = 2,33 m)

X_0, м	*a*, м	h, м	X_0/a,	φ*,°	φ_0, °
0,02	3	2,33	0,0066	25,8	0,382
0,05	3	2,33	0,0166	25,8	0,955
0,08	3	2,33	0,0266	25,8	1,528
0,1	3	2,33	0,033	25,8	1,91
0,15	3	2,33	0,05	25,8	2,865
0,2	3	2,33	0,06	25,8	3,82
0,25	3	2,33	0,083	25,8	4,775

Table 3. Dependence of angle φ* on the ratio X_0/a (a = 1,4 m, h = 5 m)

X_0, м	*a*, м	h, м	X_0/a,	φ*,°	φ_0, °
0,02	1,4	5	0,0142	46,4	0,819
0,05	1,4	5	0,036	45,4	2,046
0,08	1,4	5	0,057	44,7	3,274
0,1	1,4	5	0,071	44,1	4,093
0,15	1,4	5	0,107	42,6	6,139

0,2	1,4	5	0,143	41,1	8,185
0,25	1,4	5	0,179	39,4	10,231

Table 4. Dependence of angle φ* on the ratio X_0/a (a = 4 m, h = 1,75 m)

X_0, м	a, м	h, м	X_0/a,	φ *,°	φ_0, °
0,02	4	1,75	0,005	17,8	0,286
0,05	4	1,75	0,013	18,0	0,716
0,08	4	1,75	0,02	18,1	1,15
0,1	4	1,75	0,025	18,1	1,43
0,15	4	1,75	0,038	18,2	2,15
0,2	4	1,75	0,05	18,5	2,86
0,25	4	1,75	0,063	18,7	3,58

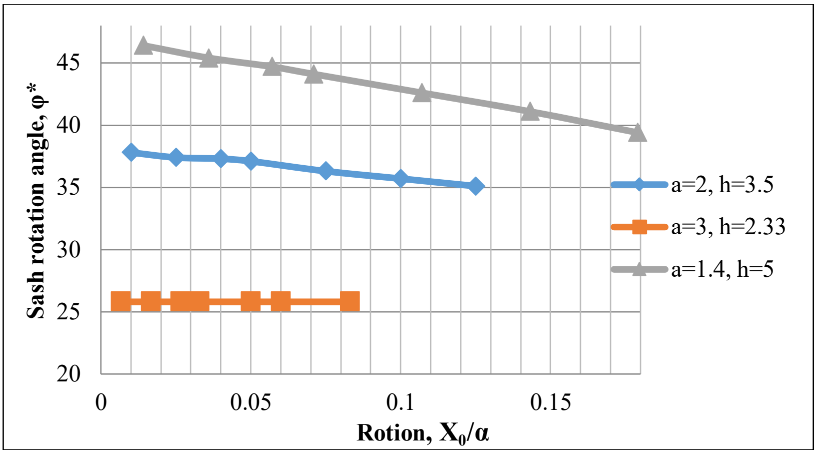

Fig.3. General graph of the dependence of the angle φ* on the ratio X_0/a

4 Discussion

With the same values of *"h"* and *"a,"* the maximum possible outflow area increases with decreasing X_0.. The opening angle from φ_0 is also larger as the X_0 value decreases. At the same time, the total angle of rotation for complete opening of the φ = (φ_0 + φ*) is greater, the greater the X_0 value. Consequently, the arrangement of safety structures with a smaller X_0 is more efficient, since in this case a larger area is opened with a smaller overall angle of rotation.

5 Conclusion

To ensure the safety of buildings from internal explosions, a sufficient large number of different types of safety structures have been developed. But their ability to open openings for gas outflow depends on various factors that are associated not only with the explosion development process, but also on the characteristics of the safety structures themselves, such as geometric parameters.With regard to rotary safety structures, their effectiveness also depends on the opening angle of this structure.

The area through which gases flow depends on the angle of rotation of the flap of the safety structure. There is a limit opening angle φ*at which the outflow area reaches a maximum value equal to the area of a fully open opening. The greater the value of this angle, the smaller the depth of closure of the safety structure - X_0.. But at the same time, the total angle of rotation (for complete opening) is ≈, the greater the larger the X_0.

Therefore, a safety structure with a lower X_0. will be more effective, since a larger area is opened with a smaller overall angle of rotation of the flap

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