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Relationship between gas-dynamic flows and impacts of emergency explosions indoors

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Abstract. The paper demonstrates that gas-dynamic flows generated by explosive combustion bear a decisive influence on the entire course of explosion emergency. The conclusion is borne out by analysis of calculation results, test data and consequences of real-life emergency explosion in residential housing.

1 Introduction

Emergency explosions indoors occur in the deflagration mode of explosive transformation with specific features [1-6]. Apparent flame speed with deflagration is much below the speed of sound; therefore, the deflagration type of explosive transformation realizes the principle of quasi-static overpressure, understood as independence of the blast load from the spatial coordinate.

During combustion, explosion products expand in ε times (approximately 8 fold). Flame moves at normal combustion speed U_u relative to explosion products. Apparent flame speed (speed at which the flame moves relative to a stationary observer) is the total velocity of expansion of the mix during combustion and its burnout speed (normal combustion speed). Considering that the speed related to expansion of the mix during combustion is much higher than that of normal combustion, one can theorize that gas-dynamic flowsthat accompanya deflagration explosion should mainly determine its further evolution.

Mathematical description of gas-dynamic flows created indoors by explosive combustion should base on two main principles that greatly simplify the task. First, explosive loads indoors must be significantly below the atmospheric pressure due to the bearing capacity (strength) of main structural elements of buildings [7,8].Second: fairly consistent adherence to the principle of quasi-static overpressure; this helps to overlook non-stationary equations of gas dynamics, and to consider the established gas-dynamic flow pattern for each point in time.

Solution to the gas-dynamic problem for each point in time not only describes the dynamics of the flame front,but also the speed rate of fresh mix, as necessary to evaluate the combustion process intensification coefficient.

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The writers calculated gas-dynamic flows created indoors when the explosive combustion scenario is realized. The results of calculation representing the fields of air flow velocity along with the deflagration explosion are represented in Figure 1.

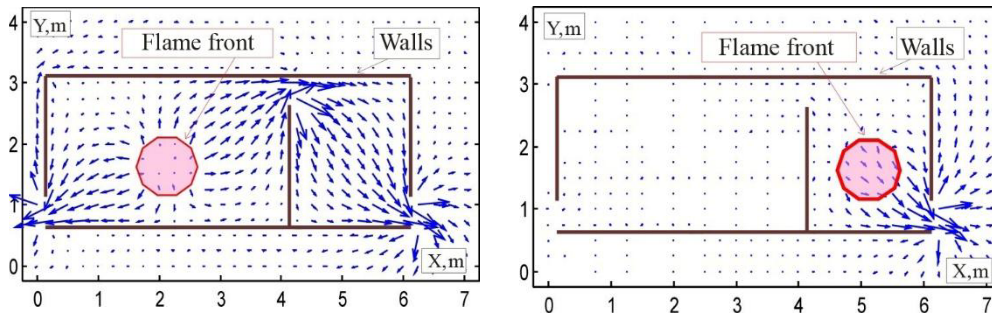

Fig.1. Speed vectors of air flows accompanying explosive combustion indoors

The calculations focused on adjacent rooms and gas-dynamic flows, because significant destruction of buildings during emergency explosions is mainly caused by mix overflowing from room to room, and resulting turbulence. When this mix is ignited, this typically results in a destructive explosion.

The calculations have demonstrated that the shape of flame front bears little effect on gas-dynamics flows indoors. This is particularly true for adjacent rooms. The main factor is the speed of released explosion products (source efficiency).

When explosive combustion occurs in an apartment room (such as the kitchen), air pressure in the adjacent rooms drops significantly. This creates significant inflow of fresh mix to the adjoining rooms and rapid growth of explosive pressure.

Experimental research of the explosive combustion process in adjacent volumes confirmed the main findings of the calculations.

Fig.2 is a photo of a deflagration explosion of propane-air mixin adjacent chambers. We can clearly observea jet stream of the mix from chamber to chamber. Fig. 2 proves that considerable turbulence in the mix occurs, and consequently speeds up its burnoutrate, which in turn causes significant inflow of explosion products and abrupt increase in explosion pressure.

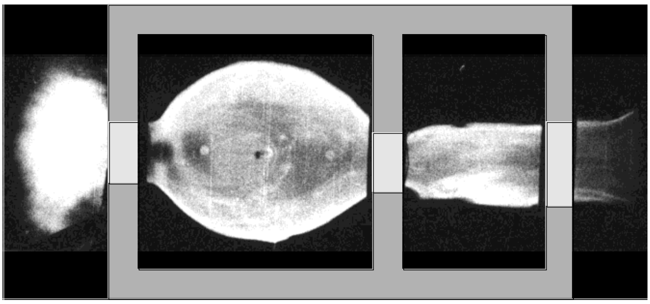

Fig.2. Photo of propane-air mixexplosionin adjacent chambers

Based on the above, let us consider the impact of emergency explosions in residential buildings.

The following observation is necessary at first. The emergency explosions described below had the following shared circumstances: Explosion Safety NTC (of MGSU) participated in expert investigation, and so these writers well know the circumstances of the emergency; in each case, it is known that a gas leak and ignition of the mix occurred in the kitchens of the buildings in question.

Fig.3 is a photo of the emergency explosion impact in the kitchen of a two-room apartment on level 5 of a 9-story building.

Fig.3. Photo of emergency explosion impact from propane-air mixin a two-bedroom apartment on level 5 of a 9-story residential building

A leak of propane gas from the supply hose on the gas stove caused explosion of the propane-air mix. The relay of a refrigerator in the kitchen was the source of ignition. From the picture above we can see that most of the destruction (and, respectively, the greatest impact) occurred in the rooms joined the kitchen.

In fact, total collapse was observed in the room most remote from the kitchen. This indicates that gas-dynamic flows absolutely determine the explosion emergency scenario. In this case, the sequence of events was as follows. The mix gets ignited in the kitchen. Influx of explosion products causes a slight increase of pressure (the apartment's windows and doors were closed); this drives the mix into the corridor and adjacent rooms. Thus causes turbulence and oxygenation of the mix, because near the source of ignition the mix on the kitchen floor is rich: propane is heavier than air and leaks spread over the ground. The triggered process is similar to jet stream in the right chamber as shown in Fig. 2. Explosion pressure rises abruptly due to rapid burnout of the mix and large influx of explosion products. Therefore, the highest pressure and greatest destruction will occur in the furthest room. It should be noted that such effect is only typical for explosion emergencies, completely contrary to fire impacts when the extent of burnout grows towardsthe source of ignition. Therefore, based on their experiences with fire accidents, investigators are often baffled when they consider consequences of explosion accidents.

A similar pattern was observed with emergency explosion of methane in the kitchen of a one-bedroom apartment on level 5 (apartment layout similar to the one above) in a 5-story building. Fig. 4 is a photograph representing the consequences of the explosion. Apparently, explosion pressure came a little short of bringing down the wall panels. The general picture of the explosion was identical with the situation described above.

In conclusion, let us discuss the impact of an explosion accident with a similar scenario, although in a brick building apartment. A photo of the impact is given as Fig. 5. In that case, the owners had merged two apartments into one, but the accident unfurled along a scenario that was generally consistent with above situations.The only difference was that the kitchen had double-glazing windows with enhanced strength characteristics installed that require sufficiently high pressure to open. This example of the explosion impact also illustrates that brick buildings are less resistant to blast compared to bearing-wall structures.

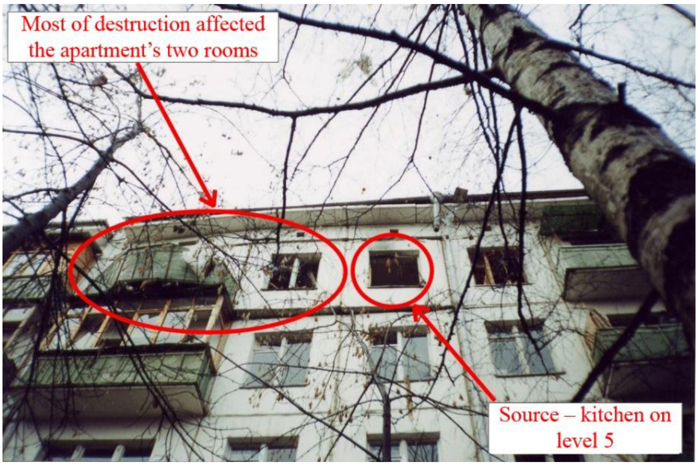

Fig.4. Photo of explosion impact from methane-air mix in a two-bedroom apartment on the 5th level of a 5-story residential building

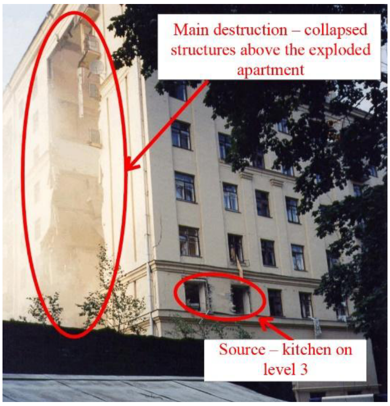

Fig.5. Photoofexplosion impact from methane-air mix in an apartment on level 3 of a 10 story brick building

The following conclusion results from the above. Gas-dynamic flows created by explosive combustion of gas-air mixburning indoors absolutely determine its evolution, play a crucial role in generation of explosive loads and, therefore, totally determine the nature of the building's destruction.

Conclusions

The paper quotes calculations of the parameters of gas-dynamic flows created by emergency explosions indoors. Analysis of calculated results and test studies demonstrates that gas-dynamic flows generated by explosive combustion are the decisive factor for the entire course of the explosion accident.

Analysis of impacts from real-life emergency explosions inside residential buildings supported the conclusion that gas-dynamic flows created by explosive combustion of air-gas mixindoors absolutely determine the process; they play a crucial role in formation of explosive loads, and so fully determine the nature of destruction in the building.

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