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110. The New Method of Heterogeneous Systems Estimation of Accidents Caused by Explosions

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Introduction

In today's world neither of countries can ignore branches of industry, which are environmental and human hazardous and have enlarged risk level of accidents. Most of national chemical, petrol, energetic complexes, transport arteries and other industry branches and objects can be classified as enlarged risk accidental objects, which have their own reliability and safety requirements. It is natural and understandable, because ecological outcomes of technological accidents, disasters and terrorist hits are hardly evaluated. From one side, if it is possible to calculate material losses, then from the other side the outcomes for genetic code, psychological aspects are unpredictable.

The problem of estimation of accidents caused by explosions is dealt with. This problem is of current concern to various objects, particularly for enlarged risk technologies.

Our aim is to develop and examine the methodology allowing calculate the qualitative changes of the heterogeneous systems under explosion and create the method for such accident estimation.

Problem formulation

Suppose we have the object 1 – underground bunker (Fig. 1), which can be loaded due to a nearby explosion after of specific explosive device 2. It is evident that damage done by explosion will depend on the power of charge, the location of the explosion in the space of analysed system and physical-mechanical characteristics of the elements, which composed heterogeneous system. As seen, in this context we can exclude three main groups of characteristics:

1) characteristics, which define explosive charge;
2) characteristics which define object;
3) characteristics which define the contact of the object and the charge

The characteristics of the first group can be group by the form of explosive charge (e.g., spherical, cylindrical, etc) and the type of explosion (e.g., chemical, nuclear, etc.). The second group characteristics can be grouped into three subgroups by the nature of deformations: when th object is elastic, plastic or elastically plastic. In the third group it is purposeful to exclude two subgroups by the nature of contact: when the contact of explosive charge and object is direct or indirect, i.e. through the other medium (e.g. water or air). So, we have got a specific hyperstructure of the problem systemic view, which could be more detailed, but main parameters are depicted in the scheme (Fig. 2). It is obvious, that analysis and research of dynamic processes of interaction between system elements and explosion impact, considering to presented in Fig. 2 scheme, is complicated and can be analysed only using differentiated physical and mathematical modelling. The latter can be implemented in analytic way or using finite elements method (FEM). Analytical and discrete mathematical modelling allows analysing widely interaction of shock impulse impact with dynamics of object processes, but it also has its own restrictions.

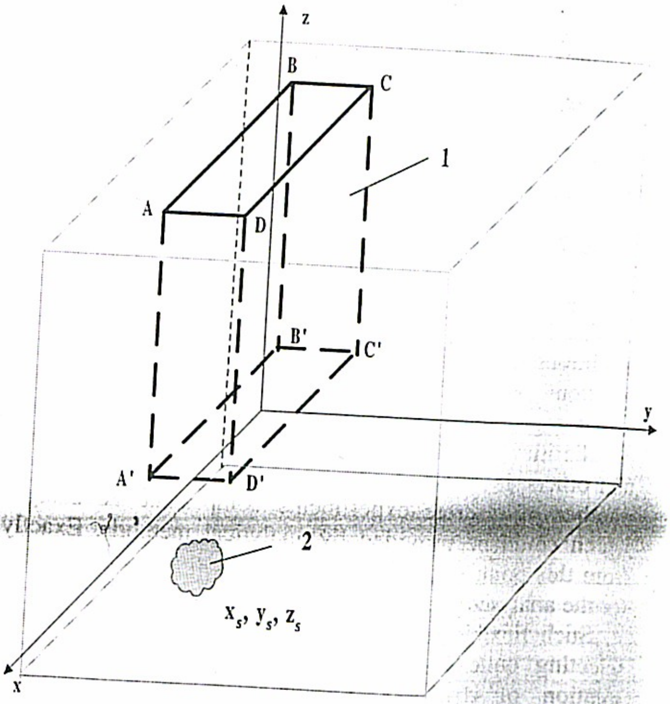


Fig. 1. The scheme of heterogeneous system

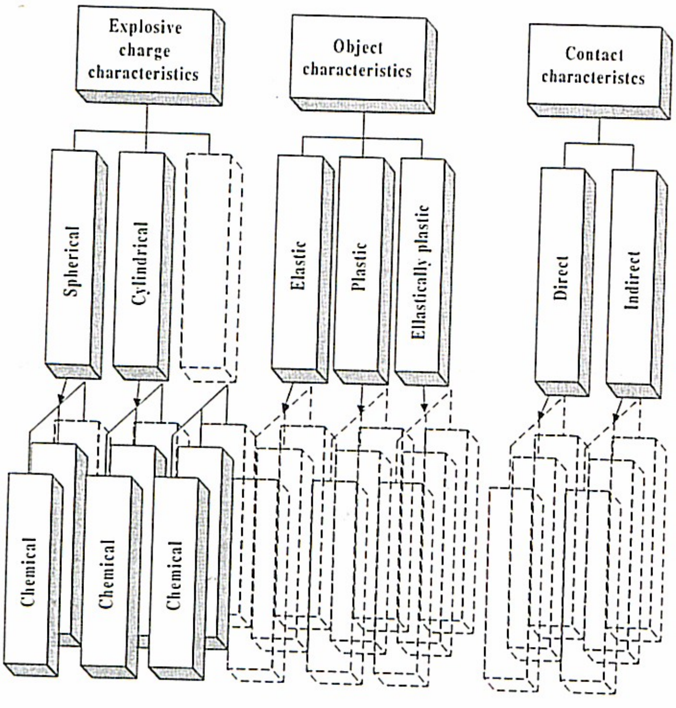


Fig. 2. Structural scheme of features of explosion influence to object

The latter is concerned with evaluation of boundary conditions and selection suitable analytical description functions. The boundary conditions depends on structure of heterogeneous system, so on purpose to evaluate all its peculiarities, for example, stiffness of separate elements and others, it is purposeful to use FEM and with a greater number of discrete experiments compensate advantages which could be provided by analytical methods. Exactly from this point it is important to apply some FEM aspects for the analysed problem.

Such flexible using of mathematical modelling allows selecting quite fast, as for express analysis, analytical solution of dynamics problems, but with particular assumptions and restrictions or allows perform more comprehensive investigation, using powerful set of finite elements method, for example, with AUTODYN software. So problem analysis needs to set and solve two tasks, depending on the interact~~ion~~ of object and explosion device.

Mathematical models

In the first task the loading on an underground bunker due to a nearby explosion is using our mathematical method based on analytical calculation of soil displacements [1]. The mathematical models obtained in accordance with scheme in Fig.2 allow the estimation of influence of the shock impact action on the displacement of elastically plastic substance and compare it. The shock impact load and the interaction of resulting displacements have been analysed by applying Hamilton's principle, the theory of elastically plastic body and the low of geometrical similarity. The mathematical model was set up in which the soil is elastically plastic body with the parameters (density of soil ρ, shearing modulus G, Poisson's ratio μ) known from the physical investigation.

In the second task the loading on an underground bunker due to a nearby explosion is simulated using Euler Lagrange coupling in AUTODYN software [2] in accordance with diagram in Fig.3.

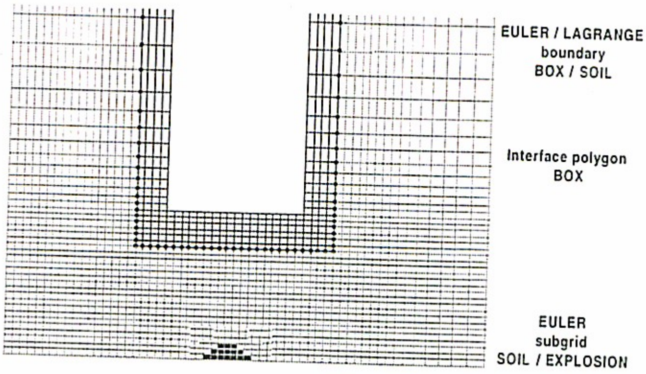
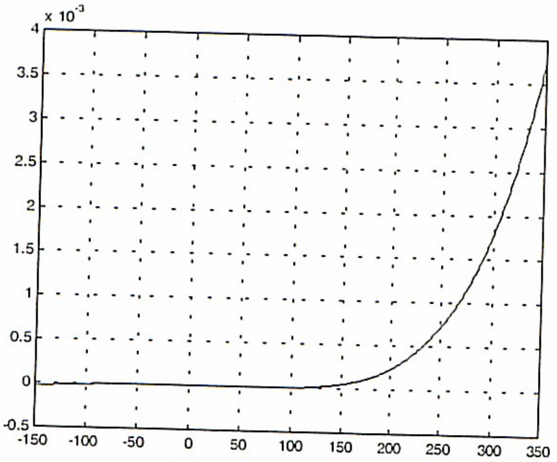


Fig. 3. The diagram in Autodyn sofware

There Euler-Lagrange coupling - Euler and Lagrange grids interact in a very general and powerful way. A Lagrange interface may "cut" through the fixed Euler mesh in an arbitrary manner. The Euler cells intersected by the Lagrange interface define a stress profile for the Lagrange boundary vertices. In return, the Lagrange interface defines a geometric constraint to the flow of material in the Euler grid. AUTODYN recognizes that the Euler cells adjacent to a Lagrangian boundary may be partially covered by the Lagrangian grid and that their control volumes and face areas may be continually changing. In a large displacement problem, an Euler cell that was originally not covered may become completely covered by a Lagrange mesh as the Lagrange mesh moves over it. Similarly, an Euler cell may become "uncovered". As the Lagrange mesh moves across the interacting Euler mesh, Euler control volumes can become very small, tending to 0 when completely covered. To maintain stability, AUTODYN automatically and dynamically combines (clumps) a small control volume (cell) with its larger neighbours to form a single larger control volume. Similarly, when a cell becomes uncovered enough to be independent it can be "unclumped".

Results

Comparisons of the displacements calculated in the analytical model are given in Fig. 4 and Fig. 5.



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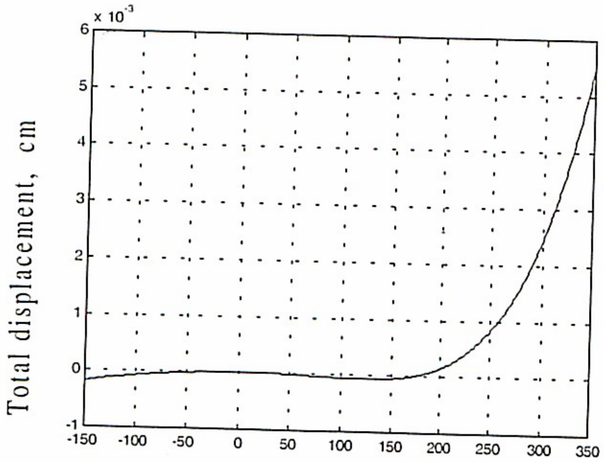

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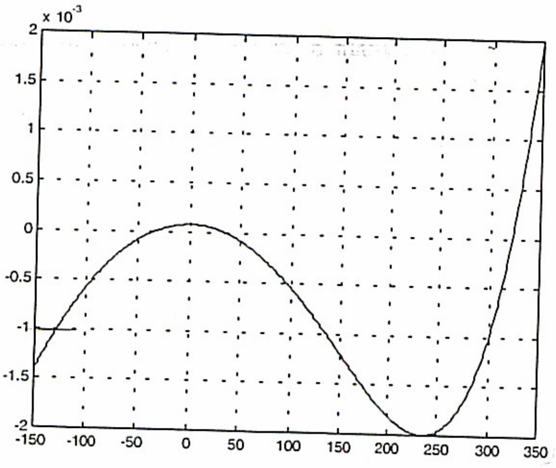
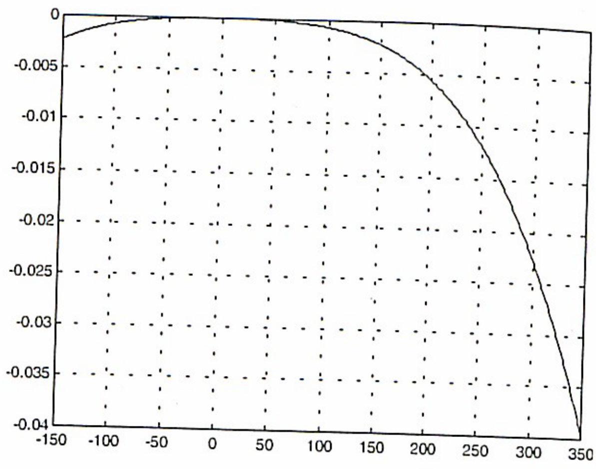


x= -250 cm; z= -10 cm;

Fig. 4. Fragments of analytical calculation

These pictures illustrate distribution of the total displacements of soil in the same vertical cross section yOz (see Fig.1) for different coordinate z value when the charge is exploded at the same point xs= -290 cm, ys= 0 cm, zs=-90 cm.



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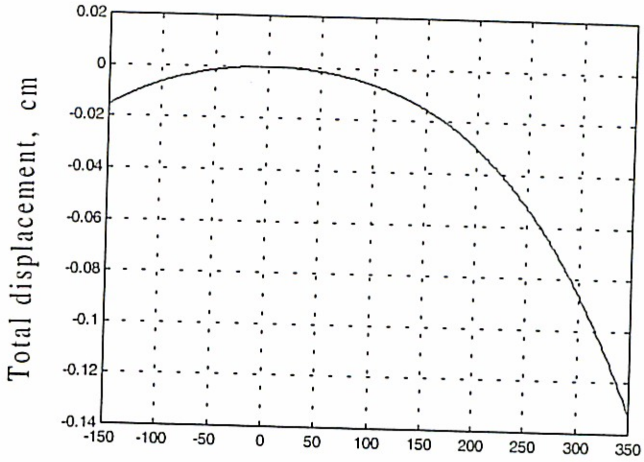

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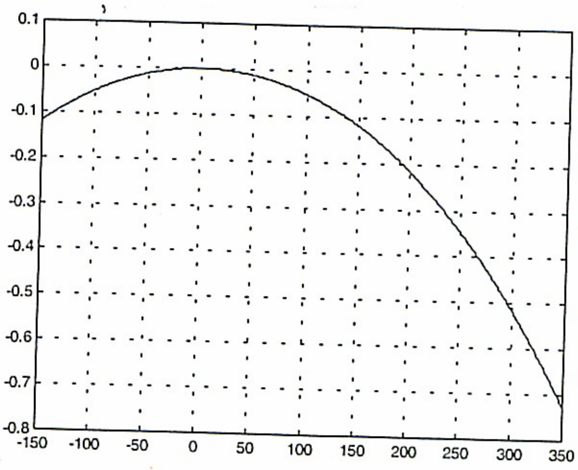

x= -250 cm; z= -90 cm;

Fig. 5. Fragments of analytical calculation

The simulation of the model in AUTODYN software and obtained fragments of results are given in Fig. 6. It illustrates distribution of the velocity vectors, material status of the system structural elements and distribution of the pressure at fixed time. The energy summary plots for each material are shown in Fig. 7.

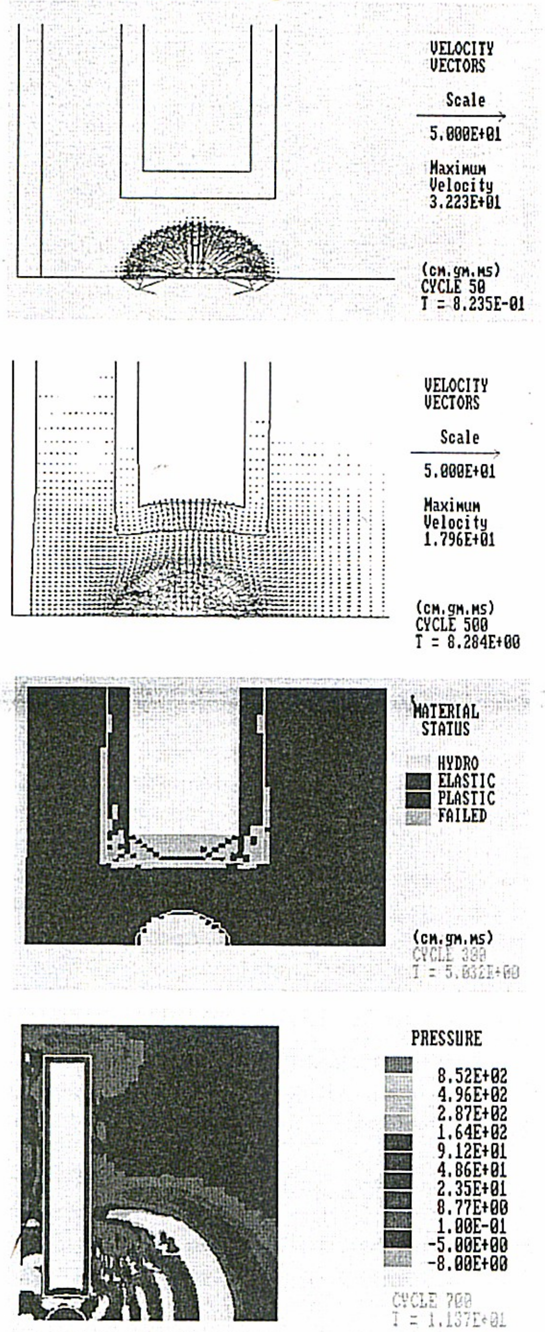

Fig. 6. Fragments of calculation with AUTODYN

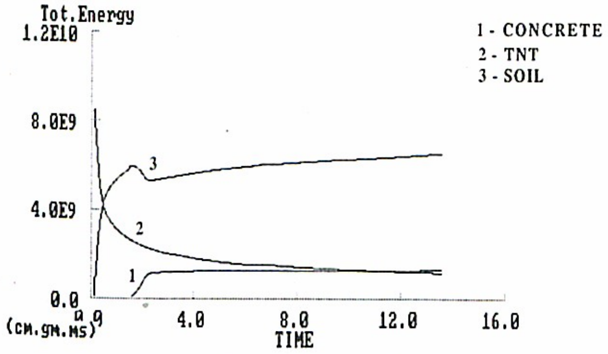

Fig. 7. The energy summary plot

Method formulation

Referring to the results and analysis we have created a method of heterogeneous systems estimation of accidents caused by explosions. This can be realized by calculation value that we called a point of risk level and lettered D. It's can be given by calculation the following mathematical equations:

$$D = \lg\left(\frac{S_d}{S_t}\right)^{\alpha} \quad (1)$$

$$D = \lg\left(\frac{P_d}{P_t}\right)^{\alpha} \quad (2)$$

where

S_d – maximum displacement in contact zone under explosion;

S_t – very small standard displacement;

P_d – maximum pressure in contact zone under explosion;

P_t – very small standard pressure;

α - secondary influence function $\alpha = f(\alpha_i)$, that depends on indirect factors like inflammable of structural element, existence of dangerous material or technology and etc. This function can be given by summary all indirect influence coefficients.

$$\alpha = \sum_{i=1}^{n} \alpha_i \quad (3)$$

Conclusions

The proposed method could provide reliable estimates for potential dangerous systems and groups it's by different point of risk level of accident caused by explosions. This method allows to implement prevention of dangerous objects.

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