COMPUTER FLUID DYNAMICS DETERMINATION OF INSIDE DOMAIN WAVES BLAST DEVELOPMENT PROCESS

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REZUMAT. În ultima perioada de timp, datorită creşterii puterii de calcul şi a perfecţionării continue a metodelor numerice destinate descrierii proceselor fizice complexe, acestea au fost implementate în aplicaţii inginereşti care să asigure un nivel cât mai ridicat de siguranţă în exploatare. În acest sens, lucrarea îşi propune analiza modului de propagare a undelor de soc produse de o explozie generată într-un domeniu închis, utilizând o metodă de modelare a dinamicii gazului bazată pe rezolvarea ecuaţiilor Euler pentru domenii 2D sau 3D cu configuraţie oricât de complexă. În prezent, astfel de probleme au fost modelate utilizând metode bazate pe viteza de ardere a combustibilului şi propagare a undelor de presiune, bazate pe metoda impulsivă [1, 3]. La baza acestor metode stau determinările experimentale, făcute pentru fiecare tip de exploziv în parte. De regulă, în multe cazuri, mai ales în ultimul timp, sunt folosite diverse reţete de explozibili, al căror impuls şi caracteristici explozive nu sunt cunoscute în prealabil. Din aceasta cauză, în lucrarea de faţă s-a căutat o soluţie energetică având un grad mare de generalitate. La baza dezvoltării algoritmilor din lucrare stau metode de tip TVD, iar interacţiunea cu pereţii a fost obţinută prin impunerea condiţiilor de frontieră pentru diversele configuraţii geometrice din apropierea zonei de frontieră solid-gaz. Astfel, se obţine un model de propagare a undelor de şoc în interiorul unui domeniu oricât de complex. În lucrare s-a utilizat un domeniu 3D cu laturi egale, cu descărcarea energetică în centrul acestuia, problemele legate de geometrii foarte diverse, fiind de fapt diverse reaşezări ale condiţiilor la limită deja dezvoltate în lucrare.

Cuvinte cheie: modelare folosind dinamica fluidului, undă de şoc, explozie, sistem de alimentare, structură de alimentare.

ABSTRACT. In the last time period, the computer power increase day by day and the numerical methods dedicated to modeling the more complexes physical phenomenon are more accurate and simples. Those models are in trends to be used in the engineering design of diverse products and get higher safety and efficiency. In that trends, the paper want to analyze the wave's blast propagation inside the 2D/3D complexes closes domains. This type of problems was analyzed in diverse research works [1,3] based on the specific impulse method, for each knotweed propeller or explosive. As is known, in many cases, in the last age, more of explosives used consist in diverse mixtures with unknown experimental specifically impulse or other characteristics. This is the cause of developing other solution types, based of energetically solution with great generalization applications. The method is based on volume finite method, VOF, with flux limiter between adjacent cells developed in TVD technique. The walls boundary cells, considerate the case solid-gas boundary where for density is used the method of ghost cells and for moments and energy was used the classical RENS methods. In this way a new method of simulation of blast waves inside domains 3D with great complexity is get and tested on an explosion located in the middle of a cubic space, case that put in oeuvre all the boundary cases specifically of 3D modeling and the quickly evaluation of software program developed become more easy and the loading pressures systems dynamics too.

Keywords: computer fluid dynamics, wave's blast, explosion, loading system, structural loading.

1. INTRODUCTION

The classical methods of explosions simulations are based on specific impulse of an energetic material and consider that characteristics as the most important of their performance. Thus it is the widely used property of propellants [1, 2]. Due to the discharge of gaseous products formed, an energetic material develops a recoil force named as thrust forces in some cases. The specific impulse, represent the integral of the thrust, per unit weight of material, over the time of combustion [2, 3]. The specific impulse can be estimated by some experimental work [4, 5]. It can be also predicted if one knows the detonation velocity and with the notation D_{CJ}, in Chapman-Jouguet expression and density, by using the empirical formula of Keshavarz and Pouretedal which is in its original form estimates D_{CJ} if Is value and density are known [6] .

Propellants are energetic materials and differ from explosives with their low rates of combustion that will ideally burn at uniform rates after ignition without requiring atmospheric interaction [2]. Desirably, they should have no brisance effect.

Propellants are usually a mixture of various components, including an energetic oxidizer, a plasticizer to facilitate processing and a polymeric binder. Thus, the specific impulse value of such a propellant is that of the composite mixture. The thrust propellant is expressed in Newton × seconds/ kilograms masses. In the classical explosions, TNT and diverse mixtures based on them are used frequently but the burn rates, temperature and pressure variation is differed in time after ignition. The blast waves generate by the explosion and the inside room pressure have a quick modification and intensity variation. Usually, some experimental wave's pressure time repartition is used for simulation the impact of an explosion on an environmental structure [8, 9, 10, 11].

In the present paper we use the Euler governing equations for the wave's blast propagation, method that get real results for both propellants and explosives without theoretical simplifications' difficulties.

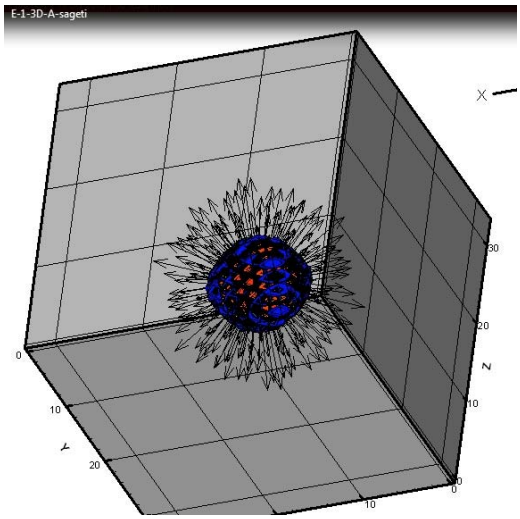


Fig. 1. Incipient wave's blast formation inside domain of calculation.

2. NUMERICAL ANALYSIS

2.1. Governing Equations of waves blast

The blast wave's process is generate by the energy heats absorbed on the specimen surface above its melting point to the vaporization temperature and then gaseous diffused generate a surrounding chemical vapors unstable atmosphere. The equilibrium of that process is attended by gases stable at current pressure and temperature values. In differential form, the equations are:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \cdot \vec{u}) = 0 \tag{1}$$

$$\frac{\partial (\rho \cdot \vec{u})}{\partial t} + \nabla \cdot (\vec{u} \otimes (\rho \cdot \vec{u})) + \nabla p = \vec{0} \tag{2}$$

$$\frac{\partial E}{\partial t} + \nabla \cdot (\vec{u} \cdot (E + p)) = 0 \tag{3}$$

Where ρ is the fluid mass density, $\vec{u}$ the fluid velocity vector, $E = \rho\, e + ½\, \rho\, (u^2 + v^2 + w^2)$ the total energy of the unit volume, e is the internal energy of the unit mass of the fluid, p the fluid pressure, $\otimes$ the tensor product and $\vec{0}$ the vector null. The solver was developed using the conservation of mass, ρ, momentum, ρu, ρv, ρw and energy, E from the equation formed based on e conforming (4) equation results

$$e = c_v T = \frac{p}{(\gamma - 1)\rho} \tag{4}$$

$$E = \frac{p}{\gamma - 1} + \frac{\rho}{2}\left(u^2 + v^2 + w^2\right) \tag{5}$$

The fluxes on x, y, and z direction noted with, F, G, and H give the equation system in conservative form and using the m notation, there expression become:

$$\frac{\partial m}{\partial t} + \frac{\partial F}{\partial x} + \frac{\partial G}{\partial y} + \frac{\partial H}{\partial z} = 0 \tag{6}$$

where

$$m = \begin{pmatrix} \rho \\ \rho \cdot u \\ \rho \cdot v \\ \rho \cdot w \\ E \end{pmatrix} \qquad F = \begin{pmatrix} \rho \cdot u \\ p + \rho \cdot u^2 \\ \rho \cdot u \cdot v \\ \rho \cdot u \cdot w \\ u \cdot (E + p_x) \end{pmatrix}$$

$$G = \begin{pmatrix} \rho \cdot v \\ \rho \cdot u \cdot v \\ p + \rho \cdot v^2 \\ \rho \cdot v \cdot w \\ v \cdot (E + p_y) \end{pmatrix} \quad H = \begin{pmatrix} \rho \cdot w \\ \rho \cdot u \cdot w \\ \rho \cdot v \cdot w \\ p + \rho \cdot w^2 \\ w \cdot (E + p_z) \end{pmatrix} \tag{6,..,9}$$

For gases with 2 atoms in molecules, N_2 or O_2 the value of γ is considerate 1.4.

The system is closed by the ideal gas condition $p = \rho\, (\gamma - 1)\, e$ where γ represent the adiabatic coefficient and e the internal energy (eq. 4).

The sound velocity, c was computed with the general expression $c = \sqrt{\gamma \cdot p / \rho}$ and is adapted to density of waves. The Riemann solution for the arbitrarily direction $\vec{n}$ consists in two acoustic eigenvalues $(\vec{n} \cdot \vec{u}) \pm c$ and three degenerate eigenvalues $\vec{n} \cdot \vec{u}$ that modelles the jumps in the density and two jumps in the transverse velocities of the waves that is propagate on $\vec{n}$ direction.

2.2. Boundary Conditions

The conditions on boundary are considerate as solid/gas condition using the ghost cells exactly as in classical volume finite methods for hyperbolical equations. In this method, the density, speeds and energy are imposed for each time step function of the previous time step values inside the volume control, with the scope to get correctly the reflected waves. The solver was made in the hypothesis:

1) the walls deformations are small;

2) the heat dissipation and the turbulent indices are calculated only in the fluid control volume;

3) the domain is closed and without any input or output.

2.3 Sources cells

The development of the induced sources was done for two cases:

A. The imposed front waves characteristics. In the center of any control volume inside the gas can be produced an explosion with the front propagation conforming with the Hugoniot expression:

$$\frac{A}{R_1}e^{-R_1V_J}+\frac{B}{R_2}e^{-R_2V_J}+\frac{C}{\omega}V_J^{-\omega}=E_0+\frac{1}{2}P_J(1-V_J) \tag{10}$$

where: A = 3.712; B = 0.0323; C = 0.0104527; R_1 = 4.15; R_2 = 0.95; $\omega = 0.3$; $E_0 = 4.46\ 10^6$ J/kg; $P_J = 6.93\ 10^2$ MPa.

B. The imposed concentrate energy in the center of any gas finite volumes, case usefully when a laser impulse is focused in the gas domain.

3. RESULTS AND CONCLUSIONS

The implementation method was made in Microsoft Visual C/C++ 6.0 and the results, *r, p, E, u, v, w* was prepared for export to Tecplot postprocessing program. Waves blasts characteristics are presented in the figures 2, 3, 4, 5 respectively for a laser focusing in the center volume finite of the domain.

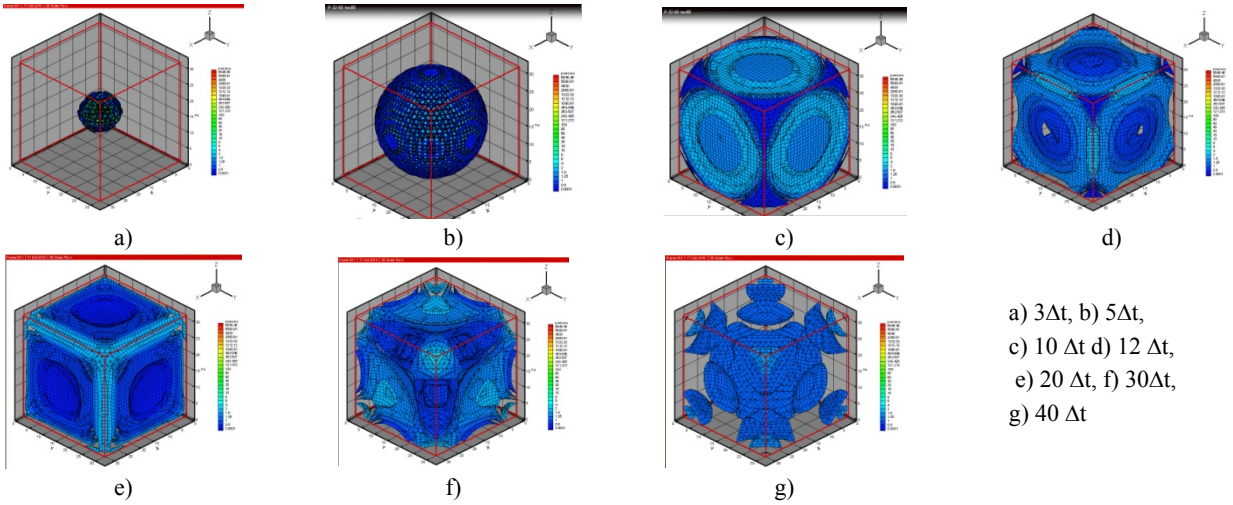


Fig. 2. The pressure dynamics in the gas domain [MPa].

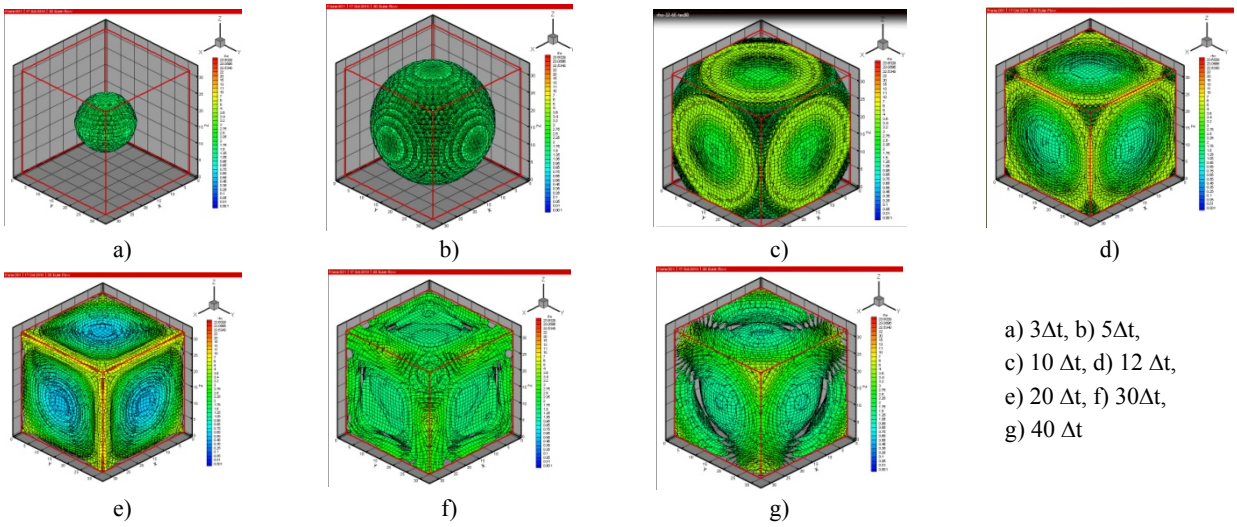
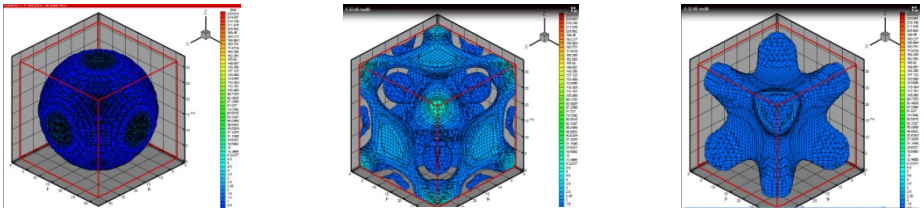


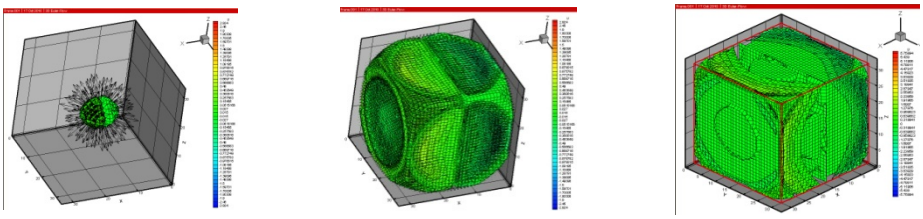
Fig. 3. The density dynamics in the gas domain [kg/m^3].



a) 5 Δt
b) 30 Δt
c) 35 Δt

a) b) c)

Fig. 4. The wave's energy variations inside the domain [kJ].



a) 5 Δt
b) 12 Δt
c) 25 Δ

a) b) c)

Fig. 5. The waves speed on *Ox* axes, $u \times 10$ m/s.

From the above work some conclusions may be imposed

– the Euler system of partial differential equations give useful information for walls pressures dynamics used to modeling the loading system of explosions or fire induced by propellants

– the conditions imposed on geometrical configurations do not impose great difficulties in the process of solving the gas dynamics inside the domain using Euler system of equations

– the solver developed for that type of problem, based on Volume Finite Method with TVD with MC-limiter based on van Leer [12] can assure the stability of the algorithm for the condition imposed by this type of problem

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