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ELECTRIC FORCE INTERACTION IN A PROTON BLAST WAVE

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Abstract: The paper presents theoretical foundations for the behavior of positively charged nuclei, namely uranium fission fragments, within a blast wave. The complexity of the problem stem from the fact that moving electrically charged bodies generate complex electric fields within which these bodies interact, being at the same time under the influence of inertial forces and dissipation forces caused by the opposition of the real environment. As it turned out, partial compensation of the effects of transverse motion in the form of magnetic fields is far from sufficient. Consequently, it was necessary to employ the longitudinal motion and the finite speed of propagation of force signals in the electric field to consider the phenomenon as a whole.

The theoretical results are accompanied by the findings of integrating the differential equations of the radial motion of the nuclei of barium and krypton, along with analytical calculations. Ill.: 3, bibliography 7.

Keywords: electric surface anti-tension, adapted Coulomb's law for moving electric masses, explosive proton blast wave.

Introduction

This is represents a further development of the theory of dynamic interaction of moving charged bodies in an electric field, a subject explored in the author's previous works [1–3]. In this instance the task is too complex. The process under scrutiny has been shown to result in the fission of the uranium atom nucleus U_{92}^{235} into barium Ba_{56}^{139} and krypton Kr_{36}^{85} fragments, culminating in an explosion. On the one hand, the complexity of the problem lies in the fact that moving electrically charged fragments generate complex vortex electric fields with which they interact, being at the same time under the influence of inertial forces and dissipation forces caused by the opposition of the real environment. On the other hand, the laws of classical electricity, in their as static form, are not applicable to the analysis of the all-encompassing motion of charged bodies. As it turned out, partial compensation of the force effects of motion in the form of magnetic fields is far from sufficient to take into account the phenomenon as a whole. In the theoretical part we will show how to solve this problem.

Theoretical part

To simplify the analysis, the model of the physical process is based on two assumptions – the point nature of the charges and the isotropic nature (homogeneity with the same properties in all directions) of the medium, regardless of where we are. In reality, this means that the process takes place in the atmosphere at a considerable height above the ground.

The universal law of interaction of point charged bodies is Charles Coulomb's law (1785), which expresses the magnitude and direction of the force acting between them.

$$\mathbf{F}_c = k\frac{q_1 q_2}{d^2}\mathbf{r}_0\,, \qquad (1)$$

where $\mathbf{F}_c$ – Coulomb force vector; q_1, q_2 – electric masses (charges) of interacting bodies; d – distance between centers of masses; $\mathbf{r}_0$ – unit vector directed from the center of a given mass to the point of electrical interaction; k – electric constant.

Unfortunately, it is not possible to use (1) in the case of moving charges. Therefore, let us turn to the adapted law for the case of moving charges [4–6]

$$\mathbf{F} = k\frac{q_1 q_2}{d^2}\left(1+\frac{v^2}{c^2}+2\frac{v}{c}\mathbf{r}_0\cdot\mathbf{v}_0\right)\mathbf{r}_0\,, \qquad (2)$$

where $\mathbf{F}$ is the force vector; v is the mutual velocity of motion; c is the speed of light; $\mathbf{v}_0$ is the unit velocity vector.

The required value $\mathbf{r}_0\ \mathbf{v}_0$ is found from the corresponding coordinate equations of mechanical motion [4]

$$\mathbf{r}_0\cdot\mathbf{v}_0 = \frac{r_x v_x + r_y v_y + r_z v_z}{rv}\,,$$
$$r=\sqrt{r_x^2+r_y^2+r_z^2}\,;\;\; v=\sqrt{v_x^2+v_y^2+v_z^2}\,, \qquad (3)$$

If necessary, the product $\mathbf{r}_0\ \mathbf{v}_0$ can be easily obtained from the geometric constructions depicted in Fig. 1.

Law (2) has been successfully tested in problems of micro-, macro- and mega-space (in mechanical formulation) at nearluminal and subluminal velocities.

Expression (2) is simplified under the condition $\mathbf{r}_0\cdot\mathbf{v}_0=\pm 1$

$$\mathbf{F} = k\frac{q_1 q_2}{d^2}\left(1\pm\frac{v}{c}\right)^2\mathbf{r}_0\,, \qquad (4)$$

and the sign "+" indicates the removal of interacting masses, and the sign "–", on the contrary, indicates their convergence.

We point out that at real expansion rates of the charge accumulation in the two-mass formulation, the additional increase in kinetic energy will not produce the desired physical effect. Here, given the homogeneity and isotropy of the system, the problem must be solved as a multi-mass problem! However, as the complexity of this task is beyond the scope of a journal article, the focus will be on the main physical situations and features in the construction of a corresponding single inseparable mathematical model of electromechanical motion! At the same time, we will allow ourselves to consider the subjective situations on the principle of superposition. This is due to the fact that our focus is on a cognitive process, and not on a real one, fastened by mechanical motion.

We write the coordinate equations of motion of the uranium nucleus fragments in spherical coordinates in the radial direction:

$$\frac{dv_\rho}{dt}=\frac{1}{m}\left(F_\rho(R,v)-\upsilon v_\rho^2\right),\quad \frac{dR}{dt}=v_\rho, \tag{5}$$

where $F_\rho(R,v)$ is the modulus of force (4); m is the inertial mass of the moving body; R is the current radius; υ is the drag coefficient of the medium.

Fig. 1 shows the simplest geometric diagram of the explosion. All the symbols on it correspond to those in the theoretical part, which is entirely subordinated to the geometry of the diagram.

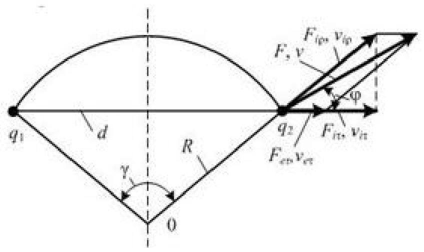

Fig. 1. Geometric interpretation of force and velocity interactions of a physical process in a two-mass electrical system.

The charges from the surface layer of the blast wave, entering into an electric force interaction with the same neighboring charges, cause an additional centrifugal acceleration g by their total radial force component. This results in creating an *electric surface antitension*.

Then the radial velocity of the explosion expansion is taken as the sum of the inertial and electrical components:

$$v_\rho = v_0 + gt > 0\,, \tag{6}$$

where v_0 is the conditional initial velocity of the explosion, which is found as a result of linear approximation of the upper part of the velocity characteristic depicted in Fig. 4.

Let us now consider the electrical interaction between moving in opposite directions bodies located, at a distance d. First of all, this distance must be related to the radius of the wave front

$$d = 2R\sin\frac{\gamma}{2} \approx \gamma R\,, \tag{7}$$

where γ is the angular distance; the approximate result corresponds to the smallness of the angle, in reality.

The tangential inertial velocity $v_{i\tau}$ is found as a result of differentiation (7)

$$v_{i\tau} = 2v_{i\rho}\sin\frac{\gamma}{2} \approx \gamma v_{i\rho}\,. \tag{8}$$

The tangential component of the surface antitension force γ can be found from the differential equation

$$\frac{dv_{e\tau}}{dt}=\frac{1}{m}F_{e\tau}(d,2v_e),\quad \frac{dd}{dt}=v_{e\tau} \tag{9}$$

and $F_{e\tau}$ is found according to (4).

The modulus v of the resulting velocity vector, taking into account (8), is obtained as

$$v=\sqrt{v_{i\rho}^2+v_{e\tau}^2+2v_{i\rho}v_{e\tau}\sin\frac{\gamma}{2}}. \tag{10}$$

The tangential electrical velocity is found as the sum

$$v_\tau = v_{i\tau} + v_{e\tau}\,. \tag{11}$$

The resulting modulus of the resultant force vector is found similarly to (10) according to the sines theorem and taking into account (11)

$$F=\sqrt{F_{i\rho}^2+F_{e\tau}^2+2F_{i\rho}F_{e\tau}\sin\frac{\gamma}{2}}\,. \tag{12}$$

The direction angle of vectors (10), (12) can be found, if necessary, based on the theorem of sines

$$\varphi=\frac{\pi-\gamma}{2}-\arcsin\left(\frac{F_\tau}{F}\cos\frac{\gamma}{2}\right). \tag{13}$$

The vector **F** (12), (13) is the spatial vector of the resultant force acting on a moving charged body.

This is what the key issues would look like when modeling the transition process in the case of a two-mass system. In the multi-mass setting in an isotropic medium, the process is simplified due to the absence of transverse electromechanical motion in the spherical coordinate system, compensated by neighboring electric fields. So let us turn to the constructions depicted in Fig. 2.

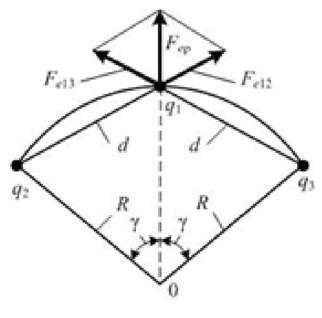

Fig. 2. Geometric interpretation of force and velocity interactions of a physical process in a three-mass electrical system.

In this case, based on geometric constructions with equality of neighboring charges, it can be shown that the modulus of the surface anti-tension force will be

$$F_{e\rho} = F_{e12}\sqrt{2(1-\cos\gamma)}\,. \tag{14}$$

The radial force is found as the sum

$$F_\rho = F_{e\rho} + F_{i\rho} \, . \quad (15)$$

When analyzing a multi-mass system, the process must be modeled in the projections of a single spatial coordinate system, in a *D*-dimensional space, as implemented in [5, 6]. The presence of mechanical motion in the system makes it nonlinear. Based on spatial symmetry, this problem can be solved with sufficient accuracy in 2D space.

Example. Let us consider a model example of the electrical interaction of two fragments of the nucleus of a uranium atom U_{92}^{235} from the surface layer of the blast wave, namely: barium Ba_{56}^{139} and krypton Kr_{36}^{85}, with masses:

$$m_1 = 0.32381 \cdot 10^{-24} \text{ kg}; \quad m_2 = 0.20093 \cdot 10^{-24} \text{ kg}$$

and the corresponding charges:

$$q_1 = 0.89722 \cdot 10^{-17} \text{ C}; \quad q_2 = 0.57678 \cdot 10^{-17} \text{ C}.$$

The rest of the input information is smoothed out as follows:

$$c = 0.2997925 \, \text{ms}^{-1}; \; k = 8.98774 \cdot 10^9 \text{ Nm}^2\text{C}^{-2};$$

Let us write the system of equations of motion (4), (5) for the specific case

$$\frac{dv_{\rho 1}}{dt} = \frac{1}{m_1}\left(k\frac{q_1 q_2}{d^2}\left(1+\frac{v_\rho}{c}\right)^2 - \upsilon_1 v_{\rho 1}^2 \right); \; \frac{dR_1}{dt} = v_{\rho 1};$$
$$\frac{dv_{\rho 2}}{dt} = \frac{1}{m_2}\left(k\frac{q_1 q_2}{d^2}\left(1+\frac{v_\rho}{c}\right)^2 - \upsilon_2 v_{\rho 2}^2 \right); \; \frac{dR_2}{dt} = v_{\rho 2}, \quad (16)$$

and $d = R_1 + R_2; \; v_\rho = v_{\rho 1} + v_{\rho 2}$.

The uniqueness of the solution (16) is ensured by the initial conditions:

$$R_1(0) = 0.222 \cdot 10^{-15} \text{ m}; \quad v_1(0) = 0 \, \text{ms}^{-1};$$
$$R_2(0) = 0.198 \cdot 10^{-15} \text{ m}; \quad v_2(0) = 0 \, \text{ms}^{-1}.$$

The simulation results are shown in Fig. 3 and Fig. 4.

The first one shows the force interaction on the uranium nucleus U_{92}^{235} on fragment Ba_{56}^{139} in the epicenter of the explosion at the initial stage of the transition process.

The second one shows the corresponding velocity response to the corresponding force action.

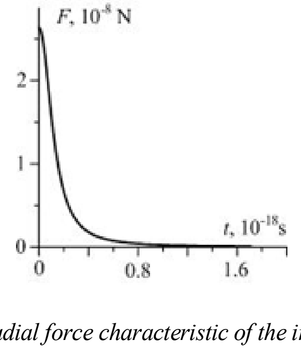

Fig. 3. Radial force characteristic of the interaction of two charged bodies

As follows from Fig. 4, in a given time interval the front of the blast wave moves with acceleration. This will continue until the dissipation forces involved in the differential equation (16) enter into force interaction, which will ultimately cause the process to stop

$$\upsilon v_\rho^2 > F_\rho(R, v) \, . \quad (17)$$

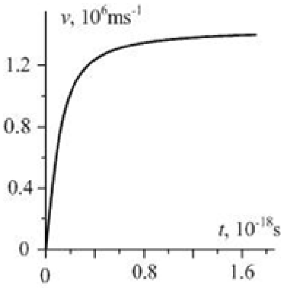

Fig. 4. Radial velocity characteristic of the interaction of charged bodies, corresponding to Fig. 3

The analysis of the transient process on the time interval $[t = 0 \div 1 \cdot 10^{-14} \text{ s}]$ revealed that the maximum transient velocity reaches 1440 kms^{-1}, which is significantly higher than the previously estimated value of 440 kms^{-1}.

The wave front will be analyzed at a time point $t = 1 \cdot 10^{-14}$ s based on the results of integration (16):

$$v_{\rho 1} = 1.44 \cdot 10^6 \text{ ms}^{-1}, \; R_1 = 1.44 \cdot 10^{-8} \text{ m}, \; F_{i\rho 1} = 2.03 \cdot 10^{-8} \text{ N}.$$

For the sake of certainty, the angular distance between two neighboring charged flying fragments is assumed to be $\gamma = 1^0 = 0.01745$ rad, and the dissipation coefficient is assumed to be zero: $\upsilon = 0$ due to its smallness R_1.

The fixed distance between neigh-boring fragments will be found according to (7)

$$d = 0.25128 \cdot 10^{-9} \text{ m}.$$

Then the tangential force of interaction is found according to Coulomb's law (1) (due to the smallness of the mutual velocity)

$$F_{e\tau 1} = 7.357 \cdot 10^{-8} \text{ N}.$$

It is this force that creates a negative electric surface tension, which does not slow down the propagation of the wave front, but, on the contrary, makes it more aggressive. If we turn to the analogous explosive gravitational wave (we are talking about the Big Bang theory), then there the gravitational surface tension creates a real braking effect on the expansion of the Universe [7]. It is possible that the Big Bang was also electric, since there are no other versions (!).

The resulting surface force is found according to (12)

$$F_1 = 7.806 \cdot 10^{-8} \text{ N}.$$

The direction angle of the vector (10) is found according to (13)

$$\varphi = 27.9^0.$$

The right-hand side of the velocity differential equations (16) determines the radial acceleration of the moving mass (6) $g = 6.25665 \cdot 10^{16} \text{ ms}^{-2}$. It can also be obtained directly from Newton's second law as:

$$g = \frac{F_{i\rho 1}}{m_1} = 6.25665 \cdot 10^{16} \text{ ms}^{-2}.$$

This makes it possible to identify expression (6)

$$v_\rho = 1.44006 \cdot 10^6 + 6.25665 \cdot 10^{16} t \text{ ms}^{-1}.$$

In the case of a three-mass electrical system, for the sake of symmetrical geometric constructions of Fig. 2, we will assume the equality of all three electrical masses $q_1 = q_2 = q_3 = 0.89722 \cdot 10^{-17}$ C, which is by no means fundamental, and therefore, for the uniqueness of the results $\gamma = 5^0 = 0.08725$ rad., we will find the modules of the forces of intermass interaction according to (1)

$$F_{12} = F_{13} = 0.458 \cdot 10^{-8} \text{ N}.$$

The modulus of the surface anti-tension force is found according to (14)

$$F_{e\rho} = 0.03995 \cdot 10^{-8} \text{ N},$$

and the resulting radial force is found according to (15)

$$F_\rho = 2.0695 \cdot 10^{-8} \text{ N}.$$

This is what needed to be shown. Based on the analysis, some conclusions can be drawn.

Conclusions

1. The positively charged bodies (nuclei of uranium fission atoms) of the blast wave are subject to very complex electric fields, static and dynamic, generated by motion. It has been determined that the concept of a magnetic field is insufficient to take into account the effects of transverse motion. Here, longitudinal motion and the finite speed of propagation of electric waves must also be taken into account. The fulfillment of these requirements is attributed to the application of Coulomb's law adapted to the context of moving charges, which is used in this work.

2. Charged bodies at the edge of the blast wave form an electric surface anti-tension, which, unlike gravitational surface tension, which slows down the expansion of the Universe, does not slow down the movement of the blast wave, but, on the contrary, makes it sharper.

3. The complex problem of dynamic interaction of moving charges at the tip of an electric blast wave solved in this work is not feasible for classical electrodynamics due to the static nature of Coulomb's law of force interaction.

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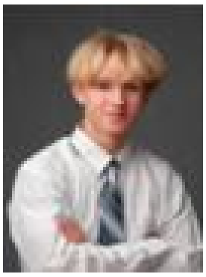
ЕЛЕКТРИЧНА СИЛОВА ВЗАЄМОДІЯ У ПРОТОННІЙ ВИБУХОВІЙ ХВИЛІ

Світозар Чабан, Василь Чабан

У роботі запропоновано теоретичні підстави поведінки позитивно заряджених ядер, осколків поділу ядра урану у вибуховій хвилі. Складність задачі полягає в тому, що рухомі електрично заряджені тіла породжують складні електричні поля, з якими вони взаємодіють, перебуваючи водночас під дією інерційних сил і сил дисипації, зумовлених протидією реального середовища. Як виявилося, часткова компенсація ефектів поперечного руху у вигляді магнетних полів є далеко не достатньою. Тому довелося задіяти поздовжній рух і скінченну швидкість поширення силових сигналів у електричному полі, щоб урахувати явище загалом.

Теоретичні результати супроводжуються результатами інтегрування диференціальних рівнянь радіального руху ядер барію і криптону, а також аналітичними розрахунками.



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