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Some Shock Wave and Energy Implications**

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# The Dynamic Theory: Some Shock Wave and Energy Implications

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# THE DYNAMIC THEORY: SOME SHOCK WAVE AND ENERGY IMPLICATIONS

by

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## ABSTRACT

The Dynamic Theory, a unifying five-dimensional theory of space, time, and matter, is examined. The theory predicts an observed discrepancy between shock wave viscosity measurements at low and high pressures in aluminum, a limiting mass-to-energy conversion rate consistent with the available data, and reduced pressures in electromagnetically contained controlled-fusion plasmas.

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## I. INTRODUCTION

The Dynamic Theory is described in Refs. 1-4. Briefly, the theory begins with three postulates, which are generalizations of classical thermodynamic laws. A unifying five-dimensional theory of space, time, and matter derives from the postulates. The fundamental principles of Newtonian and relativistic mechanics, Einstein's General Theory, Maxwell's electromagnetism, thermodynamics, and quantum effects occur as special cases of the Dynamic Theory. In addition, new phenomena are predicted, some having cosmologic as well as significant energy and shock wave implications. This report attempts to identify and evaluate the energy and shock wave implications.

## II. VISCOSITY IN SHOCKED SOLIDS

J. R. Asay and L. D. Bertholf<sup>5</sup> have shown that a viscosity estimate may be obtained from jetting experiments. They also have indicated that the Russian estimates of  $10^4$  and  $10^5$  P for high pressures in aluminum are not consistent with low-pressure estimates from jetting experiments. The Dynamic Theory<sup>1,2</sup>

offers new theoretical evidence indicating that both low- and high-pressure estimates of viscosity in aluminum may be correct. Further, these viscosity estimates provide a method of estimating a new universal constant appearing in the Dynamic Theory.

Although detailed development of the Dynamic Theory and its application to shock fronts will not be attempted here, a short discussion seems appropriate. The Dynamic Theory is based upon generalizations of the three classical thermodynamic laws. It is consistent with current theories, such as Special and General Relativity and quantum dynamics. The aspect of the theory that applies to shock fronts is rooted in the theory's deviation from the relativistic four-dimensional world view. This deviation adds a new dimension, mass density, to the space-time view and takes this new five-dimensional metric to be the manifold in which all physical phenomena may be described. However, in very few phenomena is mass not conserved. In ordinary shocks mass is conserved; thus we may write the mass density as a function of space and time. From a five-dimensional world view of space, time, and mass density, the conservation of mass embeds a four-dimensional hypersurface within the five-dimensional space. If, indeed, nature obeys the five-dimensional world view, then the geometric properties of the embedded hypersurface may reveal themselves. This geometric character of the hypersurface predicts the viscous effects presented here.

The total stress, in one dimension, given by the Dynamic Theory is

$$\sigma_D = P \left\{ 1 - \left( \frac{1}{a_0} \right)^2 \left( \frac{\partial \rho}{\partial x} \right)^2 \right\} + \eta \left( \frac{du}{dx} \right) . \quad (1)$$

The constant  $a_0$  is a universal constant appearing in the Dynamic Theory. If Eq. (1) is specialized to steady shocks and jump conditions,

$$\left. \begin{aligned} \rho u &= k_1 \\ k_1 u + \sigma &= k_2 \\ k_1^2 E - \frac{\sigma^2}{2} &= k_3 \end{aligned} \right\} \quad (2)$$

are used, then the total stress may be written as

$$\sigma_D = P + \left\{ \eta - \frac{k_1^2 P}{a_0^2 u^4} \left( \frac{du}{dx} \right) \right\} \left( \frac{du}{dx} \right) \quad (3)$$

If the coefficient of the velocity gradient is defined as the total effective viscosity, then it is

$$\eta_T = \eta - \frac{k_1^2 P}{a_0^2 u^4} \left( \frac{du}{dx} \right) \quad (4)$$

Thus the total viscosity, as given by the Dynamic Theory, will depend on the shock strength.

Using the second jump condition, an expression for the velocity gradient is

$$\frac{du}{dx} = \frac{a_0^2 U^4 \eta}{2k_1^2 P} \left\{ 1 - \sqrt{1 + \frac{4k_1^2 P}{a_0^2 u^4 \eta^2} [P - k_2 + k_1 u]} \right\} \quad (5)$$

which may be approximated by

$$\frac{du}{dx} \cong -\left(\frac{1}{\eta}\right) [P - k_2 + k_1 u] \left\{ 1 - \frac{k_1^2 P}{a_0^2 u^4 \eta^2} [P - k_2 + k_1 u] \right\} \quad (6)$$

The effect of the correction term on the velocity gradient is seen in Eq. (6), because the multiplicative factor outside the brackets is the classical expression for the velocity gradient. The effect of the correction term lessens the negative velocity gradient and extends the shock front.

The effect of the correction term in Eq. (4) is estimated by considering the strong shock dependence of pressure upon shock velocities. For instance, the shock pressure, from the jump conditions, is

$$P = \rho_0 U u_p \quad (7)$$

If the shock velocity is related linearly to the particle velocity as

$$U = C_0 + S u_p \quad , \quad (8)$$

then Eq. (7) becomes

$$P = \frac{\rho_0 U}{S} (U - C_0) \quad . \quad (9)$$

Thus, for strong shocks, P varies approximately as the square of the shock velocity.

Consider Eq. (5) or Eq. (6). From either of these equations, the velocity gradient varies as the square of the shock velocity. Using these two conclusions in Eq. (4) for the total viscosity  $\eta_T$  and remembering that the integration constant  $k_1$  is

$$k_1 = - \rho_0 U \quad ,$$

the total viscosity varies approximately as the square of the shock velocity or, essentially, as the pressure.

The conclusion is that if the total viscosity varies with the pressure, an increase in pressure by a factor of  $10^3$  must be accompanied by a viscosity increase by the same factor of  $10^3$ . This explains the apparent discrepancy between the low- and high-pressure aluminum viscous effects. For instance, the Asay-Bertholf limits are

$$\begin{array}{ll} P = 25 \text{ GPa} & \eta > 40 \text{ P} \\ P = 36 \text{ GPa} & \eta < 2500 \text{ P} \end{array} \quad .$$

Another experiment<sup>5</sup> places an upper limit of  $10^3$  P for a shock pressure of 40 GPa. If  $10^2$  P is considered representative of the viscosity when  $P \cong 10$  GPa, then from Eq. (4), a pressure of  $10^3$ - $10^4$  GPa must be accompanied by a viscous effect of  $10^4$ - $10^5$  P.

This total viscosity estimate is supported by numerical integration across the shock front using the Tillotson equation of state for aluminum. The classically predicted risetimes for shocks of 40 GPa with  $\eta = 575$  P and  $5 \times 10^3$  GPa with  $\eta = 5 \times 10^4$  P are duplicated by using the total viscosity expression in Eq. (4) with  $\eta \cong 1.0$  P and  $a_0 \cong 365$  g/cm<sup>4</sup>.

Thus the Dynamic Theory correlates these data points that appear contradictory by classical theory. Further, these data points provide an estimate of the new universal constant appearing in the Dynamic Theory. This value of  $a_0$  provides an estimate of other predictions of the theory in fields other than shock waves.

### III. RATE OF MASS CONVERSION

In nuclear weapons and reactors, mass is converted into energy. However, Einstein's theory, which predicts the energy released in this conversion, says nothing about the rate at which this conversion can or does proceed. On the other hand, the Dynamic Theory not only provides an additional equation of motion that can be solved to find the mass conversion rate as a function of time, but it predicts a limiting rate of mass conversion. The question addressed here is: What is this limiting rate and how does it compare with experimentally achieved rates? If the experimental rates exceed the predicted limit, something is wrong. If, on the other hand, the predicted limiting rate is not seen experimentally, then its existence is still possible.

The Dynamic Theory provides a five-dimensional metric as the foundation for describing physical phenomena. In the Euclidean metric, the rate of change in the arc length is

$$\frac{dq_0}{dt} = \sqrt{1 - \frac{v^2}{c^2} - \frac{\dot{\gamma}^2}{a_0^2 c^2}} \quad , \quad (10)$$

where  $\gamma$  is the mass density.

The first two terms of Eq. (10) are seen in the Special Theory of Relativity, where the limiting aspect of the theory is imposed as  $dq_0/dt = 0$ . This same limitation, imposed by the Dynamic Theory, yields



$$\dot{\gamma}_{\max} = a_0 c \quad (11)$$

for a stationary system where  $v = 0$ .

If  $a_0$  is known, then Eq. (11) may be used to find the minimum time of converting mass into energy. To see this, consider

$$E = mc^2 \quad ; \quad (12)$$

thus the rate of energy conversion becomes

$$\frac{dE}{dt} = c^2 \frac{dm}{dt} \quad . \quad (13)$$

However, the mass may be found from

$$m = \int_{\tau} \gamma d\tau = \int_{\tau} \tau d\gamma \quad . \quad (14)$$

Putting the second expression of Eq. (14) into Eq. (13) gives

$$\frac{dE}{dt} = c^2 \tau \frac{d\gamma}{dt} \quad . \quad (15)$$

Using Eq. (11), the maximum rate of conversion is

$$\frac{d\epsilon}{dt}_{\max} = \frac{c^2}{\gamma} (a_0 c) = \frac{a_0 c^3}{\rho} \quad , \quad (16)$$

where  $\epsilon$  is the energy per unit of mass so that  $\tau$  becomes  $1/\gamma$ . Equation (16) determines the minimum time in which mass may be converted into energy, because

$$\Delta t_{\min} = \left( \frac{\gamma}{a_0 c^3} \right) \Delta \epsilon \quad . \quad (17)$$

As an example, consider uranium. The density is  $18.95 \text{ g/cm}^3$  and  $\epsilon$  is  $9 \times 10^3 \text{ J/g}$ . By using Eq. (17) and the value of  $a_0$  determined by the low- and high-pressure shock data, ( $a_0 = 365 \text{ g/cm}^4$ ), then for 1 g of uranium

$$\begin{aligned} \Delta t_{\min} &= \frac{(18.95 \text{ g/cm}^3)(9 \times 10^{13} \text{ J})}{(365 \text{ g/cm}^4)(3 \times 10^{10} \text{ cm/s})^3} \\ &= 1.731 \times 10^{-12} \text{ s} \end{aligned}$$

Thus the fastest a gram of uranium may be converted into energy is 1.7 ps. This time is very short; considering that this time is several orders of magnitude larger than the minimum time possible for the fissioning of one atom, there is no reason to rule out the estimate of the constant  $a_0$ .

#### IV. ELECTROMAGNETICALLY CONTAINED IONIZED PLASMAS

Controlled-fusion programs use variations of electromagnetic containment of ionized plasmas. The Dynamic Theory predicts forces on these plasmas and pressures generated that are important to various fusion programs.

The five-dimensionality of the theory provides an additional equation of motion that becomes effective when mass is no longer conserved. Thus the theory may offer a better description of the actual fusion process than current theories do. Any implications of the theory using this additional equation of motion during actual mass conversion have not been explored yet.

On the other hand, conservation of mass embeds a four-dimensional hypersurface in the five-dimensional space and provides two implications for fusion systems before mass conversion. Both derive from the fact that within the Dynamic Theory the energy-momentum tensor for matter under the influence of electromagnetic fields has two parts. The first part is the relativistic energy-momentum tensor, and the second part contains the geometric properties of the embedded hypersurface.

The first implication for fusion systems lies in the additional forces that must be considered a result of this geometric term in the energy-momentum tensor. These forces also depend on the density gradient, as does the viscosity in shocked materials; namely, the geometric forces are

$$F_{\text{geo}}^u = - \frac{4 \pi}{c^2} (h^{\mu\nu} \epsilon)_{,\nu} \quad (18)$$

$$\text{where } h^{\mu\nu} \equiv \left( \frac{-1}{a_0^2} \right) \left( \frac{\partial \gamma}{\partial x^\mu} \right) \left( \frac{\partial \gamma}{\partial x^\nu} \right) ,$$

and  $\epsilon$  is the electromagnetic energy density given by

$$\epsilon = \frac{1}{8\pi} (E^2 + B^2) .$$

Because these forces have the multiplicative factor of  $(a_0 c)^{-2}$ , the density gradient components must be large before they are evident.

The geometric term in the energy-momentum tensor also predicts reduced pressures in the plasma as a result of electromagnetic pressure. The pressure given by the Dynamic Theory is

$$P_D = \frac{\epsilon}{3} \left\{ 1 - \left( \frac{1}{a_0^2} \right) \left[ \left( \frac{\partial \gamma}{\partial x^1} \right)^2 + \left( \frac{\partial \gamma}{\partial x^2} \right)^2 + \left( \frac{\partial \gamma}{\partial x^3} \right)^2 \right] \right\}$$

or, because the classical pressure is  $P_c = \epsilon/3$ , the Dynamic Theory's pressure becomes

$$P_D = P_c \left\{ 1 - \left( \frac{1}{a_0^2} \right) \left[ \left( \frac{\partial \gamma}{\partial x^1} \right)^2 + \left( \frac{\partial \gamma}{\partial x^2} \right)^2 + \left( \frac{\partial \gamma}{\partial x^3} \right)^2 \right] \right\} . \quad (19)$$

Note that the Dynamic Theory predicts a reduction in the pressure dependent on the mass density gradient. The value of the constant  $a_0$  determined previously by the shock data indicates that a density gradient of  $36.5 \text{ g/cm}^4$  could produce a 10% pressure reduction.

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