L.G.Philippenko

Preprint of the article
" The Shock Heat Transference"

I. Contemporary industry needs for the such technologies of transformation of the materials for which it is necessary exceptionally high pressures and temperatures (for example graphite $\rightarrow$ diamond, deuterium $\rightarrow$helium). In ordinary earthly conditions this parameters can be arrived at the Shock Waves (SW). None the less desirable technology effects so far had not be achieved. The diamonds turns out well only as the fine powder; the reaction deuterium $\rightarrow$ helium – the thermonuclear reaction – for industrial utilization is not realized so far.
The experimental searches of the solution of these problems are lasting decades. For their realization are attracted the leading scientists – specialists in this field; are attracted the powerful collectives of excellent engineers; expenditures are formed billions dollars. Are attempted the lot of a wonderful by resourceful (and by wit) experimental methods. But visible results are absent. This negative result leads to inevitable conclusion: the reason lies deeply than in deficiencies or scarcities of equipment's or than experimental errors.
Experimenters plans their experiment by proceed from the having at them the theoretical ideas about the process which is investigated – from the accessible to them a theory of phenomenon; from the same ideas (the same theory) they proceed when think over its results. Therefore in first turn it is necessary to control the adequacy of the everywhere using contemporary theory, by which are influenced experimenters in their work.

II. Any motion in a material environment (here is considered as a continuum) take place in the conformity with a three basis laws of conservation: the mass, the impulse and the energy. By them it are determined the boundary conditions on SW, which in contemporary theory are wrote as so called the Rankine – Hugoniot (R.-H.) system of equations:

$$\begin{aligned} \upsilon / V &= \upsilon_0 / V_0; \\ p &= p_0 + (V_0 - V)(\upsilon_0 / V_0)^2; \\ \varepsilon - \varepsilon_0 &= \tfrac{1}{2}(p + p_0)(V_0 - V); \end{aligned} \qquad (1)$$

here υ, p, V and ε - the normal to the shock rupture component of mass velocity, the pressure, the specific volume and the specific inner energy respectively directly behind of shock rupture, and υ_0, p_0, V_0 and ε_0 - the same parameters but directly in front of it [1,2,3] *. If the tensor of stresses $\mathbf{P}$ is not spherical,

$$p = -P_{nn} \; ; \qquad (2)$$

the $\vec{n}_s$ is a normal vector to SW **.
The standard form of energy equation is:

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* The values of p , V , υ and ε are obtained by limit passage from $x < x_s$ to $x = x_s$, and the values of p_0, V_0 , υ_0 and ε_0 - by limit passage from $x > x_s$ to $x = x_s + 0$; here $x_s = Const.$ - the coordinate of shock rupture in the system of coordinate connected with a SW.

** If $\vec{D}$ - the velocity of SW along the substance in front of it, then $\vec{n}_s \bullet \vec{D} > 0$

$$\Delta\varepsilon = \Delta Q + \Delta w \quad , \tag{3}$$

where ΔQ - the quantity of heat by which the material particle exchanges with its encirclement while it is realized the work Δw. The Hugoniot equation $(1)_3$ means that in contemporary theory for all SW: with any amplitudes, in any materials, under any other conditions, - the shock deforming of the particle is assumed as an adiabatic one, $\Delta Q = 0$. No had been published works making more precise or detailed of this theory does not went out from this adiabatic hypothesis: the Hugoniot equation remains as a basis equation in all cases.
As far as D is not less than the sound velocity, the substance in front of SW remains not mechanical disturbed. In view of $\Delta Q = 0$ it remains not disturbed at all, and its state remains the same to that while the wave was absent. Provided that are absent the strange sources of excitement, it signifies:

$$\begin{aligned} p(x = x_s + 0) &\equiv p_0 = p_\infty \equiv p(x \to \infty), \\ V(x = x_s + 0) &\equiv V_0 = V_\infty \equiv V(x \to \infty) \ , \\ \varepsilon(x = x_s + 0) &\equiv \varepsilon_0 = \varepsilon_\infty \equiv \varepsilon(x \to \infty), \end{aligned} \tag{4}$$

and so for other parameters [1,2,3].
In the materials without of the heat conductivity the adiabatic character of the any waves is inevitable; in the real materials it becomes dubious. The changing the parameters of motion along axis Ox (here it is assumed that Ox had been directed along $\vec{n}_s$) leads to the changing of heat stream $q(x,t)$; the power of heat sources $\aleph \equiv div\vec{q}$ increases with an increasing of the gradients p , V . . . On the rupture, as on the limit of succession of continuous waves with an equal amplitudes and decreasing thickness $h \to 0$, $\aleph \to \infty$, and it is incompatible with the assumption about of adiabatic character of SW ; this assumption is found valid only if the deformations are elastic in every waves from succession (and, consequently, in their limit form – shock rupture, $h = 0$), because an adverse effect of the elastic deformations is incompatible with $div\vec{q} \neq 0$ [4].
The properties of the adiabatic SW (with $\Delta Q = 0$) – which only are examined in a contemporary theory, having the Hugoniot equation as the only basis equation on energy conservation law - are determined on the base of following suggestion.

Suggestion. If the Hugoniot equation is valid (that is, really express by itself the energy conservation law) on the shock wave, then its velocity along the substance D not depends from the amplitude of the wave and is equal to the adiabatic velocity of sound in this material in front of wave:

$$D = -\upsilon_0 = c_0 \tag{5}$$

The proof of this suggestion was for the first time published in the article [5] * . The strict detailed analysis of the properties of adiabatic shock waves (on which the Hugoniot equation is legitimate) had been fulfilled in [5] and in the monograph [6]. It was proved: only waves in which deforming of the matter is elastic one can be the adiabatic waves – and, consequently, only on the elastic waves can be legitimate the Hugoniot equation. It is fully naturally: the Hugoniot equation $(1)_3$ is a particular case of an adiabatic energy equation $\Delta\varepsilon = \Delta w$, which came

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* See hyperreference “The consequences from the Hugoniot equation” on this site.

from (3) with $\Delta Q = 0$. In all such cases the work of deforming is the function of state ($dw = d\varepsilon$ is the full differential). Therefore it depends only from the initial and final states of the particle, and not depends from the way of transition, that is from the profile of the wave: in the waves with any profiles, which have the same initial and final states, the work Δw will be one and the same in the shock or continuous, compressing and stretching or stretching and compressing waves. It means the mutual simple dependence between the strains and deformations tensors which does not contain any other variables. It is possible only in the elastic materials; in the thermodynamics this circumstance is known long ago. In essence the had been proved **Suggestion** occurs as a yet one illustration of this thermodynamics fact.

III. The most significant consequence from the had been proved **Suggestion** is: the not adiabatic Shock Waves for which $\Delta Q \neq 0$, $D > c_0$, and Hugoniot equation is incompetent, exist. More than that: any shock wave the velocity of which along the substance in front of it exceeds the sound velocity is without fail not adiabatic one, in it $\Delta Q \neq 0$, and Hugoniot equation is incompetent for it: for it is competent general equation (3) (later on instead of ΔQ we will use, bear in mind the shocking character of deformations, symbol $\hat{Q}$ for the specific value of ΔQ).

The appearance of $\hat{Q} \neq 0$ in equation (3) for SW means the setting of the existence of the special natural phenomenon, had not been described in a literature before – the **Shock Heat Transference** (SHT) – it also can be named as "Shock Heat exchange"; it displace himself only when shock deformations are not elastic. Within an infinitesimal time period of intersection of shock front, the infinitesimal particle is in time to exchange with around material by certain (not small!) specific quantity of heat $\hat{Q}$: the heat transference take place not gradually but by jump. In the essence only just non adiabatic shock waves – with the Shock Heat Transference – are worthy be named as genuine Shock Waves.

Existence of SHT leads to necessity of introduction the principle correctives in the fundamental theory of shock waves; this work was fulfilled in the monograph [6]. Here we shall mention only two from them.

-- Just the SHT is a reason of the curvature of graphs $p = p(V)$ - the "shock curves" – which were measured in experiments on the sufficiently strong SW *. From a such shock curves it is impossible to determine the "energy's equation of state" $\varepsilon = \varepsilon(p,V)$ by the way in general use, because of from not adiabatic shock curve it is possible by that way to determine only the sum $(\varepsilon - \hat{Q})$ which is not any function of state. Contemporary experimenters take this sum as a function of state $\varepsilon(p,V)$ only because of they does not know another theory besides of in general use adiabatic one.

-- Any share (or the whole) of heat $\hat{Q}$ are transferenced to the material in front of SW. Therefore p_0, V_0 and ε_0 directly in front of not adiabatic SW does not coincide already with a p_∞, V_∞ and ε_∞ far ahead from SW , as it was in the adiabatic SW, but appears the functions of amplitude significances p, V, and also from p_∞, V_∞ (so far as such function is $\hat{Q}$). Therefore

* At the adiabatic – elastic – shock waves this graph is a linear one: it was shown in [5,6] and illustrate by experiments. Just so – linear – graph is a genuine "shock adiabat".

the point (p_0, V_0) at not adiabatic SW ($\hat{Q} \neq 0$) already is not found on the crooked shock curve. Thus it lose of the sense the in general used ways of the graphic calculation the velocity of SW and also distribution of energy on the kinetic and inner parts.

IV. The fundamental conclusions for SW lead from the second principle of thermodynamics. Contemporary theory in this cases essentially refers to the Zemplen theorem:

$$\Delta s = -\frac{1}{12T_0}\left(\frac{\partial^2 p}{\partial V^2}\right)_{s,V=V_0}\left(\Delta V\right)^3 \qquad \Delta V \equiv V - V_0 \ , \tag{11}$$

where s is the specific entropy, T - temperature.

So far as by inference of (11) it essentially use the Hugoniot equation, this theorem is useful only for adiabatic SW. But on account of elasticity of deformations in a such SW, $\Delta s = 0$, and on account of linearity of shock adiabat, $\left(\partial^2 p / \partial V^2\right) = 0$, so that theorem (11) as a matter of fact signifies $0 = 0$*.
On the characteristics of not elastic SW decisive influence renders the SHT.
The right expression for the change of entropy on SW, suitable for any SW in any materials, we obtain from the second principle of thermodynamics [4]:

$$ds = d_e s + d_i s,$$
$$d_e s = dQ / T, \qquad d_i s \geq 0 \, ; \tag{12}$$

here $d_e s$ - the change of entropy owing to interaction with the outward bodies, $d_i s$ - owing to inner processes in material of the particle. By multiply it on T and integrate (in according to Lebesgue) from t_0 (the moment of time when the particle arrive at coordinate x_0) to t_s (when $x = x_s$), we obtain

$$T\left(t_s\right)\Delta s = \hat{Q} + T\left(t_s\right)\Delta_i s,$$

so that

$$\Delta s \equiv s - s_0 = \hat{Q} / T\left(t_s\right) + \Delta_i s \tag{13}$$

As it seen from (13), the second principle of thermodynamics does not difference between a pressing and stretching SW; therefore later on we will bear in mind either.
Let the SW is an adiabatic one: $\hat{Q} = 0$. Then $d_e s = 0$, and as $ds = 0$ from an elastic character of wave, $d_i s = 0$ also: in adiabatic SW it cannot be carried out no dissipated processes (as for example viscosity)*.
Let now the deformations are not elastic, SHT take place: the SW is not adiabatic one. The inner change of entropy which is stipulated with a viscosity and chemical reactions is defined from a differential equation [6] :

$$\frac{d_i s}{dt} = \frac{V}{T}\mathbf{P}' \bullet\bullet\, grad\vec{\upsilon} - \frac{1}{T}\sum_k \mu_k dg_k / dt \, , \tag{14}$$

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* The detailed analysis of this theorem see in [6].
* What, strictly speaking, follow directly from the definition of the such processes; see for example [7].

where $\mathbf{P}'$ - the tensor of viscosity strains, μ_k and g_k - the chemical potential and the mass portion of k – st chemical component. For the straight plain SW in an inertial coordinate system OXYZ (axes $OX \uparrow\uparrow \vec{n}_s \uparrow\uparrow Ox$, U - the velocity of particle along OX) the equation (14) with register the mass conservation is wrote :

$$Td_i s / dt = \eta\left(\partial U / \partial X\right)\left(dV / dt\right) - \sum_k \mu_k dg_k / dt \quad ^{**} \tag{15}$$

By integrate (15) from t_0 to t_s, we obtain

$$T\Delta_i s = \eta\left(\partial U / \partial X\right)\left(\Delta V\right) - \sum_k \mu_k \Delta g_k \tag{16}$$

Let us consider the conclusions from this equation. The changing of the amplitude of SW is the result of influence of the matter which is direct behind of it front: the amplitude increase if $\left|p - p_0\right|_{x<x_s} > \left|p - p_0\right|_{x_s}$, and decrease in adverse effect. In a pressing SW it means that with the increasing amplitude $\left(\partial U / \partial X\right) < 0$ at $X = X_s\left(t\right)$ (the back layers of matter runs over the shock front). In a stretching SW we like this obtain $\left(\partial U / \partial X\right) > 0$ on $X = X_s\left(t\right)$, if the amplitude increase (this layers runs away from the front the faster the further from the front its are found; here $\vec{U} = -\vec{n}_s U = \vec{e}_X U$). Decreasing of the amplitude is accompanied with $\left(\partial U / \partial X\right) > 0$ at pressing and $\left(\partial U / \partial X\right) < 0$ at stretching on the rupture $X = X_s\left(t\right)$. At last, if the SW is stationary then also stationary will be the motion behind its front , and $\left(\partial U / \partial X\right) = 0$ at $X \le X_s\left(t\right)$. Thus the viscous share of $\Delta_i s$ depends not only from the sign of ΔV but also from the direction of change of the SW amplitude (from the sign of derivative $d\left|p\right| / dt$). When an amplitude of SW (pressing or stretching – with indifference) increase, the contribution from viscosity in $\Delta_i s$ is positive one, so that such SW all are thermodynamically permissible (with $\sum_k \mu_k \Delta g_k = 0$). At the decreasing of the amplitude the product $\left(\partial U / \partial X\right)\left(\Delta V\right)$<0 , also with indifference from the sign $\left(\Delta V\right)$: the existence of not adiabatic SW (both pressing and stretching) at the decreasing of its amplitude is permissible only if negative investment in $\Delta_i s$ from the viscosity is compensated from positive investment at the expense of change the inner structure of matter. If the matter have only 1 had not been changed component (as in graphite or deuterium at insufficient high T), the existence of non adiabatic SW with a decreasing amplitude is not permissible: such a wave, even if it will arise, instantly will lose its shock nature and turns into the ordinary continuous wave.

Let now examine the spherical meeting pressing SW with k=Const.=1: $\vec{U} = \vec{n}_s U = -\vec{e}_r U$,

$$T\left(d_i s / dt\right) = V\mathbf{P}' \bullet\bullet grad\,\vec{U} \tag{17}$$

By writing (17) in a spherical coordinates and integrating on $\left[t_0, t_s\right]$ we obtain

$$T\Delta_i s = \eta\left(\frac{\partial U_r}{\partial r} + \frac{2U_r}{r}\right)\left(\Delta V\right) \quad ^{[6]} \tag{18}$$

The first item in a brackets equals to $\left|\partial U / \partial r\right|$; at the gases it is small and the shock character of the meeting pressing wave is thermodynamic permissible already at relatively large r . At the

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** The strict inference and detailed analysis of this equation see in [6].

solid materials and fluids this item is considerably greater and the meeting pressing wave may take for a shock character only at small r. But will such transition of wave (from continuous to shock) be took place or will not - it depends from the sign of parameter Γ which had been investigated in [6]; in examined conditions

$$\Gamma = -\left(d^2 p / dV^2\right)\left(\partial V / \partial r\right) \tag{19}$$

so that possibility of such transition depends on the mechanical properties of the material and on the profile of the (continuous at large r) wave.

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