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FALSIFICATIONS OF THE ENERGY BALANCE EQUATION, PUASSON ADIABATS AND LAPLACE SOUND SPEED

Abstract. The falsity of the energy balance equation with a specific heat capacity coefficient at constant pressure, the fake Poisson adiabat, and the fake Laplace formula of adiabatic sound velocity are established. Universal formulas of adiabatic ideal gas and sound velocity are proposed and substantiated. Bibl.10.

Keywords: equation, sound, heat capacity, adiabat, isobaric.

1. Falsifications of the heat equation with specific coefficient of heat capacity at constant pressure

Scalar product of the equation of dynamics

$$\rho\frac{d\mathbf{v}}{dt}=\rho\mathbf{F}+\frac{\partial\mathbf{p}_x}{\partial x}+\frac{\partial\mathbf{p}_y}{\partial y}+\frac{\partial\mathbf{p}_z}{\partial z}+\mathbf{f}$$

on speed gives kinetic energy equation

$$\rho\frac{d\mathbf{v}}{dt}\cdot\mathbf{v}=\rho\mathbf{F}\cdot\mathbf{v}+\frac{\partial\mathbf{p}_x}{\partial x}\cdot\mathbf{v}+\frac{\partial\mathbf{p}_y}{\partial y}\cdot\mathbf{v}+\frac{\partial\mathbf{p}_z}{\partial z}\cdot\mathbf{v}+\mathbf{f}\cdot\mathbf{v}, \tag{1.1}$$

which is part of the energy balance equation

$$\rho\frac{d}{dt}(E+|\mathbf{v}|^2/2)=\rho\mathbf{F}\cdot\mathbf{v}+\mathbf{f}\cdot\mathbf{v}+\frac{\partial}{\partial x}\mathbf{p}_x\cdot\mathbf{v}+\frac{\partial}{\partial y}\mathbf{p}_y\cdot\mathbf{v}+\frac{\partial}{\partial z}\mathbf{p}_z\cdot\mathbf{v}-\nabla\cdot\mathbf{q}+\rho Q,$$

as can be seen from the following:

$$\rho\frac{dE}{dt}+\rho\frac{d\mathbf{v}}{dt}\cdot\mathbf{v}=\rho\mathbf{F}\cdot\mathbf{v}+\mathbf{f}\cdot\mathbf{v}+\frac{\partial\mathbf{p}_x}{\partial x}\cdot\mathbf{v}+\mathbf{p}_x\cdot\frac{\partial\mathbf{v}}{\partial x}+\frac{\partial\mathbf{p}_y}{\partial x}\cdot\mathbf{v}+\mathbf{p}_y\cdot\frac{\partial\mathbf{v}}{\partial y}+$$
$$+\frac{\partial\mathbf{p}_z}{\partial z}\cdot\mathbf{v}+\mathbf{p}_z\cdot\frac{\partial\mathbf{v}}{\partial z}-\nabla\cdot\mathbf{q}+\rho Q$$

The abbreviation for (1.1) leads to the equation

$$\rho\frac{dE}{dt}=\mathbf{p}_x\cdot\frac{\partial\mathbf{v}}{\partial x}+\mathbf{p}_y\cdot\frac{\partial\mathbf{v}}{\partial y}+\mathbf{p}_z\cdot\frac{\partial\mathbf{v}}{\partial z}-\nabla\cdot\mathbf{q}+\rho Q$$

from which for the internal energy $dE=c_v dT$ and according to the Fourier law $\mathbf{q}=-\lambda\nabla T$ we obtain various representations of the heat equation, respectively, to the stress tensors.

With asymmetric stress tensor for Newton's law of friction:

$$\rho c_v \frac{dT}{dt} = \nabla \cdot (\lambda \nabla T) - p\nabla \cdot \mathbf{v} + \mu \sum_{i=1}^{3}\sum_{j=1}^{3}(\frac{\partial v_i}{\partial x_j})^2 + \rho Q$$

with an asymmetric tensor of the Jakupov [9-10] friction law:

$$\rho c_v \frac{dT}{dt} = \nabla \cdot (\lambda \nabla T) - p\nabla \cdot \mathbf{v} + \sum_{j=1}^{3}\sum_{i=1}^{3}\frac{\alpha\mu}{m_i^{m_i-1}}\frac{\partial v_i^{m_i}}{\partial x_j}\frac{\partial v_i}{\partial x_j} + \rho Q, \ \alpha = 1(\frac{cek}{м})^{m_i-1}$$

and the heat equation with the symmetric Stokes stress tensor [1-8]:

$$\rho c_v \frac{dT}{dt} = \nabla \cdot (\lambda \nabla T) - p\nabla \cdot \mathbf{v} + \frac{\mu}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i})^2 - \frac{2}{3}\mu(\nabla \cdot \mathbf{v})^2, \tag{1.2}$$

which is false due to the falseness of the Stokes stress tensor [9-10].

Let us pay attention to the fact that these equations include the coefficient C_v of the specific heat capacity of a gas with a constant volume, according to the 1st law of thermodynamics.

In addition to the fact that the heat conduction equation is fake according to the Stokes friction law, the tendency to transform into an equation with the specific heat coefficient of gas C_p at constant pressure [1–9] is well known.

Specifically, Lykov (see [3] p. 32) gives the following equation:

$$\rho c_p \frac{dT}{dt} - \frac{dp}{dt} = \lambda \nabla^2 T + \frac{\mu}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i})^2 - \frac{2}{3}\mu(\nabla \cdot \mathbf{v})^2 \tag{1.3}$$

For the derivation, the universal gas constant and the Clapeyron-Mendeleev state equation are used

$$c_p - c_v = R, \ \ p = \rho RT \tag{1.4}$$

Using (1.4) in the error equation (1.2), substitutions are made

$$c_v T = (c_p - R)T = c_p T - RT = c_p T - \frac{p}{\rho},$$

$$\rho c_v \frac{dT}{dt} = \rho(c_p \frac{dT}{dt} - \frac{d}{dt}\frac{p}{\rho}) = \rho[c_p \frac{dT}{dt} - \frac{1}{\rho^2}(\rho\frac{dp}{dt} - p\frac{d\rho}{dt})] =$$

$$= \rho c_p \frac{dT}{dt} - \frac{dp}{dt} + \frac{p}{\rho}\frac{d\rho}{dt}$$

where by the continuity equation $\frac{1}{\rho}\frac{d\rho}{dt} = -\nabla \cdot \mathbf{v}$. Therefore

$$\rho c_v \frac{dT}{dt} = \rho c_p \frac{dT}{dt} - \frac{dp}{dt} + \frac{p}{\rho}\frac{d\rho}{dt} = \rho c_p \frac{dT}{dt} - \frac{dp}{dt} - p\nabla \cdot \mathbf{v}$$

Substitution in the equation (1.2) gives

$$\rho c_p \frac{dT}{dt} - \frac{dp}{dt} - p\nabla \cdot \mathbf{v} = \nabla \cdot (\lambda \nabla T) - p\nabla \cdot \mathbf{v} + \frac{\mu}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i})^2 - \frac{2}{3}\mu(\nabla \cdot \mathbf{v})^2$$

After contractions and rearrangements, the equation is obtained

$$\rho c_p \frac{dT}{dt} = \nabla\cdot(\lambda\nabla T) + \frac{dp}{dt} + \frac{\mu}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}\right)^2 - \frac{2}{3}\mu(\nabla\cdot\mathbf{v})^2 \tag{1.5}$$

For constant thermal conductivity coefficient $\lambda = const$ equation (1.5) goes over to the Lykov equation (1.3).

Theorem. The equation of heat conduction with the coefficient of specific heat capacity of gas at constant pressure

$$\rho c_p \frac{dT}{dt} = \nabla\cdot(\lambda\nabla T) + \frac{dp}{dt} + \frac{\mu}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}\right)^2 - \frac{2}{3}\mu(\nabla\cdot\mathbf{v})^2$$

is fake in flows with variable pressure, as formula C_p - Cv = is valid only for constant pressure p = const.

Evidence. The 1st law of thermodynamics is attracted [7]:

$$d'Q = dE + pdV \tag{1.6}$$

In an ideal gas $dE = c_v dT$, c_v is the coefficient of specific heat of gas at a constant volume. Between the specific volume V and the density of the gas there is a connection $V = \frac{1}{\rho},\ dV = d(\frac{1}{\rho})$.

Therefore, the 1st law is used in the form [1]:

$$d'Q = c_v dT + pd(\frac{1}{\rho}),\ d'Q = c_v dT + pd(\frac{RT}{p}) \tag{1.7}$$

Let the heat be supplied to the gas at a constant volume of $V = const$. Since $dV = 0$ in this case it follows from (1.6) $d'Q = dE = c_v dT$.

Let heat be supplied to gas $d'Q = c_p dT$ with constant pressure $p = const$.

The 1st law of thermodynamics (1.7) is converted to the form

$$c_p dT = c_v dT + pd(\frac{RT}{p}),\ (c_p - c_v)dT = p\frac{pd(RT) - RTdp}{p^2},$$

$$(c_p - c_v)dT = RdT - RT\frac{dp}{p},\ p = \rho RT$$

Dividing the last equality by dT we obtain the following formula for a universal gas constant:

$$R = c_p - c_v + \frac{1}{\rho}\frac{dp}{dT}, \tag{1.8}$$

At constant pressure $p = const,\ dp = 0$ from (1.8) we get the formula widely used in gas dynamics [1-9]:

$$R = c_p - c_v \tag{1.9}$$

By virtue of (1.8) in non-isobaric gas flows with variable pressure $p \neq \text{const}$, $dp \neq 0$, there will always be inequality $R \neq c_p - c_v$!

This axiom is also evident from the 1st law of thermodynamics

$$d'Q = c_v dT + pd(\frac{RT}{p}),\ d'Q = c_v dT + p\frac{pd(RT) - RTdp}{p^2},$$

$$d'Q = c_v dT + RdT - RT\frac{dp}{p}, \quad d'Q = c_v dT + RdT - \frac{1}{\rho}dp$$

For universal constant gas, dividing the last expression on the temperature differential, we get the formula

$$R = \frac{d'Q}{dT} - c_v + \frac{1}{\rho}\frac{dp}{dT} \qquad (1.10)$$

It is obvious, by virtue of equality (1.10), that in non-isobaric flows of gas with variable pressure $p \neq \text{const}, \ dp \neq 0$, inequality

$$R \neq c_p - c_v!$$

Consequently, the heat conduction equation with a coefficient C_p of the specific heat of a gas at constant pressure is false, since it is obtained for connection $Cp - Cv = R$, which does not hold for variable pressure $p \neq const.$

What was required to prove.

2. Falsifications of Poisson adiabat

In the dynamics of an ideal gas, a false heat equation (1.5) for enthalpy $h = c_p T, \ \lambda \equiv 0, \ \mu \equiv 0$ takes the form (see [1] p. 115):

$$\rho c_p \frac{dT}{dt} = \frac{dp}{dt}, \quad \rho\frac{dh}{dt} = \frac{dp}{dt}, \qquad (2.1)$$

therefore, it is also false.

Reducing the differential in time gives the connection

$$dp = \rho c_p dT \qquad (2.2)$$

From the fake equation (2.2), converted to Form $\frac{dp}{\rho} = c_p dT$, again using $R = c_p - c_v$, which is valid only for constant pressure, the Poisson adiabat is displayed (see Loitsyansky [1] p.115):

$$\frac{dp}{\rho} = c_p dT = \frac{c_p}{R}d(RT) = \frac{c_p}{c_p - c_v}d(\frac{p}{\rho}), \quad \frac{dp}{\rho} = k\frac{d\rho}{\rho}, \quad \frac{p}{p_0} = (\frac{\rho}{\rho_0})^k, k = \frac{c_p}{c_v}$$

Calculate the pressure differential using the Clapeyron-Mendeleev equation of state $p = R\rho T$:

$$dp = \rho RdT + TRd\rho$$

Similarly, assuming in this ratio $R = c_p - c_v$, just used to derive the Poisson adiabat, we get the true value of the pressure differential

$$dp = \rho(c_p - c_v)dT + TRd\rho,$$

whose transformed expression

$$dp = \rho c_p dT - \rho c_v dT + TRd\rho, \quad \frac{dp}{dt} = \rho\frac{dh}{dt} - \rho c_v\frac{dT}{dt} + TR\frac{d\rho}{dt} \qquad (2.3)$$

does not coincide with the differential (2.2) and equation (2.1) !!!

The difference between (2.2) and (2.3) is not equal to zero:

$$-\rho c_v dT + TRd\rho \neq 0$$

Consequently, the differential pressure $dp = \rho c_p dT$ (2.2), corresponding to a fake heat equation with a heat capacity coefficient at constant pressure is also fake.

The falsity of equations (2.1) is proven again.

Proved inequality $\rho \frac{dh}{dt} \neq \frac{dp}{dt}$!

From fake equality $\rho \frac{dh}{dt} = \frac{dp}{dt}$, the Poisson adiabat [1] is derived, consequently, the Poisson adiabat is also fake !!!

As is known, the Poisson adiabat is widely used in gas dynamics, for example, when calculating the propagation velocity of small perturbations, i.e. speed of sound.

3. Falsification of the speed of sound of Laplace

On the basis of the equation of Clapeyron –Mendeleeva Newton derived the isothermal speed of sound

$$a = \sqrt{\frac{\partial p}{\partial \rho}} = \sqrt{\frac{\partial(\rho RT)}{\partial \rho}} = \sqrt{RT}, \; a = \sqrt{\frac{p}{\rho}}$$

Laplace proposed to use the Poisson adiabat $p = p_0 (\frac{\rho}{\rho_0})^k$:

$$a = \sqrt{\frac{\partial p}{\partial \rho}} = \sqrt{\frac{\partial}{\partial \rho}(p_0 (\frac{\rho}{\rho_0})^k)} = \sqrt{k\frac{p}{\rho}}, \; a = \sqrt{kRT} \quad (3.1)$$

Connection $R = c_p - c_v$ takes place only for constant pressure $p = const$, therefore, the Laplace formula (3.1) is not only adiabatic, but also isobaric sound speed.

Consequently, due to the falsity of the Poisson adiabat, it is logical to consider the formula (3.1) to be the adiabatic and isobaric Laplace sound velocity as fake.

Using a fake link $\rho c_p dT = dp$ and the equation of state Clapeyron-Mendeleev, we organize the calculations:

$$\frac{dp}{\rho} = c_p dT = \frac{c_p}{R} d(RT) = \frac{c_p}{R} d(\frac{p}{\rho}), \; \frac{c_p}{R} d(\frac{p}{\rho}) = \frac{dp}{\rho}, \; \frac{c_p}{R} \cdot \frac{\rho dp - p d\rho}{\rho^2} = \frac{dp}{\rho},$$

$$\frac{c_p}{R} dp - \frac{c_p}{R} \cdot p \frac{d\rho}{\rho} = dp, \; (\frac{c_p}{R} - 1) dp = \frac{c_p}{R} \cdot p \frac{d\rho}{\rho}, \; (\frac{c_p}{R} - 1) \frac{dp}{p} = \frac{c_p}{R} \frac{d\rho}{\rho},$$

$$\frac{c_p - R}{R} d\ln p = \frac{c_p}{R} d\ln \rho, \; d\ln p - \frac{c_p}{c_p - R} d\ln \rho = 0,$$

$$\ln \frac{p}{\rho^\chi} = const, \; \frac{p}{p_0} = (\frac{\rho}{\rho_0})^\chi, \; \chi = \frac{c_p}{c_p - R}$$

So, from the false connection $\rho c_p dT = dp$ we get the adiabat

$$\frac{p}{p_0} = (\frac{\rho}{\rho_0})^\chi, \; \chi = \frac{c_p}{c_p - R}, \quad (3.2)$$

which for $R = c_p - c_v$ goes to the Poisson adiabat.

Calculate the speed of sound:

$$a=\sqrt{\frac{\partial p}{\partial \rho}}=\sqrt{\frac{\partial}{\partial \rho}(p_0(\frac{\rho}{\rho_0})^{\chi})}=\sqrt{\frac{p_0}{\rho_0{}^{\chi}}\chi \rho^{\chi-1}}=$$

$$=\sqrt{\frac{p_0}{\rho}\chi(\frac{\rho}{\rho_0})^{\chi}}=\sqrt{\frac{c_p}{c_p-R}\frac{p}{\rho}}$$

So, for the speed of sound, the formula is obtained (also fake, as in Laplace)

$$a=\sqrt{\frac{c_p}{c_p-R}\frac{p}{\rho}},\ a=\sqrt{\frac{c_p}{c_p-R}RT},$$

which for $R=c_p-c_v$ goes to the Laplace formula (3.1).

4. Universal adiabatic sound speed

The 1st law of thermodynamics $d'Q=dE+pd(\frac{1}{\rho})$ in an adiabatic gas (heat is not removed and not supplied $d'Q=0$):

$$0=dE+pd(\frac{1}{\rho}),\quad dE=c_v dT \qquad (4.1)$$

According to the equation of state of Clapeyron-Mendeleev we find:

$$0=c_v dT+pd(\frac{1}{\rho}),\ 0=c_v d(\frac{p}{R\rho})-p\frac{d\rho}{\rho^2}$$

Next are the necessary conversions:

$$0=\frac{c_v}{R}\cdot\frac{\rho dp-pd\rho}{\rho^2}-p\frac{d\rho}{\rho^2},\ 0=\frac{c_v}{R}\cdot(\rho dp-pd\rho)-pd\rho,$$

$$0=\frac{c_v}{R}\cdot(\frac{dp}{p}-\frac{d\rho}{\rho})-\frac{d\rho}{\rho},\ \frac{c_v}{R}\cdot\frac{dp}{p}=(\frac{c_v}{R}+1)\frac{d\rho}{\rho},\ \frac{dp}{p}=(\frac{R}{c_v}+1)\frac{d\rho}{\rho}$$

From the last equality follows adiabata (Jakupov)*:

$$\frac{p}{p_0}=(\frac{\rho}{\rho_0})^{\zeta},\ \zeta=\frac{R}{c_v}+1$$

which for $R=c_p-c_v$, i.e. for constant pressure too goes to the Poisson adiabat.

So, the logic for the speed of sound is the formula (Jakupov)*

$$a=\sqrt{\frac{\partial p}{\partial \rho}}=\sqrt{(\frac{R}{c_v}+1)\frac{p}{\rho}},\ a=\sqrt{(\frac{R}{c_v}+1)RT},$$

which, for a constant pressure, when performing $R=c_p-c_v$, goes to the

Laplace formula (3.1).

Note. The barometric formula [7] $p = p_0 \exp(-\frac{Mgz}{RT})$ confirms the fact that even in a stationary atmosphere V = 0 pressure is a variable function.

* These adiabatic names and the universal formula for the speed of sound are necessary to emphasize novelty and differences from the Poisson and Laplace formulas.

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ПУАССОННЫҢ АДИАБАТАСЫНЫҢ, ЛАПЛАСТЫҢ ДЫБЫС ЖЫЛДАМДЫҒЫНЫҢ ЖӘНЕ ЭНЕРГИЯЛАР БАЛАНСЫНЫҢ ТЕҢДЕУІНІҢ ЖАЛҒАНДЫҚТАРЫ

Аннотация. Қысым тұрақтылықтығы, жылусыйымдылық еселеуіші бар энергиялар балансының жалғандығы, сонымен қатар Пуассонның адиабатысының және Лапластың дыбыс жылдамдығының кейіте-мелерінің қателіктері нақты дәлелделінген. Идеалдық газдардың адиабатасының кейіптемесі орнатылған, оған байланысты дыбыс жылдам- дығының жаңадан универсальдық тұрпаты негізделген. Библ.10.

Түйін сөздер: теңдеу, жылусыйымдылық, адиабата, изобарлық.

УДК 532.533

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ФАЛЬСИФИКАЦИИ УРАВНЕНИЯ БАЛАНСА ЭНЕРГИЙ, АДИАБАТЫ ПУАССОНА И СКОРОСТИ ЗВУКА ЛАПЛАСА

Аннотация. Установлены фальшивость уравнения баланса энергий с удельным коэффициентом теплоемкости при постоянном давлении, фальшивость адиабаты Пуассона и фальшивость формулы Лапласа адиабатической скорости звука. Предложены и обоснованы универсальные формулы адиабаты идеального газа и скорости звука. Библ.10.

Ключевые слова: уравнение, звук, теплоемкость, адиабата, изобарический.

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