

Confirmation of the First Law of Thermodynamics in Theory and Extended Bernoulli Equation

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Abstract

The internal energy change of ideal gas does not depend on the volume and pressure. The internal energy change of real gas has not any relation with the volume and pressure, which had been proved. If the internal energy change had not any relation with the volume and pressure, we could confirm the first law of thermodynamics in theory. Simultaneously, the internal energy change is the state function that shall be able to be proved in theory. If the internal energy change depended on the volume and pressure, we could not prove that the internal energy change is the state function and the chemical thermodynamics theory is right. The extended or modified Bernoulli equation can be derived from the energy conservation law, and the internal energy change, heat, and friction are all considered in the derivation procedure. The extended Bernoulli equation could be applied to the flying aircraft and mechanical motion on the gravitational field, for instance, the rocket and airplane and so on. This paper also revises some wrong ideas, viewpoints, or concepts about the thermodynamics theory and Bernoulli equation.

Keywords

First Law of Thermodynamics, Chemical Thermodynamics, Bernoulli Equation, Static Pressure Head, Friction

1. Introduction

Any spontaneous or realistic process has to obey the Clausius inequality [1] [2] [3] [4]. We know that the internal energy change of ideal gas does not depend on the volume and pressure. The internal energy change of real gas had been

proved to be the temperature function and without any relation with the volume and pressure by author [5]. The heat and work are taken as positive if the energy is supplied to the system and negative if the energy is lost out of the system. In a process, the heat, work, and internal energy change can transfer each other, but the relation of heat, work, and internal energy change has to obey the energy conservation law namely the first law of thermodynamics [6]-[11]. In the thermodynamics, the internal energy change is the state function, the heat and work are the path functions in many processes, but the heat or work might be the state functions in some special paths. The old equation calculating the internal energy change is given by

$$dU = C_V dT + \left[T \left(\frac{\partial p}{\partial T} \right)_V - p \right] dV, \quad (1)$$

where, U expresses the internal energy, T is thermodynamic temperature, p indicates pressure, V expresses volume. C_V is the heat capacity at the constant volume, and it is the temperature function. The subscript V indicates constant volume at the Equation (1). The internal energy change is the state function that might be proved by the ideal gas equation of state and van der Waals gas equation of state. It is impossible to prove that the internal energy change is the state function utilizing other gas equations of state in mathematics. Attentively, d is total differential symbols, ∂ is partial differential symbol.

The thermodynamics laws should be all able to be proven by mathematics or experiments, otherwise, thermodynamics theory is incorrect. Therefore, the old Equation (1) has some errors.

The Bernoulli equation will be extended or modified in the text, and it can be derived from the energy conservation law [12] [13] [14] [15], and it could explain or explore the real reasons why the particles or body can fly up to the sky.

2. Relations of Heat, Work, and Internal Energy Change

2.1. Relations between Reversible or Irreversible Paths in Theory

In a spontaneous or realistic process, the (B) and (A) express the realistic path and reversible path, respectively. The realistic paths may include the reversible or irreversible paths. $Q_r(A)$ and $W_r(A)$ are the heat and work in the reversible process, respectively. $Q_{real}(B)$ and $W_{real}(B)$ are the heat and work in the realistic process, respectively. For the gas, $Q_{pf}(B)$ and $W_{pf}(B)$ are originated by the friction and irreversible process. For the solids or liquids, $Q_{pf}(B)$ and $W_{pf}(B)$ are only caused by the friction. The friction does not exist in any reversible process. The follow equations derived from the Clausius inequality have to be obeyed [5] [16] [17] [18], they are as follows: $Q_r(A) \geq Q_{real}(B)$, $W_r(A) \leq W_{real}(B)$, and $Q_{pf}(B) = -W_{pf}(B) \leq 0$. Here, assuming that $Q_{real}(B) = Q_r(A) + Q_{pf}(B)$, $W_{real}(B) = W_r(A) + W_{pf}(B)$. If any work doesn't exist, the internal energy change is equal to the heat, hence, $Q_r(A) = Q_{real}(B)$, namely that, the heat is the state function at the moment. In any adiabatic

process, the internal energy change is equal to the work, consequently, $W_r(A) = W_{real}(B)$, namely that, the work is the state function at the moment. So that, the equality is for the identical reversible paths and special irreversible paths, the inequality is for the other irreversible paths. The reversible path (A) and its realistic path (B) are not arbitrary discovered by experiments, their initial state and final state have to be identical, furthermore, they must contain the same or similar processes (see **Figure 1**), for example, the isothermal process, constant pressure process, constant volume process, or adiabatic process. Otherwise, thermodynamics theory will be confusion and chaos. In **Figure 1**, T_i expresses the initial state temperature, T_f expresses the final state temperature, and T_{res} expresses the thermodynamics temperature of surroundings or reservoirs. Attentively, T_f and T_{res} might be different temperature in other non-isothermal processes.

2.2. Confirmation the First Law of Thermodynamics in Theory

In any spontaneous or realistic process, we always have [5] [18]

$$dU = C_v dT. \quad (2a)$$

For a matter in the same phase state, the internal energy change has to be equal to zero in any isothermal process. The Equation (2a) can be derived from the Clausius inequality. The real gases obey the Equation (2a) had been proven [5]. The ideal gas, real gases, liquids, and solids all obey the Equation (2a) too.

If a matter appears phase transition in the isothermal process, the following equation will be given by

$$\Delta U = \int_f C_v dT - \int_i C_v dT = C(f) - C(i), \quad (2b)$$

where, i and f express the initial state and final state of a matter in the phase transition, respectively. $C(i)$ and $C(f)$ are all the indefinite integral constant.

When the matters occur the variety at the chemical reactions or nuclear reactions in the isothermal process, we can obtain the Equation (2b) too, but i and f express the reactants and products respectively. $C(i)$ and $C(f)$ are all the indefinite integral constant too. Hence, ΔU has to be equal to constant or zero in

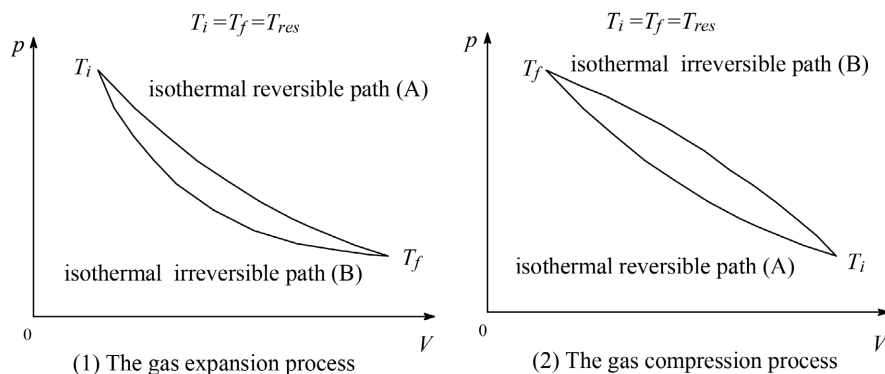


Figure 1. The reversible path (A) and its irreversible path (B) for the closed gases in the isothermal expansive or compressive processes.

any isothermal process. Then, in the isothermal process, the follow equation can be given by

$$C(f) - C(i) = \Delta H - p\Delta V, \quad (2c)$$

where, $\Delta H = C_p\Delta T$, ΔH is the enthalpy change (namely that, the latent heat of phase transition, or the chemical or nuclear reaction heat at the constant pressure), C_p is the heat capacity at the constant pressure. The item $-pdV$ indicates the pressure-volume work namely the expansion work, the other work also called the non-expansion work does not belong to ΔH . The enthalpy change at the constant pressure is the state function. Attentively, Δ expresses the quantity change value, \int is integral symbol.

In any isothermal processes, we can obtain the equation as follows

$$\Delta U = Q + W. \quad (3)$$

In any isothermal path, the internal energy change obeying the Equations ((2a), (2b)) will not be affected by the heat or any work. Therefore, the Equation (3) confirms to the first law of thermodynamics (namely the energy conservation law) and Hess's law in theory.

3. Extended Bernoulli Equation

In a process, the relations among the internal energy change, gravitational potential energy change, and kinetic energy change and so on had been investigated [19] [20] [21]. According to the conservation law of energy, we can obtain

$$\Delta U_r - Q_r + \int_i^f mgdh + \Delta E_{kin} + \Delta E_{ele} + \int_i^f pdV + \int_i^f Vdp = 0, \quad (4a)$$

$$\Delta U_{real} - Q_{real} + \int_i^f mgdh + \Delta E'_{kin} + \Delta E'_{ele} + \int_i^f pdV + \int_i^f Vdp = 0, \quad (4b)$$

where, the Equation (4a) is for the reversible path, the Equation (4b) is for the realistic path. $\int_i^f mgdh$ is the gravitational potential energy change, m is the mass, g is the acceleration of gravity, h is the elevation. ΔE_{kin} and $\Delta E'_{kin}$ are the kinetic energy change in a reversible and realistic process, respectively. ΔE_{ele} and $\Delta E'_{ele}$ are the electrical energy change in a reversible and realistic process, respectively. $\int_i^f pdV$ is produced by the closed gases and jet streams (or exhaust gases), but it could be not applied to the constant volume process. The mechanical energy includes the kinetic energy and gravitational potential energy. The item $-\int_i^f Vdp$ expresses the work done by the buoyancy and resistance which are all not the friction, and it could be not applied to the constant pressure process. Attentively, p is the pressure (it isn't internal pressure [22]), p_i is the initial pressure, p_f is the final pressure. For the fluids, the item $\int_i^f \frac{V}{mg} dp$ expresses the static pressure head, $V = \frac{m}{\rho}$, where, ρ expresses density. Thus, $\int_i^f \frac{V}{mg} dp = \int_i^f \frac{1}{g\rho} dp$. When the volume of fluids or bodies is constant, for example the solids, $\int_i^f Vdp = \int_i^f Shdp$. S expresses a cross section that is the

vertical projection of object (or body) on the earth surface. Here, the flying or motional direction is consistent with the direction of p_i , but the flying or motional direction is opposite to the direction of p_f . In the Equation (4b), Q_{pf} and W_{pf} had been already considered, but they could not appear in the Equation (4b) according to the equation $Q_{pf}(B) = -W_{pf}(B)$. In a process, the absorbed heat is positive, and the released heat is negative.

For the fluids of pipeline, if $\int_i^f p dV$ and $\Delta E'_{ele}$ might be neglected, the Equations ((4a), (4b)) can be rewritten as

$$\Delta U_r - Q_r = -\left(mg\Delta h + \Delta E'_{kin} + \int_i^f V dp\right) = W_r, \quad (5a)$$

$$\Delta U_{real} - Q_{real} = -\left(mg\Delta h + \Delta E'_{kin} + \int_i^f V dp\right) = W_{real}, \quad (5b)$$

where, the Equation (5a) is for the reversible path, the Equation (5b) is for the realistic path. We may assume

$$W_r = -(mgH_e - mgH_f) \text{ or } W_{real} = -(mgH_e - mgH_f), \quad (6)$$

where, H_e expresses the delivery head or pump head, H_f expresses the loss of head. So that, Bernoulli equation can be given by

$$mgH_e = mg\Delta h + \Delta E'_{kin} + \int_i^f V dp + mgH_f, \quad (7a)$$

$$mgH_e = mg\Delta h + \Delta E'_{kin} + \int_i^f V dp + mgH_f, \quad (7b)$$

where, the Equation (7a) is for the reversible path, the Equation (7b) is for the realistic path. Therefore, we can obtain the extended Bernoulli equation as follows

$$W_r = -\int_i^f mg dh - \Delta E'_{kin} - \Delta E'_{ele} - \int_i^f p dV - \int_i^f V dp = -\left(\int_i^f mg dH_e - \int_i^f mg dH_f\right), \quad (8a)$$

$$W_{real} = -\int_i^f mg dh - \Delta E'_{kin} - \Delta E'_{ele} - \int_i^f p dV - \int_i^f V dp = -\left(\int_i^f mg dH_e - \int_i^f mg dH_f\right), \quad (8b)$$

where, the Equation (8a) is for the reversible path, the Equation (8b) is for the realistic path.

4. Results and Discussion

4.1. Key Equation on the Chemical Thermodynamics

If the other work doesn't exist for a chemical reaction in an isothermal and constant volume process, we have $\Delta U_{TV} = Q_V$, where, ΔU_{TV} is the internal energy change, Q_V is the chemical reaction heat. If the other work doesn't exist for a chemical reaction in an isothermal and constant pressure process, we have $\Delta U_{Tp} = \Delta H - p\Delta V$, where, ΔU_{Tp} is the internal energy change, and ΔH is the chemical reaction heat.

In an isothermal process for the same chemical reaction, we can find $\Delta U_{TV} = \Delta U_{Tp}$ in two different paths (see **Figure 2**). In **Figure 2**, if the gases participated the chemical reaction, the final states of two different paths are not the same (one is an isothermal and constant volume process, another is an

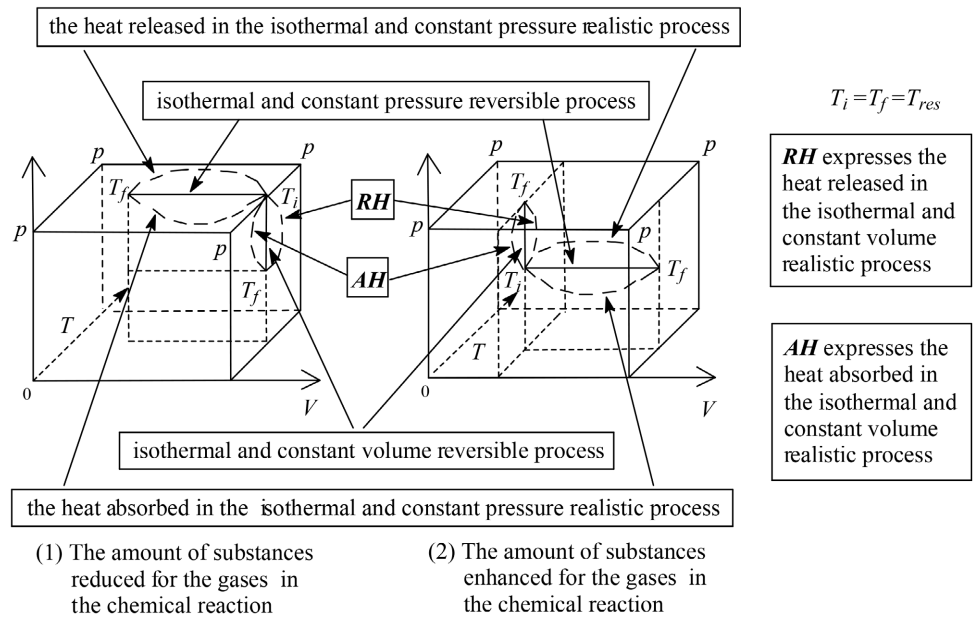


Figure 2. Two different paths for the gases in the same chemical reaction.

isothermal and constant pressure process). The result is

$$Q_V = \Delta H - p\Delta V, \tag{9}$$

where, p is the constant pressure.

If the internal energy change depended on the volume and pressure, and the gases participated the chemical reaction, we would obtain $\Delta U_{TV} \neq \Delta U_{Tp}$ in an isothermal process for the same chemical reaction. Otherwise, there are many errors on the chemical thermodynamics.

4.2. Force Diagram of Aircraft

In the extended or modified Bernoulli equations, ΔE_{kin} and $\Delta E'_{kin}$ are all equal to $\int_i^f mvdv$ or $\sum_i^f mvdv$, $\int_i^f Vdp = \sum_i^f Vdp$, $\int_i^f Shdp = \sum_i^f Shdp$ for the constant volume process, $\int_i^f mgdH_e = \sum_i^f mgdH_e$, $\int_i^f mgdH_f = \sum_i^f mgdH_f$, and $\int_i^f mgdh = \sum_i^f mgdh = -\int_i^f G_0 \frac{m \cdot m_0}{h^2} dh = -\sum_i^f G_0 \frac{m \cdot m_0}{h^2} dh$, where, v expresses velocity, m_0 is the mass of earth, G_0 is the gravitational constant.

According to Boltzmann density distribution equation for the atmosphere, we can obtain an approximate equation as $h = -\frac{kT}{Mg} \ln \frac{p}{p_0}$, where, M is mass of air molecule, k is Boltzmann constant, p is equal to p_0 when $h = 0$. Attentively, \ln expresses natural logarithm symbol, Σ is summation symbol.

If the aircraft flies or motions in the horizontal direction, the downward atmospheric pressure (namely that p_f) and molecule gravity will decrease on the surface of aircraft like the position of air molecules 1 and 2. Below the surface of aircraft, the downward pressure and molecule gravity will decrease, but the up-

ward atmospheric pressure (namely that p_i) will increase such as the position of air molecules 3 and 4. Simultaneously, on the slope surface of ahead part of body, the downward atmospheric pressure (namely that p_f), molecule gravity, and friction will decrease like the position of air molecule 5. Below the slope surface of ahead part of aircraft, the downward pressure, molecule gravity, and friction will decrease, so that, the upward atmospheric pressure (namely that p_i) will increase such as the position of air molecule 6. Obviously, the atmospheric pressure of position of air molecules 3, 4, and 6 are more than those of air molecules 1, 2, and 5 at the surface of aircraft. Besides, the buoyancy will increase for the aircraft in the vertical direction of earth surface (see **Figure 3**), and the non-friction resistance could increase for the aircraft in the horizontal direction of earth surface (see **Figure 4**).

If the rocket flies or motions upward in the vertical direction of earth surface, the friction will decrease, and the atmospheric pressure will increase comparing with the corresponding origin pressure on the slope of ahead part of rocket surface such as the position of air molecules 7, 8, and 9 (see **Figure 5**).

The atmospheric pressure could be influenced by the following factors such as the air density, gravity, temperature, elevation, or friction. Attentively, the relative motional direction of air molecules can transform the direction of gravity and friction, which will generate the tangential force.

$\int_i^f Vdp < 0$ at the vertical upward direction of earth surface, or the flying and motional direction of aircraft erects or inclines upward, the force diagram of aircraft sees **Figure 6**. In **Figure 6**, the value of item S will reduce, therefore,

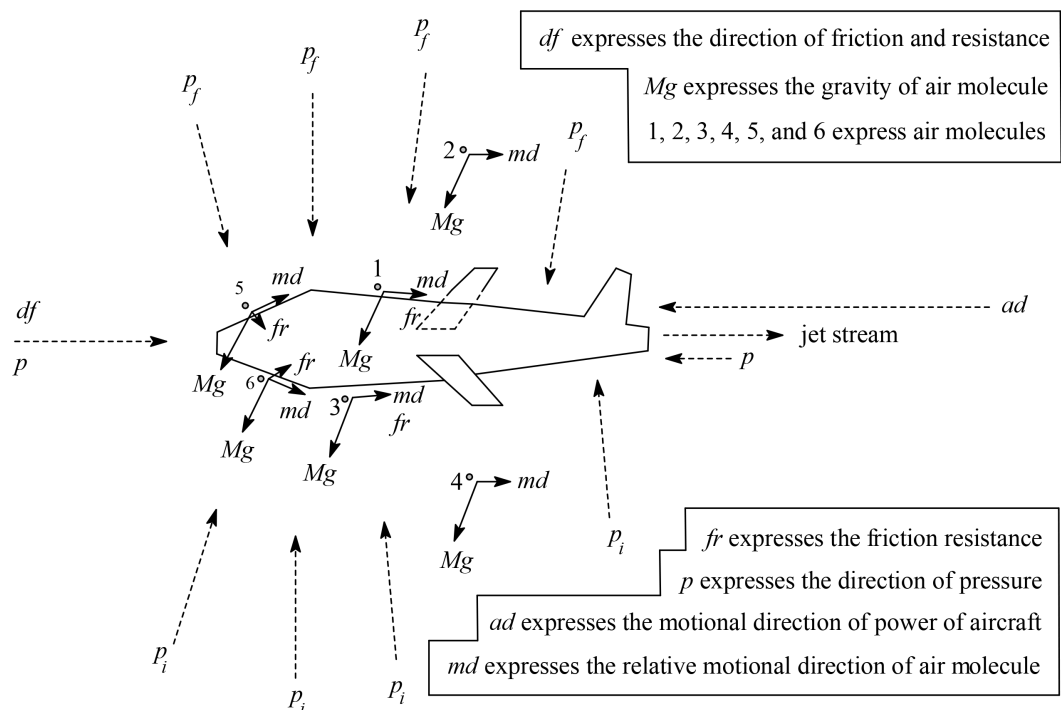


Figure 3. The force diagram of air molecules on the aircraft surface in the vertical upward direction of earth surface.

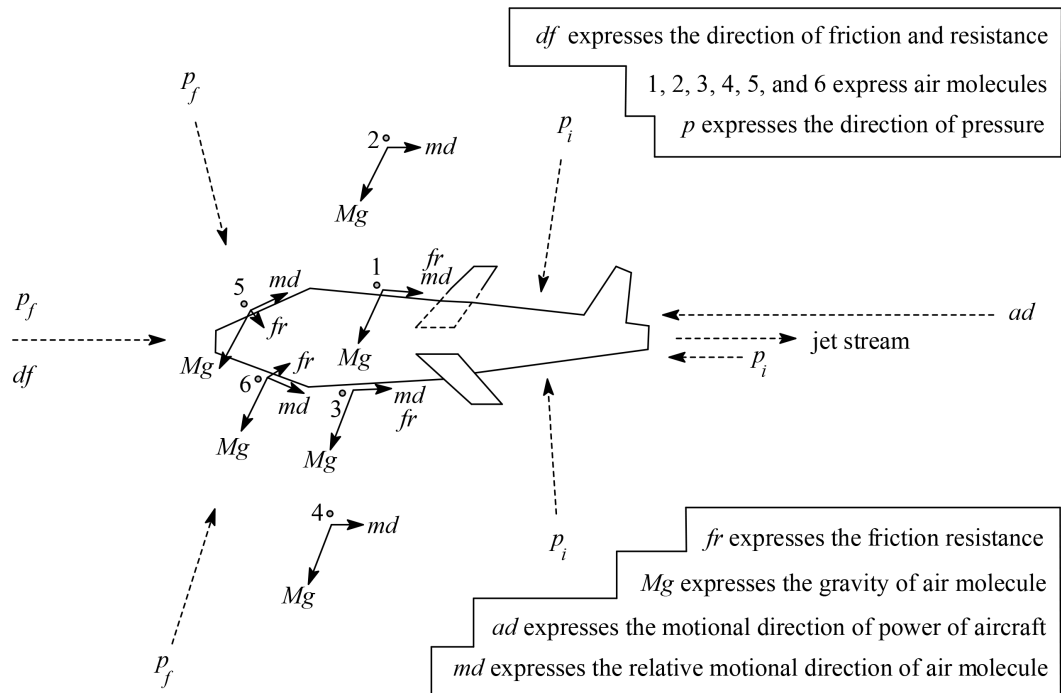


Figure 4. The force diagram of air molecules on the aircraft surface in the horizontal direction of earth surface.

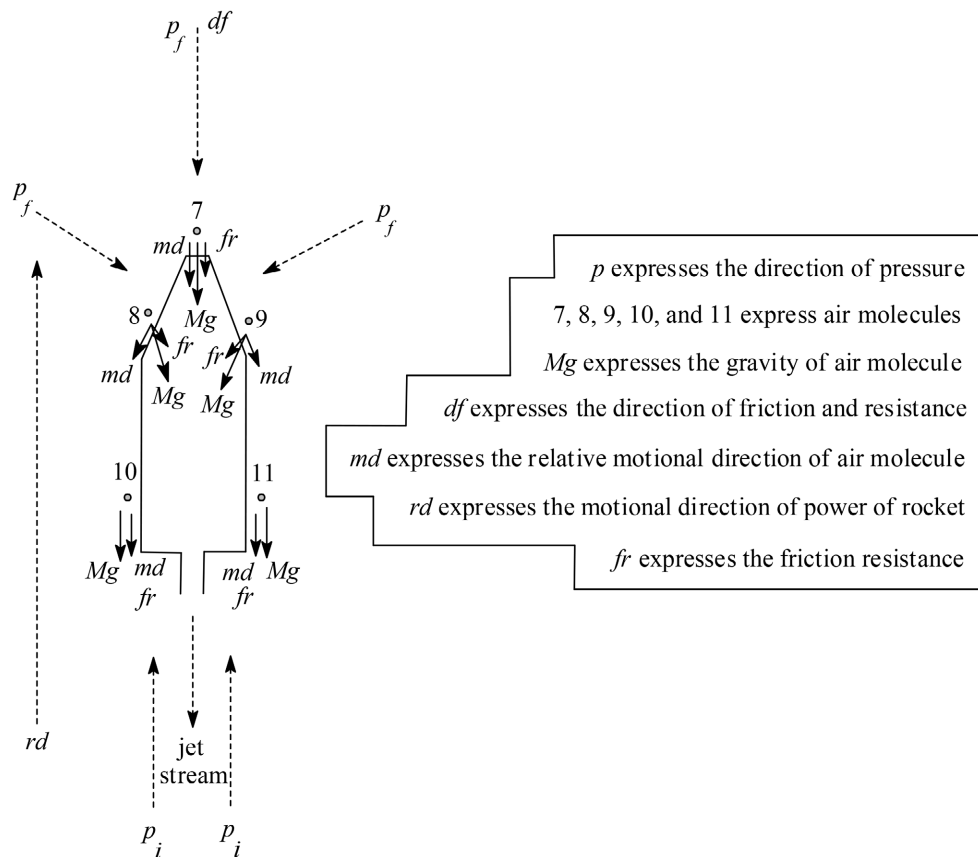


Figure 5. The force diagram of air molecules on the rocket surface in the vertical upward direction of earth surface.

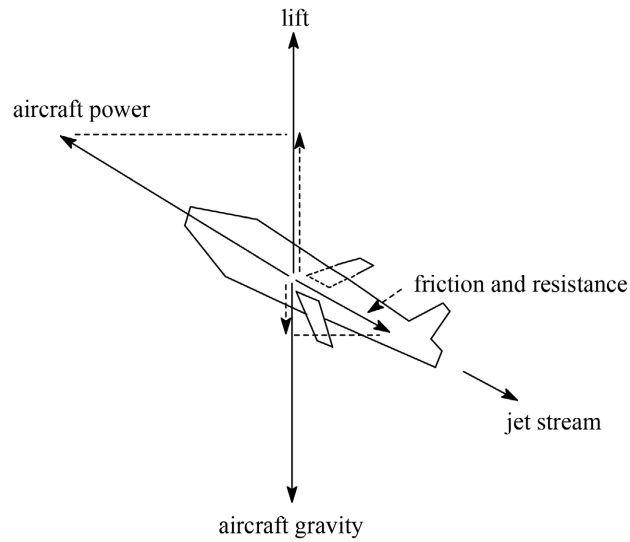


Figure 6. The force diagram of aircraft in the upward incline direction of earth surface.

the absolute value of $\int_i^f Shdp$ will reduce too.

4.3. Application of Extended Bernoulli Equation

If the body (or objects) could fly or be lifted, they would obey the equations as follows

$$\int_i^f mgdh = Q_r - (\Delta U_r + \Delta E_{kin} + \Delta E_{ele} + \int_i^f pdV + \int_i^f Vdp) \geq 0, \quad (10a)$$

$$\int_i^f mgdh = Q_{real} - (\Delta U_{real} + \Delta E'_{kin} + \Delta E'_{ele} + \int_i^f pdV + \int_i^f Vdp) \geq 0, \quad (10b)$$

where, the Equation (10a) is for the reversible path, the Equation (10b) is for the realistic path. At this time, if $h = 0$, the maximum mass is the maximum take-off weight.

Attentively, $\int_i^f pdV$, electrical energy change, and kinetic energy change all belong to W_{real} or W_r . Because $W_{real} \leq 0$ and $W_r \leq 0$, then,

$W_{real} + \Delta E'_{kin} + \Delta E'_{ele} + \int_i^f pdV \leq 0$ or $W_r + \Delta E_{kin} + \Delta E_{ele} + \int_i^f pdV \leq 0$. According to the Equations (8a) and (8b), we have

$$\int_i^f mgdh + \int_i^f Vdp = -W_r - \Delta E_{kin} - \Delta E_{ele} - \int_i^f pdV \geq 0, \quad (11a)$$

$$\int_i^f mgdh + \int_i^f Vdp = -W_{real} - \Delta E'_{kin} - \Delta E'_{ele} - \int_i^f pdV \geq 0, \quad (11b)$$

where, the Equation (11a) is for the reversible path, the Equation (11b) is for the realistic path. For the aircrafts, if $\int_i^f Shdp < 0$ at the vertical upward direction of earth surface, we have $\int_i^f mgdh > 0$, $\int_i^f mgdh$ may be more than the absolute value of $\int_i^f Shdp$ or $\sum_i^f Shdp$, these are reasons why the body can fly up to the sky.

For the helicopter, while $\int_i^f Shdp < 0$ at the vertical upward direction of

earth surface, we have $\int_i^f mgdh > 0$, namely that $h > 0$. For the falling parachute, $\int_i^f Shdp$ is resistance, so that, $\int_i^f Shdp > 0$. When birds fluttered their wings, $\int_i^f Shdp$ is lift namely that $\int_i^f Shdp < 0$, the atmospheric pressure will increase under wing and will decrease above wing. For the upward motional balloon, m is the balloon mass including the gas mass, m_1 is mass of air (which possesses the same volume with the balloon), so that,

$$\int_i^f Shdp = Sh \left(\frac{mg}{S} - \frac{m_1g}{S} \right) = gh(m - m_1), \quad \int_i^f Shdp \text{ is buoyancy.}$$

The natural wind is unsafe and interference factors for the flying and motional aircraft.

5. Conclusions

The internal energy changes of ideal gas, real gases, liquids, and solids do not depend on the volume and pressure. The internal energy change is still always the state function and temperature function. The van der Waals gas equation of state is approximate, therefore, that its internal energy change depends on the volume and pressure is not right.

The paths of liquids and solids are the motional track. The paths of gases have a relation to the volume and pressure. Attentively, it is impossible that a realistic process is not only the reversible process but also the irreversible process at the same time. For the extended or modified Bernoulli equation, the reversible path has to be in vacuum and the liquids have to be the ideal fluid.

The extended Bernoulli equation may calculate H_c and H_f . The extended Bernoulli equation can be applied to the rocket, bullet, airplane, helicopter, parachute, kite, birds, hot air balloon, and shell and so on. Of course, the mechanical work, $-\int_i^f pdV$, $-\int_i^f Vdp$ and so on have to be all considered in the extended Bernoulli equation, but they are unable to be repeatedly calculated. For examples, the system is only the closed gas, the mechanical works with the pressure-volume work are unable to be repeatedly calculated. If the system in the bullet and rocket does not include the ammunition or fuel, the obtained energy from the burned ammunition or fuel need avoid repeating calculation with the mechanical work. When the systems are different, the internal energy change will vary, too.

The friction of streamline body is the least. The lift has the relations with the gravitational potential energy change, kinetic energy change, friction, resistance, and $\int_i^f Vdp$.

The mass may vary in the extended Bernoulli equation.

Altogether, the internal energy change is always the temperature and state functions, the Equations ((2a), (2b), (2c), (3)) are key for the thermodynamics, the Equation (9) is key for the chemical thermodynamics. The internal energy change always accompanies the temperature change, so that, the internal energy change depends on the volume and pressure could not be proven.

The forces have two types, one type forces are natural forces, such as gravity,

surface tension, and electromagnetic force. Another type forces are not natural force originated from the energy. Furthermore, some forces belong to two type forces. The forces for animal are controlled by the neural organization system.

In fact the gas equations of state are complicated and varied, but the internal energy change has to be simple state functions. The thermodynamics laws have to be able to be derived from the mathematics, otherwise, the thermodynamics laws will lose the theory foundation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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