ORIGINAL RESEARCH ARTICLE

Discussions on Bernoulli Equations

Hongxiao Yu,Hao Yan,Yunbing Jiang

School of Physics and Information Engineering, Xinyu University of Science and Technology, Jiangxi, China

ABSTRACT
The Bernoulli equation is an energy equation that can be derived through many methods. In this paper, we derive the Bernoulli equation from the aspect of dynamics based on work-energy principle. We studied the derivation of the Bernoulli equation of the ideal fluid in steady flow. We discussed the physical significance of the equations in different conditions, and then discussed the meaning of dynamic pressure in Bernoulli equation and the relationship between dynamic pressure and static pressure. We also listed out the application of Bernoulli equation in production and in life.

KEYWORDS: dynamics; Work-Energy principle; Bernoulli equation, dynamic pressure

1. Introduction

Fluid mechanics is the basic discipline to explore the laws of nature, a study on the fluid flow in the movement of the relationship between the parameters, as well as the cause of movement and fluid on the surrounding objects, while the Bernoulli equation is the most basic study of the most commonly used fluid One of the basic laws, for the flexibility to master and better use, need to understand its derivation process and the physical significance of related items.

2. History of Bernoulli equation

In 1726, Bernoulli found that an increase in the velocity of a stream of fluid resulted in a decrease in pressure in order to commemorate the contribution of the scientist, this discovery is called 'Bernoulli effect'. The Bernoulli effect is applicable to all fluids, including gas, which is one of the basic phenomena when the fluid is in steady flow. It reflects the relationship between the pressure of the fluid and the flow rate. The relationship between the flow velocity and the pressure: the greater the fluid flow rate, the smaller the pressure; the smaller the fluid flow rate, the greater the pressure.

Daniel Bernoulli (1700-1782) was born on January 29, 1700 in Groningen of Nederland., He developed great interest in various fields of natural science from childhood due to family influence. In 1716 - 1717, he studied Medicine in the University of Strasbourg; In 1718 - 1719 he studied Philosophy in the University of Heidelberg; In 1719 - 1720, he studied Ethics in the University of Strasbourg , then specializing in Mathematics; In 1721, he received a Medical degree; In 1725 - 1732, he worked in the St. Petersburg Academy of Sciences, and served as a mathematics teacher; In 1733 - 1750, he served as an anatomy and a botany professor in the University of Basel,; In 1750, heserved as a physics and philosophy professor, and was elected as a member of the British Royal Society the same year ; On March 17, 1782, he died in Basel at the age of 82 years. Daniel is the most successful scientist in the Bernoulli family. He made outstanding contributions in mathematics and physics, and had been awarded the annual grant from the French Academy of Sciences from 1725 to 1749, and was appointed as Honorary Academician of the St. Petersburg Academy of Sciences. In mathematics, Daniel's research involved multidisciplinary content of algebra, probability theory, calculus, series theory, differential equation and so on, and has made great achievements. In physics, Daniel's success is amazing. Among them, the study of fluid mechanics and gas dynamics is especially prominent. The book 'Fluid Mechanics' published in 1738 is his representative work. In the book, the flow theory of fluid is solved according to the law of conservation of energy, and the famous Bernoulli theorem is put forward. This is one of the important basic theorems of fluid mechanics. Daniel's contribution to gas dynamics is mainly to explain the origin of the pressure of the gas on the vessel wall with gas molecular motion theory. He believes that due to a large number of high-speed regular movement of gas molecules caused by the pressure on the wall, compressed gas to produce a greater force is due to the increase in the number of

Copyright © 2017 -. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), permitting all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

gas molecules, and more frequent collision with each other. Daniel applied the series theory to the study of mechanics, which is of great significance to the development of mechanics.

3. Derivation of Bernoulli's Equation

1. Fluid flow characteristics of the ideal fluid gravity field, in the non-uniform cross-section of the flow tube for a stable flow. The fluid flow in the flow tube, in the flow field to take a small flow tube, and intercept a fluid AB is the object of study. The pressure, velocity, height and height of the fluid at point A are P1, V1, h1 and S1 respectively. The pressure, velocity and height of the fluid at point B are P2, V2, h2 and S2 respectively.

2. F1: P1S1 (F1 and v1 direction the same); B point: F2 = P2S2 (F2 and v2 direction opposite.) Δ t time in the fluid displacement at point A: AA '= v1 Δ t; B: BB' = v2 Δ t.

2.1 The total power of two forces when the fluid is moved from AB to A'B 'is given by the following equation: W = F1AA'-F2BB' = P1S1V1 Δ t-P2S2V2 Δ t = P1 (S1V1 Δ t) -P2 (S2V2 Δ t)

In the above equation, S1V1 Δ t and S2V2 Δ t are equal to the volume of fluid in the AA 'and BB' sections of the flow tube, respectively, and because the ideal fluid is stable flow,

The volume of the fluid is equal, denoted by Δ U, and the above equation can be written

W = P1 Δ U - P2 Δ U

2.2 Mechanical energy increment when fluid moves from AB to A'B 'The motion state of the A'B section of the fluid does not change during flow. The increase in mechanical energy is only reflected in the AA' and BB 'fluids.

According to the continuity equation, the mass of AA 'and BB' are equal to each other, and the increment of mechanical energy is denoted by Δ E, and the mechanical energy of the fluid is E1 and BB '

Then: ΔE = E2 - E1 = (1 / 2mv22 + mgh2) - (1 / 2mv12 + mgh1)

2.3 According to the principle of function by A = Δ E available:

P1 Δ U - P2 Δ U = (1 / 2mv22 + mgh2) - (1 / 2mv12 + mgh1)

P1 Δ U1 + mgh1 + 1 / 2mv12 = P2 Δ U2 + mgh2 + 1 / 2mv22

To Δ U in addition to the following: P1 + 1 / 2ρv12 + ρgh1 = P2 + 1 / 2ρv22 + ρgh2

2.4 Bernoulli equation P + 1 / 2ρv2 + ρgh = constant

The equation is the general form of the Bernoulli equation, where the three terms have a pressure dimension, where the 1 / 2ρv2 phase is related to the velocity, often called dynamic pressure, ρgh and P phase independent of the velocity pressure.

4. Physical significance of each of the Bernoulli equations under different conditions

1. Bernoulli equation applies to the Bernoulli equation for constant flow of incompressible liquid, the mass of force only gravity, in the gravity field for a stable flow, and in the same stream line.

2. Under normal conditions the Bernoulli equation in the meaning of each

P + 1 / 2ρv2 + ρgh = constant

The equation shows that when the ideal fluid flows steadily in the flow tube, the kinetic energy of the unit volume is 1 / 2ρv2, the gravitational potential energy ρgh, and the sum of the pressure P of the point is a constant. The 1 / 2ρv2 phase is related to the flow velocity, Pressure, ρgh and P phase has nothing to do with the flow rate, often called static pressure.

3. Physical Significance of the Bernoulli equation in the unit weight fluid

Pg = mg / v represents the weight per unit volume, with ρg divided by: p / ρg + v2 / 2g + h = constant

The equation represents the total mechanical energy of the unit weight fluid at a point in the flow field, where p / ρg represents the pressure potential of the unit weight fluid at the point in the flow field, that is, the work done by the pressure on the unit weight of the fluid, v2 / 2g represents the kinetic energy of the unit weight fluid, and h is the height of the point in the flow field. Since v2 / 2g + p / ρg + h = constants, each term in the theorem has a dimension of length, so p / The pressure potential of the point of view can also indicate that it can push the fluid pressure to a certain height.

4. Physical significance of the p / ρ term of Bernoulli equation in unit mass fluid

To ρ in addition to the following: p / ρ + 1 / 2v2 + gh = constant

In this equation, the p / ρ term represents the pressure or elastic potential energy per unit mass of fluid at a point in the flow field. From the energy point of view, the p / ρ term can also be understood as the unit mass fluid with respect to the p = 0 state energy of.

5. Through the above analysis, we can see that the Bernoulli equation is an energy equation. Although the kinetic principle is different in the analysis of the problem, the meaning of the derived equation is exactly the same, indicating that the ideal liquid for steady flow in the tube has the pressure energy , The potential energy and the kinetic energy of the three forms of energy, in the case of qualified conditions, the flow field of the three kinds of energy can be converted to each other, but its sum remains unchanged, these three energy collectively referred to as mechanical energy. The Bernoulli equation is essentially the conversion and conservation of mechanical energy.

5. Bernoulli equation 'dynamic pressure' discussion

1. Horizontal flow tube, in the application of Bernoulli equation, we know that for the horizontal flow tube, the pipe section of the small pressure is small, the flow rate is large; large cross-section pressure, small flow rate. As shown in Fig. (1), if the cross section of the rough portion b of the flow tube can be approximated infinitely with respect to the fineness a or c, then the velocity at the coarse velocity can be approximated as zero. That is, the kinetic energy of the liquid in the fine part of the rough into all the pressure.

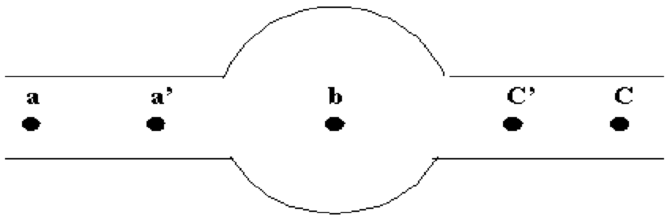

Figure 1

Consider the flow of small streams along the horizontal tube. Because the ideal fluid is not viscous, the external fluid acting on the block is not dissipated. The action of the fluid on the outside of the flow tube is perpendicular to the surface of the small block and is perpendicular to the direction of its movement without any work. Only the inside of the flow tube, before and after the small block of fluid exerted by the external force on the small block of work. The small stream block has a velocity v by the external force before reaching a, In the aa 'section, small stream of the same speed, before and after the force by the size of the same, in the opposite direction. From a 'in the a'b section, the small mass flow rate gradually reduced to reach the speed of b tends to zero, before and after the force is not as big as the front of the resistance, behind the thrust is small, before and after the force cannot be offset, Small flow block to overcome the resistance, consumption of kinetic energy to reach b, the kinetic energy will be exhausted. From a 'to b to c', the algebra of these functions is determined only by the pressure at the beginning and ending positions of the small block, although the fluid inside and outside the flow tube acts on the force of the force, and has nothing to do with the specific path of the stream in space.

It can be seen that the change of the flow rate of the small stream in the horizontal flow tube reflects the change of the pressure. The kinetic energy of the small block becomes the pressure at the speed when it becomes smaller. When the pressure gradually becomes smaller, the small block gets the acceleration, the speed becomes larger, the kinetic energy increases. If aa 'and cc' two flow tube cross-sectional area of the same, then the two flow rate, pressure are the same. Therefore, in the ideal fluid, stable flow process, the fluid is in a dynamic steady state, that is, the pressure changes in the flow tube is caused by changes in the flow rate, the horizontal tube flow rate of the same pressure everywhere. So the external force has a conservative nature, 'dynamic pressure' of the proposed practical significance.

2. Small pore flow rates and ratios compared to hosting in the Bernoulli equation application, also referred to the small pore flow rate and the ratio of the tube. (2) and (3)

The small pore velocity is assumed to be large in volume and cross-section of the container, while the small holes are small. So the liquid level of the container is very small, can be seen as zero. From Bernoulli equation, the velocity at hole B can be obtained: vB

VB = $\sqrt{2gh}$

Where h = hA-hB indicates that the velocity of the liquid flowing out of the orifice is equal to the velocity at which the liquid micrometer is free to fall from the liquid surface to the small hole. For those who have h = VB2 / 2g, ie VB = where h = hA-hB. Indicating that the height difference between the two tubes h is the flow velocity in the flow tube from vB to O. With the formation of small hole flow rate explanation: the height difference of h can produce vB speed, in turn, there are vB numerical flow rate, you can produce h height of the liquid column. From the flow and static mechanics, the static fluid within the two points of the same height, the same pressure; height difference h, pressure phase pressure pgh. Static pressure P and pgh are interlinked, 'dynamic pressure' and 'static pressure' between the mutual conversion can be.

So that P, pgh, 1 / 2ρv2 are unified with the P unit, the transition to the hydrostatic, the same flow tube, it is the total pressure is constant throughout the sub-pressure with the flow tube section And the height of the change and mutual conversion. In fact, this is just a special case of hydrodynamics. Because the assumption that the ideal fluid, when the fluid, it has been paid to the mobility of the system. Thus, the transformation between P, pgh and 1 / 2ρv2 is as simple and clear as hydrostatic.

6. Scientific explanation of the Bernoulli effect

1. ”Suction” phenomenon of cruisers

In the autumn of 1912, as 'Olympic' the largest cruiser in the world was cruising on the sea, there was a small warship 'Hawk', steering along on a course parallel to the giant ‘Olympic’ at a distance of 100 meters away. All of sudden, 'Hawk' went out of control and was pulled by an irresistible force to the giant cruiser. Hawk’s bow cut a great gash at the side of ‘Olympic’, causing a major mishap on the sea. What is the cause of this shipwreck accident? At that time, no one can say, it is said that the maritime court in dealing with this case, they have to muddlely sentenced to improper system!

Later, people can understand, this time on the sea flying accident, is the phenomenon of Bernoulli principle. We know that, according to the principle of fluid mechanics Bernoulli, the pressure of the fluid is related to its velocity, the greater the flow rate, the smaller the pressure; and vice versa. With this principle to investigate the accident, it is not difficult to find the cause of the accident. It turned out that when the two ships were traveling in parallel, the water in the middle of the two ships was faster than the outside, and the pressure on the inside of the two ships was smaller than the pressure on the outside of the two ships. So, in the lateral water under the pressure of the two ships gradually close, and finally collided. In view of the fact that such maritime accidents continue to occur and the greater the ship and warships are created, the greater the dangers of the ship and the warships in the event of a collision, the World Maritime Organization has made strict rules for the navigation rules in this case, They include the distance between the two ships in the same direction, how much distance the boat and the ship should be circumvented, and so on.

The same token, when the wind, the roof of the air flow quickly, equal to the wind speed, and the roof of the air is almost no flow. According to the Bernoulli principle, the pressure on the roof under the air is greater than the pressure on the roof. If the wind is more and more scraping, the pressure difference between the roof is getting bigger and bigger. Once the wind speed over a certain extent, the pressure difference on the 'Wow' about the roof set off the grass, so that the seventy-eight landing to the wind fluttering. As China's famous poet Du Fu 'hut for the autumn wind breaking song' said: 'August autumn high winds, roll my house on the third of Mao.

2. 'Banana ball' mystery

If you often watch the football game, then, you must have seen direct free kick. At this time, usually the defensive side of five or six players in front of the goal to form a 'wall', blocking the goal line. Attack the side of the penalty team members, kick a foot shot, the ball around the 'wall', seeing to fly away from the goal, but turn around the arc straight into the goal, so that the goalkeeper by surprise, watched The ball into the door. This is quite magical 'banana ball'.

Why does football fly in the air along the arc? The original, punished 'banana ball' when the athletes are not pulling the center of football in the kick, but slightly biased side, while the footrest friction football, so that the ball in the air while also continue to rotate. At this time, on the one hand the air facing the ball backward flow, on the other hand, due to the friction between the air and the ball, the air around the ball will be with the rotation. In this way, the flow velocity of the air on the side of the ball is accelerated, and the flow velocity of the other side air is slowed down. Physical knowledge tells us that the greater the flow rate of gas, the smaller the pressure (Bernoulli equation). As the air flows on both sides of the football is not the same, they are not the same pressure on football, so the role of football in the air pressure, forced to the air flow side of the big turn.

7. Bernoulli equation application

Application example 1.

Why can a plane fly in the sky? This is because the wings are lifted upwards by the air. When the airplane is flying, the airflow distribution around the wings of the airplane means that the shape of the wing cross section is asymmetrical, and the flow line at the top of the wings is dense, and the flow rate is large. From the Bernoulli equation we can see that the pressure above the wing is small, the pressure below the wings is big. This produces a lift in the direction of the wing.

Application example 2.

Sprayer is invented based on the principle of ‘velocity increases and pressure decreases’. . When the air flows out from the hole at high speed, the air pressure near the hole decreases. Thus the pressure above the liquid inside is relatively high, such pressure difference causes the liquid to be pushed up the small tube to form mist at the outlet.,

Application example 3.

Gasoline engine carburetor, and spray the same principle. The carburetor is a device for supplying fuel and air to the cylinder. The construction principle means that when the piston in the cylinder is in the suction stroke, the air is sucked into the tube and the flow rate is large and the pressure is small when it flows through the narrow part of the tube. The nozzles installed in the narrow section flow out and are sprayed into mist to form a mixture of oil and gas into the cylinder.

References

1. Lu Zhongqi. Fluid Mechanics [M]. Beijing: Ministry of Machinery Industry Press, 1979.
2. Zhao Kaihua, Luo Weiyin. New Concept Physics Course: Mechanics [M]. Beijing: Higher Education Press, 2004.
3. Hu Xinmin. Medical Physics [M]. Beijing: People's Health Publishing House, 2003.
4. Kuanghua Jun, editor. Medical Physics. Second Edition. Beijing: People's Health Publishing House, 1985; 40: 86
5. Huang Xiulin, editor. On Bernoulli equation 'pressure energy.' University Physics 1995; 3: 10,11
6. Department of Physics, Peking University Department of Physics. General Physics (Mechanics). Beijing: People's Education Press, 1978