The principle and applications of Bernoulli equation

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Abstract. Bernoulli equation is one of the most important theories of fluid mechanics, it involves a lot of knowledge of fluid mechanics, and is used widely in our life. This paper comprehensively the research present situation of Bernoulli equation at home and abroad, introduces the principle of Bernoulli equation and some applications in our life, and provides direction of the application for the future.

Keywords: Bernoulli equation; Principle; application.

1. Introduction
Bernoulli’s principle is an important theory in fluid mechanics, involves a lot of knowledge of fluid mechanics, and is Daniel Bernoulli (d. Bernoulli, Swiss physicists, mathematicians, 1700 ~ 1782) in 1726, is three basic equation of hydrodynamics another, it is the embodiment of objects mechanical energy conversion of hydraulics.

Bernoulli equation solves the problem of force and energy which is often involved in engineering practice, which lays the theoretical foundation for solving hydraulic calculation of actual engineering.

The application of this equation runs through the course of hydraulic mechanics.

Based on the principle of Bernoulli’s equation, this paper summarizes the research status of its application at home and abroad, and provides direction for the future application of Bernoulli equation.

1.1. The Bernoulli equation
As shown in figure 1, the ideal fluid for steady flow in the gravitational field is to take a thin flow tube, and the area of the two cross sections, and the height of their relative horizontal reference plane.

Since the ideal fluid is incompressible, the quality of the fluid between the two is equal to the mass between.

The increment of mechanical energy is the increment of mechanical energy in the process of position/flow to position /.
\[
\Delta E = \left( E_i + E_f \right)_2 - \left( E_i + E_f \right)_1 \n\]
\[
= \left[ \frac{1}{2} (\Delta m) v_2^2 + (\Delta m) gh_2 \right] - \left[ \frac{1}{2} (\Delta m) v_1^2 + (\Delta m) gh_1 \right] \\
= \left( \frac{1}{2} v_2^2 + gh_2 - \frac{1}{2} v_1^2 - gh_1 \right) \Delta m
\] (1)

The pressure of the surrounding fluid is the total work of the fluid block:

\[
\Delta A = \Delta A_1 + \Delta A_2 = p_1 S_1 v_1 \Delta t - p_2 S_2 v_2 \Delta t
\] (2)

According to the continuity principle, and

\[
\Delta m = p S_2 v_1 \Delta t = p S_2 v_2 \Delta t
\] (3)

So:

\[
\Delta A = (p_1 - p_2) \frac{\Delta m}{\rho}
\] (4)

According to the principle of function, \( \Delta E = \Delta A \) so,

\[
p_1 + \frac{1}{2} p v_1^2 + \rho g h_1 = p_2 + \frac{1}{2} p v_2^2 + \rho g h_2
\] (5)

The following relationship is always true for any section of the same flow tube:

\[
p + \frac{1}{2} \rho v^2 + \rho g h = \text{cons tan } t
\] (7)

Both of these are known as Bernoulli’s equations, and they describe the fundamental laws of the ideal fluid for stationary flow. If the ideal fluid flows along the horizontal flow tube, then

\[
p + \frac{1}{2} \rho v^2 = \text{cons tan } t
\] (8)

When the ideal fluid flows along the horizontal pipe, the area of the pipe is small and the velocity is small and the area of the pipeline is small and the pressure is strong.

So:

\[
p_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2
\] (9)
Take two points in the density of the static fluid, and make a list of Bernoulli’s equation:

$$p_A + \rho g h_A = p_B + \rho g h_B + \rho \Omega \rho - p_B = \rho g h_A - \rho g h_B$$  \hspace{1cm} (10)

If the height of two points is equal, then the upper equation shows that the pressure in the rest liquid is equal to the pressure in the two points \([1-2]\).

![Fig. 1 schematic diagram of Bernoulli equation](image)

If there is no heating or cooling fluid flow in the system, you can ignore the fluid viscosity, fluid density is constant, so, this is an ideal incompressible fluid system of isentropic flow system, the internal energy remains constant. The ability of this system is calculated, only the mechanical energy balance is required. The energy equation for the mechanical energy balance in this case is the Bernoulli equation.

In the case of incompressible heavy fluid, Bernoulli equation is the natural result of the first integral of the motion equation, which is the most important expression of energy relations in fluid mechanics \([3]\).

The principle of Bernoulli’s equation is in the same fluid, the velocity is large and the pressure is small. Small flow rate, strong pressure. Flow is automatically flowing from high pressure to low pressure. Its simple narrative is: when the ideal fluid as a stationary flow, if the level of fluid flow or the influence of the height difference was not significant (such as gas flow), Bernoulli equation can be expressed as $P + \rho V^2/2 = constant$, namely in the fluid flow, velocity $V$ of the local pressure $P$ small, velocity $V$ of small pressure $P$ big\([4]\).

2. The application of the Bernoulli equation

Bernoulli equation, the principle of using a lot of, play football or play table tennis in the stagnation pressure, inside the chimney flue gas flow rate, water pump, water power, spray flow rate and pressure of siphon and radial flow between circular plate, etc., some of the example below.

2.1. Agricultural spray gas

Agricultural sprayer is a kind of machine, the liquid dispersed currently use sprayer knapsack, stretcher and matched with the tractor traction model, rural pesticides commonly used simple and knapsack.

How can a sprayer spray water or liquid into a fog? As shown in figure 2, hard to push the horizontal tube, air from through a narrow place, by the Bernoulli principle. The narrow $A$ larger flow rate and pressure is small, and in $A$ vertical tube above the CB, CB tube, the pressure is less than the bottom pressure above the solution will be along the tube, powder under the action of wind pressure through
the door, the water plug connector, iv reaches the nozzle. As the cross section shrinks suddenly and the flow rate increases, the air from the fan outlet passes through here to generate negative pressure. Under positive pressure and negative pressure, the liquid is ejected from the nozzle, and it coincides with the high speed air flow from the nozzle.

Because the velocity of the two is very different, and the direction is perpendicular, it is cut into small droplets of 100-150 diameter by the high-speed airflow and blown into mist at the outlet of the thin tube.

This paper USES the characteristics of large liquid velocity and small pressure in the narrow part of the pipe, and the phenomenon of external liquid suction is called air suction.

![Fig. 2 A schematic diagram of the sprayer for agriculture](image)

2.2. Cooling effect

Bernoulli's equation: $p + \frac{1}{2} \rho v^2 + \rho gh = \text{cons} \tan t$

For horizontal flow pipes, there are:

$$p + \frac{1}{2} \rho v^2 = \text{cons} \tan t$$  \hspace{1cm} (11)

The ideal gas is used as the ideal fluid for horizontal flow pipes. For an ideal gas, the pressure formula is the following: \[ p = \frac{1}{3} \frac{mn}{n} \frac{v^2}{2} = \frac{2}{3} n \frac{kT}{n} = \frac{3}{2} kT = nkT \] \hspace{1cm} (12)

The Bernoulli equation in the horizontal flow tube

$$nkT + \frac{1}{2} \rho v^2 = \text{cons} \tan t$$  \hspace{1cm} (13)

(In this formula is the molecular density of the gas, the density of the gas is $\rho = mn$, the Boltzmann constant is k.)

Soya can see from the upper formula that the lower the flow velocity, the lower the temperature of the gas. When the flow velocity is large enough to a certain value, the temperature of the gas in the tube will be lowered to the freezing point and crystallized in the wall. The combustible ice (gas hydrate) produced in natural gas pipelines is an example. When the tube is not uniform, it is known from the $Sv = \text{cons} \tan t$, continuity principle that the velocity of the detail is greater than the velocity of the...
thick part. According to the above formula, the temperature in the detail is lower than the temperature in the thick.

In order to understand the cooling effect of flow gas more clearly, the formula derived from above is changed to:

\[
nkT_1 + \frac{1}{2} \rho v_1^2 = nkT_2 + \frac{1}{2} \rho v_2^2
\]

(14)

It is assumed that the density of the gas in the flow process is constant, so \( n \) is also invariable. For convenience, make the \( v_1 = 0 \).

So:

\[
T_1 = T_2 + \frac{1}{2} \frac{\rho}{nk} v_2^2 = T_2 + Kv_2^2
\]

(15)

In the equation, \( K = \frac{1}{2} \frac{\rho}{nk} = 2 \times 10^{-3} \text{Km}^{-2} \text{s}^{-2} \) (The values are for ordinary air, different for different gases)

Substitute the different air velocity into the top formwork can get the Different numerical of \( \Delta T = T_1 - T_2 = Kv_2^2 \),

The list below:

\begin{table}
| \( v_2 (m/s) \) | 1 | 5 | 10 | 20 | 30 | 50 | 70 | 100 | 200 | 300 | 400 |
|-----------------|---|---|----|----|----|----|----|-----|-----|-----|-----|
| \( \Delta T(\degree C) \) | 0.002 | 0.05 | 0.2 | 0.8 | 1.8 | 5 | 9.8 | 20 | 80 | 180 | (320) |
\end{table}

It can be seen from the table that the temperature drop is not obvious when the wind speed is small. When the wind speed is high, the temperature will decrease obviously. When the gas flow is very high, the temperature of the gas will drop very low. When the gas is very high, the temperature of the gas will be very low, and the gas cannot be considered as an ideal gas. Because for the general gas, only the pressure is not too high and the temperature is not too low to be considered an ideal gas.

Therefore, the last part of the list is written in brackets, where the temperature drop value cannot be calculated using the derived formula. Second, is derived from the formula may draw a conclusion: when the gas forming orderly movement, his disorderly thermal motion will be reined in, the higher the speed of the orderly movement, the lower the degree of disorder of thermal motion.

2.3. The collision of two ships near the road is easy to collide

As is known to all, in the fall of 1912, the "Olympic" in parallel with the cruiser HMS hack, although both are about 100 m, "hack" also is very small, but as if by ship took to the boat, don't obey the helmsman manipulation. Race 1 vigorously to the "Olympic". Finally, the ship's bow hit the side of the Olympic and hit the Olympic with a big hole.

The reason for this accident is as shown in figure 6. According to the Bernoulli principle of hydrodynamics, the pressure of the fluid is related to its velocity. The higher the velocity, the smaller the pressure; and vice versa. It turns out that when two ships parallel forward two ships in the middle of the water is faster than the outside of the water flow rate, according to the principle of Bernoulli
equation, in the middle of the water on the pressure of the two internal au 5 is smaller than the lateral pressure of two ship lateral.

Then, under the pressure of the outside water, the two boats approached and collided. Again due to the small "g", in the same size pressure, under the action of it to two ship speed is much faster, therefore, the "hack" crash "Olympic" number of accidents. This phenomenon is now referred to as "ship suction".

3. Summary
Bernoulli's equation is in a fundamental position in fluid mechanics. Although it is based on the incompressible ideal fluid, on the basis of stationary flow, but when a lot of fluid flow can be approximately regarded as ideal fluid, using Bernoulli equation can get many useful conclusions.

In practical engineering, the use of Bernoulli equation can solve many problems, such as the lift of airplane wings and the air pump. Bernoulli equation in water conservancy, shipbuilding, chemical industry, aviation and other departments have a wide range of applications, as long as a careful study of these application instance, everyone has the ability to further for the application of Bernoulli equation to find other innovations, for example, reservoir gate drain flow calculation; The calculation of the force of the pipe bend in the horizontal plane; Put a Ping-Pong ball in the inverted funnel, and blow with the mouth into the mouth of the funnel. The Ping-Pong ball will not only not fall but will be pressed more tightly with the funnel.

It can be seen that learning a little Bernoulli's knowledge is of great significance for developing intelligence and applying physics knowledge.

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