Dynamic buoyancy-the cause of aircraft lift

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Dynamic buoyancy-the cause of aircraft lift

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Abstract: The stone floating in the rapids and airplane rising in the air should follow the same principle. Through analyzing and calculating the problem that high-speed water flow makes the stone float, puts forward the concept of dynamic buoyancy, proves that dynamic buoyancy is the cause of stone floating, and applies this result to the problem of aircraft lift, the calculation formula of aircraft lift is derived, namely $F_X=\rho v^2S_x/2+\rho gV$, and solves the defects of current lift theory. Dynamic buoyancy is the cause of the lift produced by the aircraft.

Introduction

In December 1903, the Wright brothers' aircraft successfully flew for the first time, marking humanity's entry into the aviation era. But what keeps the plane flying in the air? This problem has not yet been solved theoretically.

The earliest and most popular interpretation of lift is Bernoulli's theorem, which was written in the university textbook "Aerodynamics". The content of Bernoulli's theorem is that when the incompressible, ideal fluid is flowing stably along the flow tube, the flow velocity increases， and the static pressure of the fluid decreases; Otherwise, the flow velocity decreases then the static pressure of the fluid increases. Bernoulli’s theorem attempts to explain the lift caused by the curved upper surface of the wing, because the airflow on the upper surface is squeezed and the speed is faster than the smooth lower surface, resulting in a lower static pressure on the upper surface than the lower surface. A pressure difference appears above and below the wing, generating lift, as shown in Figure 1.

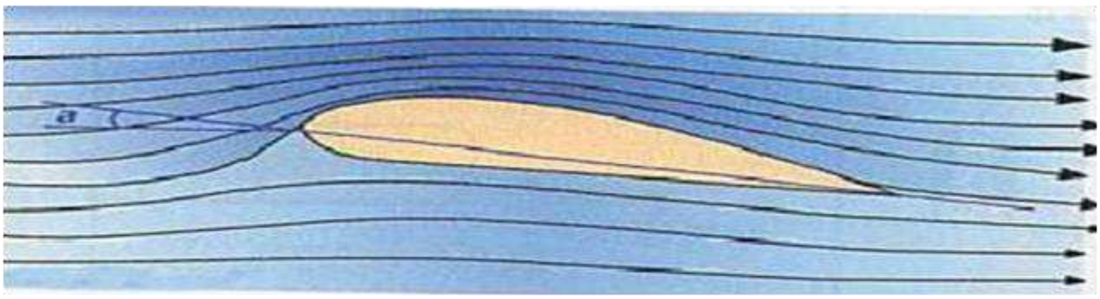

Fig 1: Wing airfoil in airflow

What actually happened challenged Bernoulli's theorem, the plane could fly upside down. The wing did not produce downward pull due to the exchange of upper and lower surfaces. This means that the lift is independent of the shape of the wing.

Cambridge University aerodynamics professor (Holger Babinsky)[1] in his article "How do wings work?"Said: when the airflow is applied to one side, the curved paper is lifted," not because the air moves at different speeds on both sides ".

The second theory of lift is based on Newton's third law of motion, the principle of acting and reaction forces. The theory states that the wing keeps the aircraft in flight by pushing the air downward.

However, this theory also cannot explain the lower pressure at the top of the wing, which exists in this area, regardless of whether the wing is bent.

In 1916, Einstein published a short article in the journal Nature, entitled "Basic Theory of Water Waves and Flight," trying to explain what caused the carrying capacity of aircraft and the wings of flying birds[2].In 1917, Einstein designed a wing based on his theory, and Berlin-based aircraft manufacturer LVG built a new aircraft based on this wing. A test pilot reported that the aircraft hovered in the air like "a pregnant duck".

In 2012, leading aerodynamics expert Doug McLean published[3] a book "Understanding Aerodynamics: Starting from Real Physics". Also in November 2018, McLean published a two-part article in "Teacher of Physics", and he proposed a "comprehensive physical interpretation" of aerodynamic lift.

Mark Drela, a professor of fluid dynamics at the Massachusetts Institute of Technology and author of "Aerodynamics of Aircraft", also gave an answer: "If the package flew away from the tangent line of the top surface of the wing, the surface Create a vacuum."

Later, Drela himself admitted that his explanation was not satisfactory in some respects. He said: "An obvious problem is that no explanation will be universally accepted."

1. Dynamic buoyancy is the reason why the rapids make the stones float

People living by the river discovered that when a torrential flood erupts, the flowing water will wash up the stones, allowing the stones to float on the surface or float in the water. This is so-called that rapids float stones. The density of the stone is several times that of water, and it cannot be suspended in still water; the density of an airplane is thousands of times that of air, it is difficult to imagine flying in the air. In fact, the nature of the two is the same. If the cause of that the rapids make the stones float is cleared, the lift of the aircraft will also be solved.

1.1 The essence of buoyancy is the pressure difference

It is necessary to review Archimedes' law of buoyancy. Suppose a piece of wood with a height of h, a base area of S, a volume of V, and a mass of m is a standard cube, placed in still water, as shown in Figure 2. The wood's upper surface is flush with the water surface, which bears the atmospheric pressure p; the pressure on its lower surface is $p+P_0$ (p is the pressure that the atmosphere transfers to water, P_0 is the pressure of the water level). $P_0=\rho gh$ (ρ is the density of water, g is the acceleration of gravity, h is the depth of water).The characteristic of liquid pressure is that there are pressures in all directions inside the liquid, and the pressures in all directions are the same at the same depth, the deeper the depth, the greater the pressure.

Because of symmetry, the pressures on the front, back, left, and right sides of the wood m cancel each other out, and only the upper and lower sides have a pressure difference ΔP, $\Delta P= p+P_0-p=P_0=\rho gh$, the buoyancy is F, $F=\Delta P\times S=\rho ghS=\rho gV$. When

F=mg, the buoyancy is balanced with the gravity of the wood, and the wood remains suspended.

It should be pointed out that due to the effect of transmission, the pressure of the atmosphere is cancelled and does not play a role in it, and it is automatically ignored in calculations later.

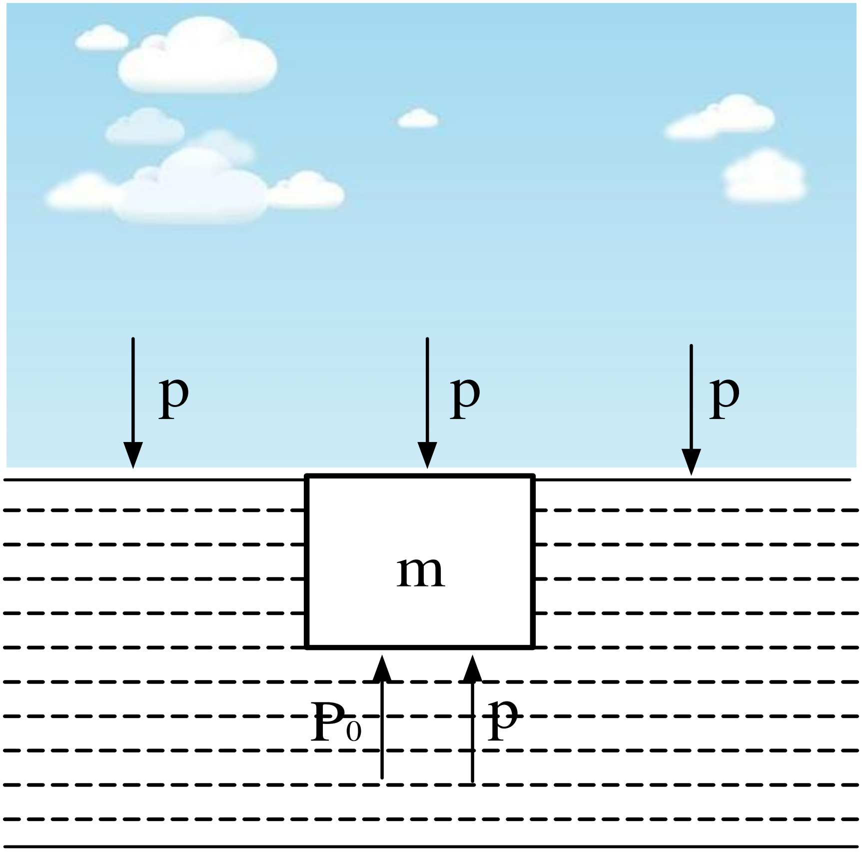

Fig 2: Wood floating on the surface of still water

There is also a case where the same wood is suspended in the water, and the upper surface does not rise to the water surface, as shown in Figure 3, the result is the same. $\Delta P = p_2 - p_1 = \rho g h$, $F = \rho g V$. If F=mg, the buoyancy is balanced with the gravity of the wood, and the wood remains suspended.

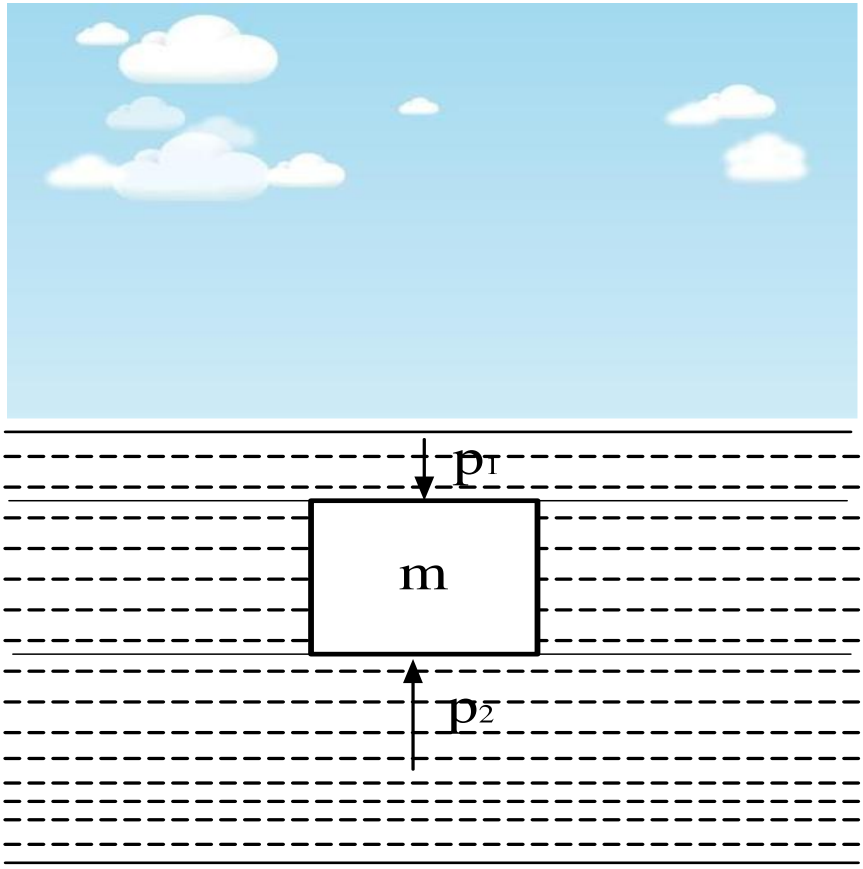

Fig 3: Wood suspended in still water

1.2 Dynamic pressure produces dynamic buoyancy

According to Bernoulli's theorem, when a fluid flows at a certain velocity v, the pressure at any point inside includes not only static pressure but also dynamic pressure, which is called total pressure, $P=P_0+\rho v^2/2$. When an object is placed in a torrent, it will be subjected to greater pressure than before, as shown in Figure 4.

A stone M of the same volume and size as m floats in the water stream, and the upper surface is flush with the water surface. At this time, the upper surface is only subjected to atmospheric pressure, which has been ignored, and the lower surface is subjected to full pressure $P=P_0+P_1$, and P_1 is dynamic pressure. Pressure difference between upper and lower surfaces $\Delta P = P$, $P_0= \rho gh$, $P_1=\rho v^2/2$.Then, the buoyancy $F=\Delta P\times S=\rho ghS+\rho v^2S/2=\rho gV+\rho v^2S/2$.

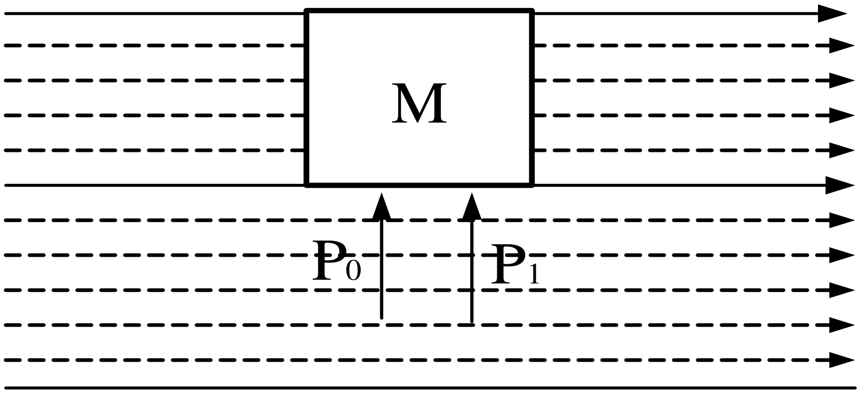

Fig 4: Stone floating on the surface of the rapids

The buoyancy at this time is divided into two parts: one part is caused by the original static pressure P_0, called static buoyancy, and the other part is P_1, caused by dynamic pressure, called dynamic buoyancy. The former is proportional to the volume of the stone, and the latter is proportional to the square of the lower surface area of the stone and the speed of the flowing water. Under the condition of keeping the volume constant, reducing the height h of the stone to the minimum, increasing the bottom area S, and achieving flattening, the dynamic buoyancy can be greatly improved.

There is also a case where stones of the same size are suspended in the water, and the upper surface does not surface, as shown in Figure 5, and the result is the same.

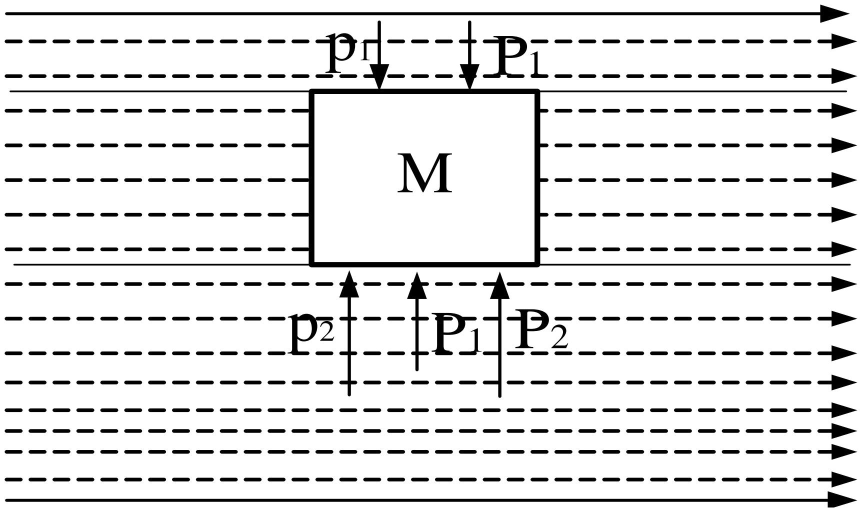

Fig 5: Stones suspended in the rapids

The total pressure on the upper surface is $p_1 + P_1$, p_1 is the static pressure, and P_1 is the dynamic pressure. Like atmospheric pressure, due to gravity, the dynamic pressure of the fluid acting on the upper surface of the stone will be transmitted from top to bottom, increasing the pressure at the lower surface position, the value is P_1.Therefore, the total pressure on the lower surface is $p_2 + P_1 + P_2$, p_2 is the static pressure at the lower surface, P_2 is the dynamic pressure, and $P_2 = P_1$.Pressure difference between upper and lower surfaces is ΔP, $\Delta P= p_2-p_1+P_2=\rho gh+\rho v^2/2$,

$F=\Delta P\times S=\rho ghS+\rho v^2S/2=\rho gV+\rho v^2S/2$.

2. Dynamic buoyancy is the cause of that the wing produces lift

Both air and water are fluid, now the above water flow is changed to airflow, and the stone M is replaced with a wing, as in a wind tunnel, as shown in Figure 6.

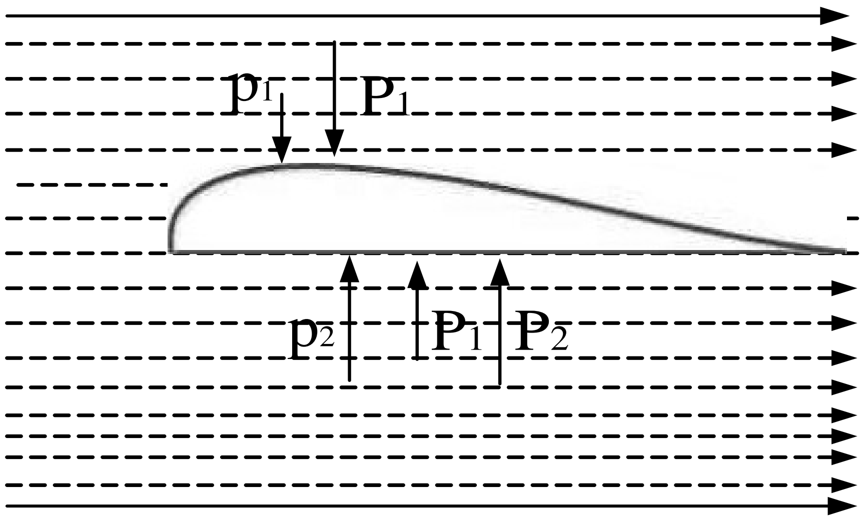

Fig 6: Wing airfoil in the wind tunnel

The upper and lower surfaces of the wing in the wind tunnel are under full pressure and seem to cancel each other out. As with atmospheric pressure, the dynamic pressure on the upper surface will be transmitted downward to the position of the lower surface, increasing the pressure on the lower surface. Because the wings are very thin, the static pressure on the upper surface is basically the same as that on the lower surface, $p_1=p_2$.The pressure difference between the upper and lower surfaces of the wing is ΔP, $\Delta P= p_2-p_1+P_2+ P_1- P_1= P_2=\rho v^2/2$.The dynamic buoyancy of the wing is F, $F=\Delta P\times S=\rho v^2S/2$.

Since the aircraft's fuselage and horizontal tail will also generate dynamic buoyancy in the airflow, the lift of the aircraft should be greater than the dynamic buoyancy F on the wings. Taking F_X as the lift, S_X is the horizontal projection area of the aircraft, $F_X =\rho v^2S_X/2+\rho gV$, $S_X > S$. Introduce a coefficient C_X, let $F_X = C_XF$, the calculation formula for the lift of the aircraft is obtained, $F_X = \rho v2SC_X / 2$, which is exactly the same as the current lift formula.

However, this does not mean that the explanation of Bernoulli's theorem is correct. Bernoulli's theorem calculates the lift as follows:

Let the velocity of the upper and lower surfaces be v_1 and v_2, respectively, then $p_1+\rho v_1^2/2= p_2+\rho v_2^2/2$,the static pressure difference between the upper and lower surfaces is ΔP, $\Delta P= p_2-p_1$, $p_2-p_1=\rho v_1^2/2-\rho v_2^2/2$.Let $v_1 = m v$, $v_2=v$, $\Delta P=（m^2-1）\rho v^2/2$. Let $m^2-1 = C$, then $\Delta P=\rho v^2C/2$, $F=\Delta P\times S=\rho v^2SC/2$.

Suppose the curve length above the wing airfoil is L_1, the time for the airflow to pass through the curve is t, then $v_1 = L_1 / t$; The length of the straight line below the wing airfoil is L, the time for the airflow to pass through it is t, then $v = L / t$, $m= v_1/ v_2= L_1/L$. Because the wings are very thin, $L_1/L<1.3$, $C= m^2-1<1.3^2-1=0.69$. $C<0.69$, it is obviously incorrect.

Of course, the dynamic buoyancy of the fuselage is proportional to its (upper or lower) surface area, that is, the plane's fuselage is flat and wide, the greater the dynamic buoyancy. This is a factor to be considered in aircraft design.

Take the Airbus A380 wide-body airliner as an example. Its maximum take-off weight is 560 tons, its wings cover an area of $845m^2$, and its take-off speed is 100 yards. Then, F_X=560000×9.8N=5488000 N, $\rho=1.293kg/m^3$, $S=845\ m^2$, v=90m/s. According to the dynamic buoyancy formula of the wing, $F=\rho v^2S/2$, $F=1.293\ kg/m^3\times 90^2\ m^2/s^2\times 845\ m^2/2=4424970N$.The dynamic buoyancy F on the wings contributes most of the lift, $C_X= F_X/F$=5488000/4424970=1.24.

When v=110m/s, $F=1.293\ kg/m^3\times 110^2\ m^2/s^2\times 845\ m^2/2=6610140N$, the lift generated by the wing is greater than the maximum takeoff weight, the aircraft will accelerate and rise until the stratosphere and stable cruise. At this time, since the air density ρ will decrease greatly, the dynamic buoyancy will decrease, However, the speed of the aircraft has risen to v = 250m / s, which will greatly increase the dynamic buoyancy, completely offset the adverse effects brought by the former, and maintain balance.

Half an hour before landing, the aircraft will gradually slow down. v↓, F↓, Flight height H drops; H↓, ρ↑, F↑, Buoyancy and gravity are balanced. In this cycle, the speed and altitude of the aircraft continue to decrease.

When approaching the airport, descending the aircraft will produce a negative pressure above the wing, that is, a static pressure less than atmospheric pressure, and a positive pressure below the wing, that is, a static pressure greater than atmospheric pressure. Therefore, the pressure difference between the upper and lower surfaces of the wing will inevitably produce a lift.

This situation is similar to the operation process of a wind box, as shown in Figure 7.The wind box consists of a sealed box, a piston, a piston rod, 2 intake valves and an exhaust port. When the piston advances forward, a negative pressure is generated behind the piston, which opens the intake valve on the rear side and attracts air into the box; the intake valve on the front side is closed, the air in front of the piston is compressed, and it is quickly discharged through the exhaust port. If the exhaust port is blocked at this time, the pressure in front of the piston will increase sharply, and the pressure difference between the front and back will increase accordingly. When the aircraft approaches the ground, it is similar to the piston in the wind box. The air underneath is under pressure from the plane but is blocked by the ground and cannot be fully “drained”, this caused the pressure difference between the upper and lower planes to increase rapidly. As long as this pressure difference reaches 0.064standard atmospheric pressure, it produces lift on the wing is F_0, $F_0=0.064\times 101325N/\ m^2\times 845\ m^2=5492209.6N=560429.6kg\times 9.8m/s^2$,about 560.4 tons, approximately equal to the total weight of the aircraft (560 tons).This is the root cause of the so-called "ground effect" effect of aircraft. The characteristic of the ground effect aircraft is that it has a large load capacity, far exceeding the transport aircraft of the same level, proving that the pressure difference between the upper and lower planes must be greater than 0.1 atm.

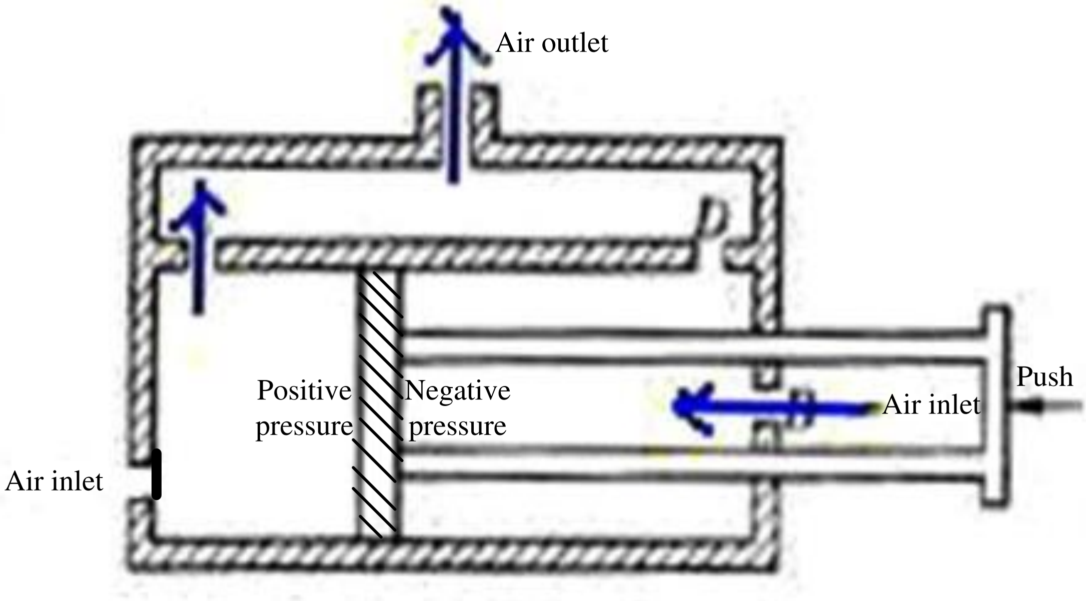

Fig7： The piston ina wind box moves forward

3. Conclusion

The velocity of air is the only source of lift. Velocity produces dynamic pressure, dynamic pressure produces dynamic buoyancy, and dynamic buoyancy produces lift.

In the final analysis, the lift of the aircraft is still the "buoyancy" of the air, but it is only dynamic buoyancy. The theory of dynamic buoyancy combines Archimedes' law and Bernoulli's theorem.

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Figures

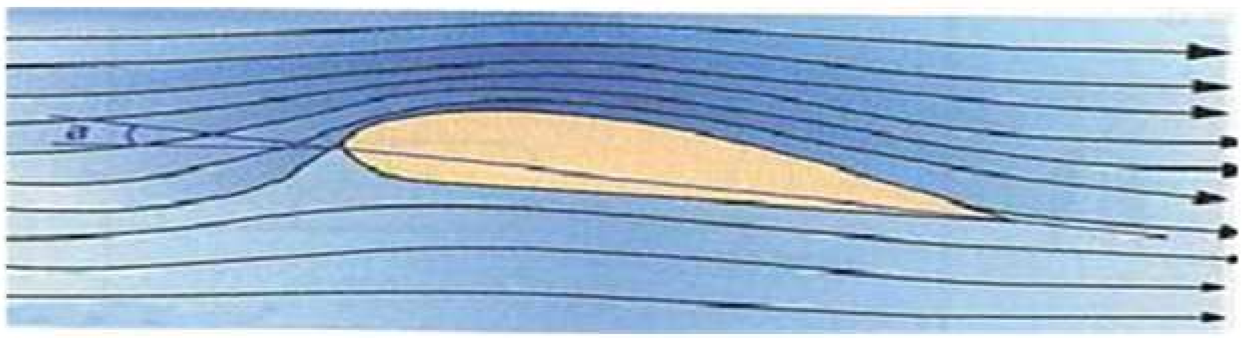


Figure 1

Wing airfoil in airflow

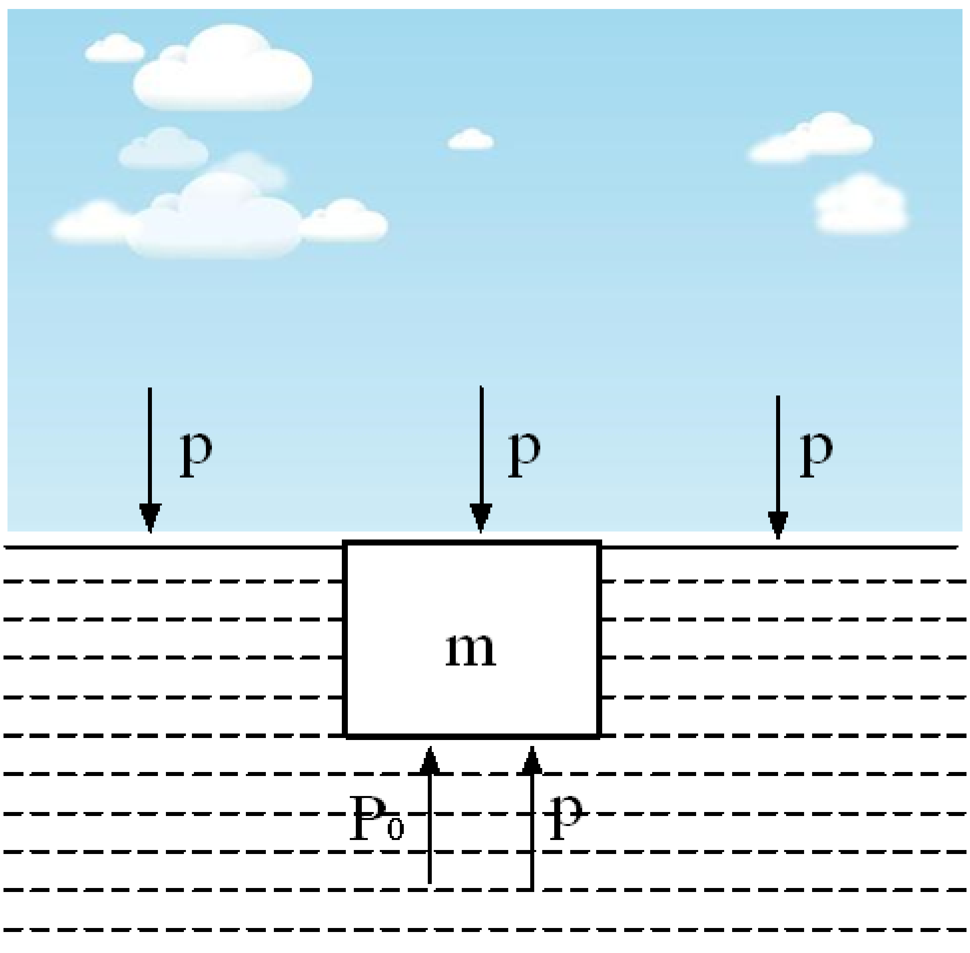


Figure 2

Wood floating on the surface of still water

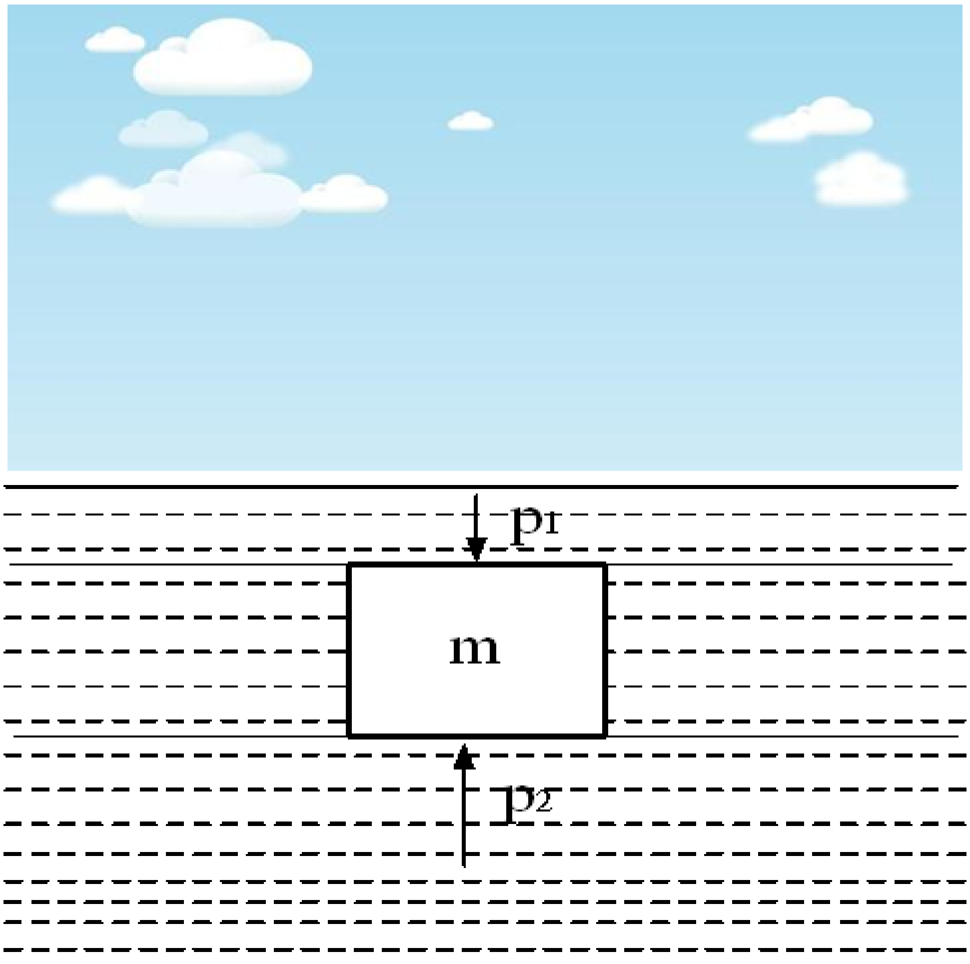


Figure 3

Wood suspended in still water

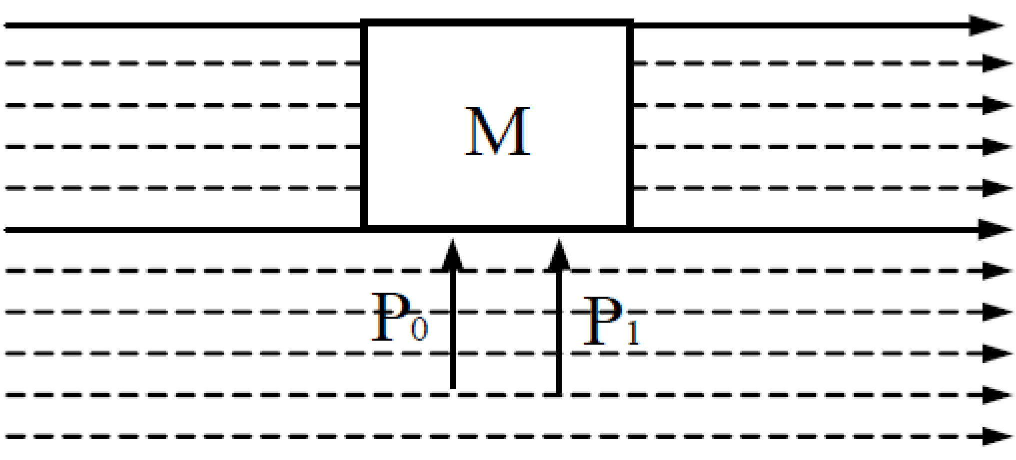
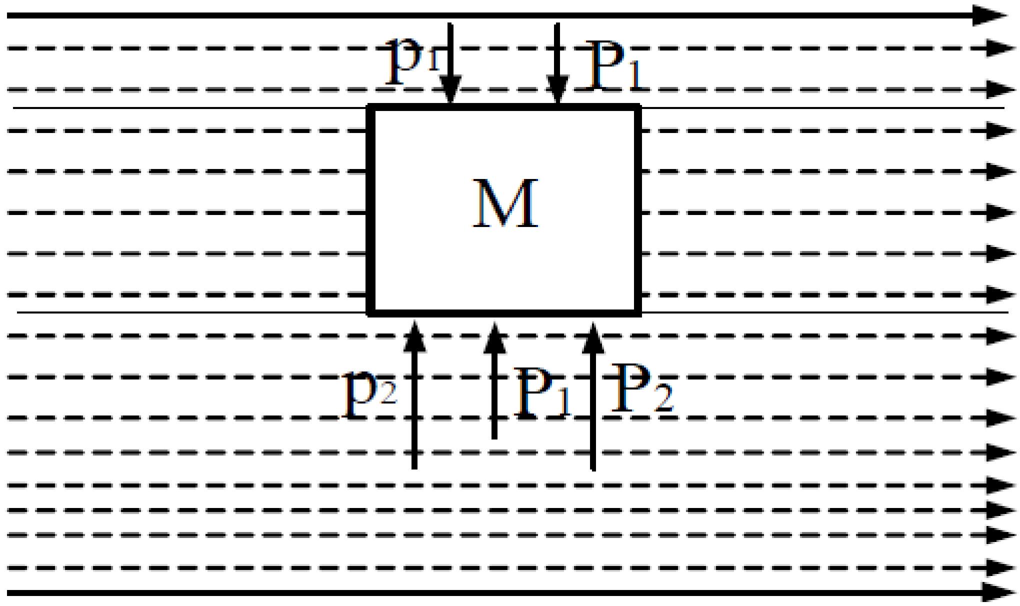


Figure 4

Stone floating on the surface of the rapids



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Stones suspended in the rapids

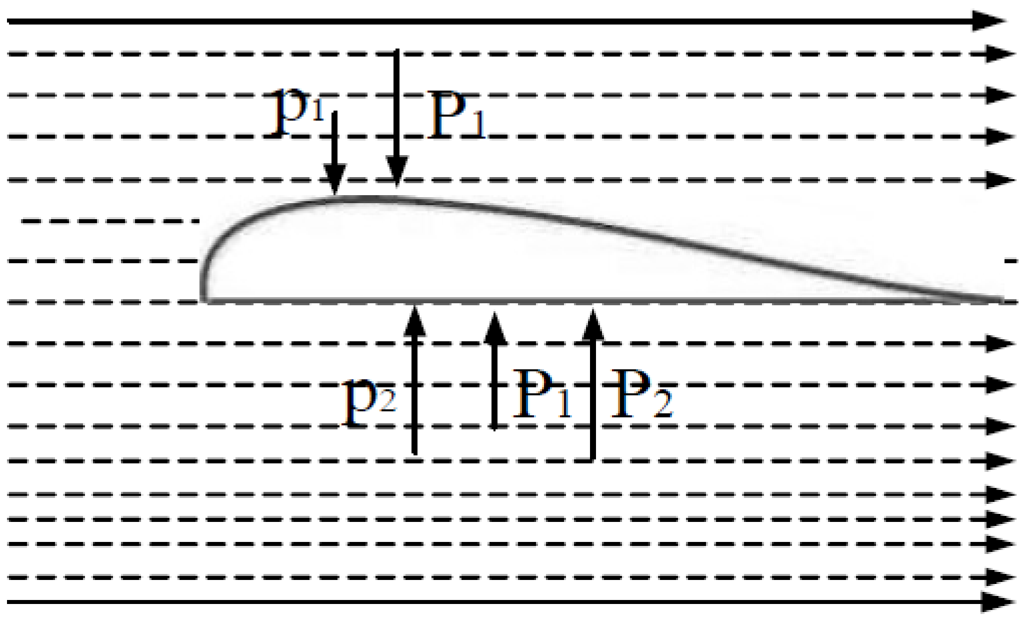

Figure 6

Wing airfoil in the wind tunnel

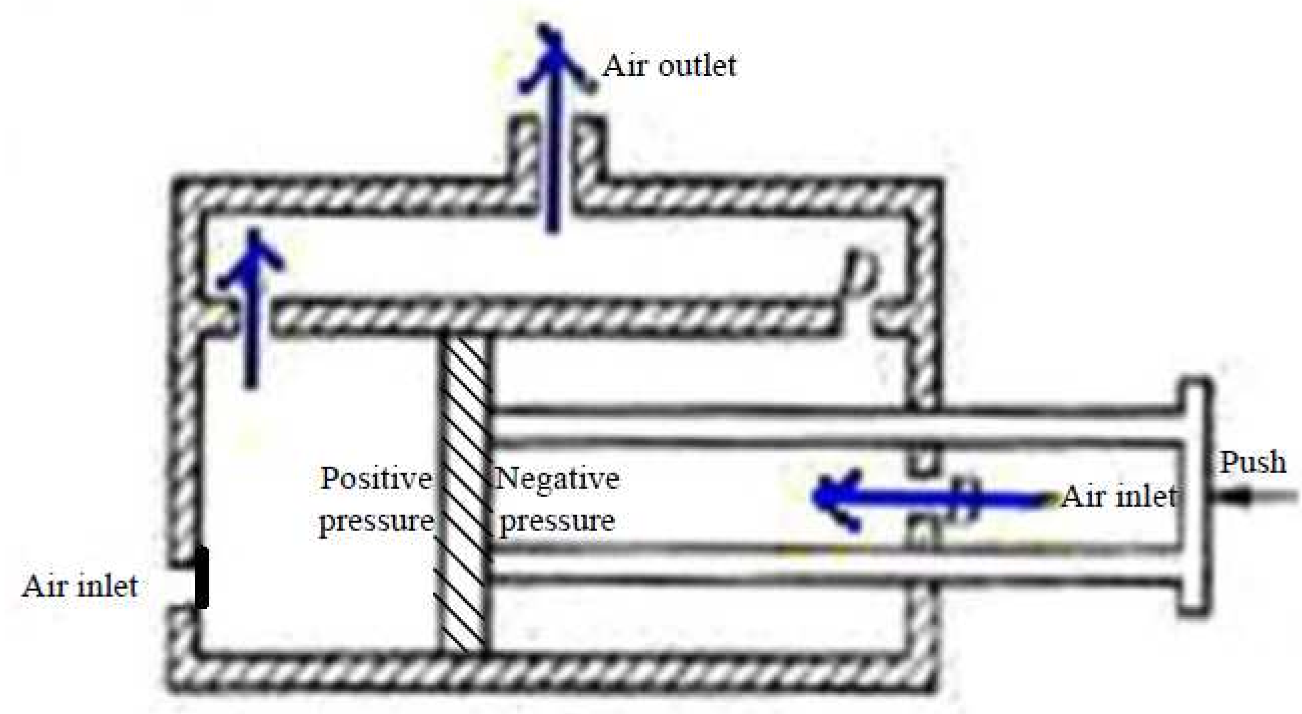

Figure 7

The piston in a wind box moves forward