Studying the Relationship Between Aircraft Stability and Shape Based on Hydrodynamics

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Abstract. In recent years, with the rapid development of industrial technology, the application of fluid mechanics in the industrial field has become more and more frequent and has been well developed. Of course, more and more scholars gradually pay attention to the development and application of fluid mechanics. As an important means of transportation in daily life, aircraft plays an important role in both civil and military affairs. The development of fluid mechanics has made an important contribution to solving the problems of aircraft design and stability. In this paper, the application and research status of hydrodynamics in aircraft design will be reviewed by means of literature analysis. At the same time, the application of hydrodynamics in aircraft design and life will be reviewed from many aspects, and the future development trend of hydrodynamics will be prospected. So far, there are many difficulties and hotspots in the development of fluid mechanics, and this paper will focus on these contents. I hope it can provide direction for its later development.

Keywords: Fluid mechanics, Aircraft stability and shape, Application of hydrodynamics, Development.

1. Introduction

Fluid mechanics is an independent branch of mechanics, is a study of fluid equilibrium and fluid mechanical motion laws and its practical application of technology science, in many industrial sectors have a widely apply in work, aviation industry in aircraft [1]. It can't be built without aerodynamics; Hydrodynamics is used in the shipbuilding sector, as are various specialties in civil engineering Add a close relationship [2]. Fluid is a general term for gas and liquid. In people's life and production activities anytime and anywhere fluid can be encountered, so fluid mechanics is closely related to human daily life and production undertakings [3]. The atmosphere and water is the two most common fluids. The atmosphere surrounds the whole Earth, and 70% of the Earth's surface is water. Atmospheric transportmotion, sea water movement (including waves, tides, mesoscale vortices, gyres, etc.) and even the flow of molten slurry deep in the earth It's all about fluid mechanics. This paper mainly explores the relationship between aircraft shape and stability in fluid mechanics, as well as different experiments to explore the correlation between them, and draw a reliable conclusion through data, showing and comparing the most popular aircraft designs in the world and the relationship between their stability and shape design [4].

It is concluded that the future development of aviation is based on the prospect of fluid mechanics [5]. In each experiment, the control variable method will be adopted to get a reliable experimental result. Through the website query and literature application, the current aircraft design will be displayed in the paper. Through the limited material simulation design, the wind tunnel experiment will be put into the simulation, and the relationship between stability and aircraft shape design will be obtained by observing the experimental results.

2. The relationship between aircraft design and stability

2.1. Introduction of the most common airplanes design over the world

The Boeing 747 and Airbus A380 are the most used commercial airliners in the world [6]. The wing of Boeing 747 adopts cantilever single wing, the relative thickness of the root wing is 13.44%, the outer wing is 8%, and the sweep Angle of the 1/4 string line is 37°30'. Double beams made of aluminum alloy hurt the safety system. The leading edge of each wing has a leading edge flap, and the leading edge of the wing has three pieces of Krueger flap at the base of the wing [7]. The wings also have aluminum honeycomb structure spoilers on their surfaces and three-slit rear edge flaps. The tail is a fully mobile horizontal cantilever structure made of aluminum alloy for damage safety. nuclear power four jet turbofan engines. The aircraft is powered by the engine through four alternators, and the auxiliary power unit contains a generator. A backup AC hydraulic pump and four different hydraulic systems. A five-prop hydraulic retractable landing gear is used.

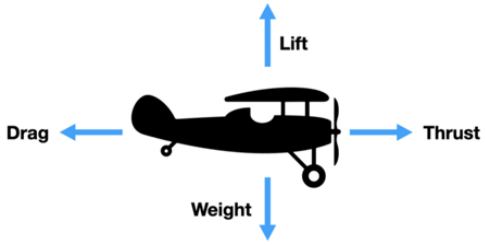


Figure 1. The forces exerted on the plane

2.2. The introduction of the work principle of the planes takeoff

Let's take a look at two incorrect explanations for the wing lift principle. The most popular explanation is that the top surface of a wing is bent and the bottom surface is flat [8]. The air above it moves more quickly than the air below it because the air flowing over the top and bottom surfaces must reach the trailing edge in the same amount of time. Additionally, Bernoulli's theorem states that lift is produced because the air pressure is low on the top surface of the wing and high on the bottom.

The air flowing over the upper and bottom surfaces of the wing does not actually reach the trailing edge at the same moment, hence this statement is wholly false.

Another explanation is based on the conservation of mass [9]. The convex surface of the wing reduces the area of flow above it, so the fluid accelerates and generates low pressure. This is not entirely true, but quantitatively the pressure drop from this contraction is minimal, and the pressure on the surface of a real wing is much lower.

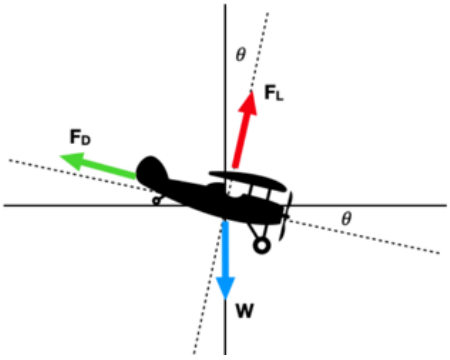


Figure 2. The inclined angle of the plane take off and the force variable with the angle [10]

2.3. Differential pressure interpretation of lift

Bernoulli's law can be used to explain the lift of a wing. Although the air flowing over the top and bottom surfaces of the wing is not in a streamline, in the far front all the air has the same pressure and

speed and has the same mechanical energy. And for the wing, the viscosity effect on the pressure can be ignored, which fully satisfies the application condition of Bernoulli's law [3].

But Bernoulli's law, which describes the relationship between the flow rate and the pressure change, doesn't say which is the cause and which is the effect. If you think of it as Newton's law, force is the cause of the change in velocity, it's the decrease in pressure that causes the increase in velocity. Therefore, the low pressure area on the upper surface of the wing can be considered first, and then the acceleration of the incoming airflow can be considered.

The produce of low pressure area can be understood that the air flow along the curved surface requires centripetal force, which is provided by the differential pressure force. The undisturbed air pressure away from the wing is atmospheric, so the air pressure near the wing surface must be lower than atmospheric. In other words, the pressure on the inside of a curved streamline must be lower than the pressure on the outside. The Kornda effect is responsible for why the air flows not in a straight line, but against the curved surface of the wing. So, the Koonda effect is the basis of lift.

The upper surface of the wing, which has a significant area of low pressure, is what produces the majority of the lift. Typically, a small area of high pressure does not exist on the bottom surface. Even some wings' lower surfaces have low pressure zones, but the pressure there is a little higher than on the upper surface. The fact that the pressure on the majority of the wing's surface is below atmospheric pressure while air is flowing around an object is due to the fluid property of fluids. Since a wing gets lift by pumping air downward, the Angle at which it leaves the wing is important. The ability to bend the airflow downward at an Angle is the key to whether a wing can generate lift. The shape design of the wing is not mainly to large lift, but to small drag. The ratio of lift and drag is called lift-drag ratio. The wing with large lift-drag ratio is the wing with good aerodynamic performance. If you just want lift instead of drag, it's really easy to do. The shape of the kite, for example, is not important, as long as it is kept at a certain Angle of attack to the wind it will generate enough lift. At this time the resistance of the kite is also very big, but the kite wire lead, do not need power, a little bit of resistance does not matter.

Factors that affect the stability of aircrafts: Position of center of gravity, speed, a very high level, flying at a high Angle of attack.

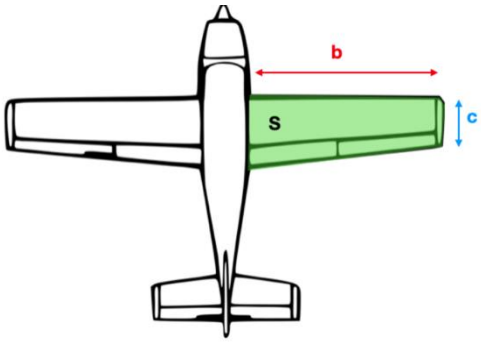


Figure 3. Design of the airfoil

3. Simulate wind tunnel experiment

3.1. Motive of this experiment

First off, fluid mechanics examines how liquids and gases move, which is why it also involves aerodynamics. Elasticity and plasticity are included in solid mechanics since it deals with the stress and strain that a solid experiences when subjected to an external force or acceleration [6]. It is clear from the standpoint of aircraft design that solid mechanics is directly tied to the structural design of aircraft while fluid mechanics is closely related to the form design and propulsion of aircraft [11]. There are always a number of solid mechanical issues that need to be resolved in the creation or usage of airplanes, particularly through the use of experimental stress analysis. To measure the strain on components or structures, photomechanics is used.

3.2. The introduction of how to use the materials in everyday life to simulate a wind tunnel

The results of the wind tunnel experiment will be used in the production of cars, helicopters, and other items in the aerospace industry. An essential step in the development of airplanes is the wind tunnel experiment. With the advancement of industrial aerodynamics, it plays a significant role not only in the study and development of aviation and aerospace engineering, but also in the transportation, housing, wind energy, environmental protection, and other areas. When creating things that fly through the air, run on roads, or ply water, wind tunnel (or water tunnel) studies must be performed.

The wind tunnel is mainly composed of tunnel body, drive system and measurement control system. The form of each part varies according to the type of wind tunnel. To replicate the airflow around an object or entity, quantify the impact of the airflow on the object or entity, and observe physical phenomena, air flow is manually created and controlled. The development of aircraft is impossible without the use of a wind tunnel [2]. With the advancement of industrial aerodynamics, it is essential for transportation, housing building, wind energy usage, and other industries in addition to playing a significant role in aviation and aerospace engineering research and development. This experimental approach makes it simple to regulate the flow conditions. The model or item is frequently fixed in the wind tunnel during the experiment, and measuring and control tools and equipment are used to collect the experimental data.

3.3. Working principle of wind tunnel and observations of different shapes aircraft have different experiment phenomenons

A few different kinds of wind tunnels exist. First, there are two variations of the low speed wind tunnel test section: open and closed. There are four different section shapes: rectangle, circle, octagon, and ellipse. The test item and the kind of wind tunnel determine the length. Since the 1960s, researchers have created wind tunnels with two or even three experimental sections. A conduit used to create artificial air flow is a wind tunnel (artificial wind). The location where a consistent air flow may be produced in such a pipe is where the automotive wind tunnel test is conducted. The energy ratio Er is frequently employed in low-speed wind tunnels to assess how economically efficient they are to operate. Where, v0 and A0 are the experimental section’s airflow velocity and sectional area, respectively; is the air density; and N are the motor's input power and system efficiency, respectively. Er is 3-6 for the wind tunnel’s closed test segment. Reynolds metric Re serves as the primary simulation variable in low-speed wind tunnel tests. However, it is required to mimic additional factors because of various experimental items and initiatives. Froude number Fr should also be reproduced in various situations where gravity is involved (such as spin, launch, and dynamic model experiments). Both the flight Mach number and the rotor tip Mach number should be recreated in the helicopter experiment.

Additionally, the transonic wind tunnel's Mach number is 0.51.3. Even if the driving force or pressure is increased, the air flow speed in the test section won't rise until it reaches the sound speed at the lowest point in the wind tunnel. Choking is the term for this occurrence. As a result, the model can only be put on the upper surface of an aircraft wing or the convex surface of the wind tunnel's bottom wall, and tests may be conducted in the transonic zone created by the upper surface's curvature. The airflow is unbalanced, and the model cannot be too huge. Later, it was discovered. At low supersonic speeds, the experimental section with the permeable wall can also minimize wall interference and weaken or abolish the wall reflection wave system. The model's shock wave reflects as an expansion wave on the free boundary and a shock wave on the real wall. The reflection wave system of the tunnel wall can be significantly reduced or completely removed if the porous wall has an appropriate free boundary.

Thirdly, a supersonic wind tunnel with a Mach number of 1.5-4.5. Before entering the experimental part of the wind tunnel, the airflow travels through a Laval tube to attain supersonic speed. The velocity of air flow in the experimental section solely depends on the ratio of the cross-sectional area of the experimental section to the cross-sectional area of the nozzle throat as long as

the pressure ratio before and after the nozzle is sufficient. The most common nozzle is a two-dimensional one with two plane sides and two profiles.

3.4. The methods to varies the shapes of aircraft and the materials of planes made in this simulation experiment

Physical experiments and model experiments are the two categories of aerodynamic experiments. The only reliable way to determine an aircraft's aerodynamic performance and calibrate the results of other experiments has always been through physical experiments, such as aircraft flight tests and live fire missile tests, which do not introduce simulation distortion issues like model and environment. Such tests can't be done at the beginning of the product development process since they are expensive and have challenging settings to manage. As a result, model experiments are typically referred to as aerodynamic experiments. According to the many ways that air (or other gases) and the model move in relation to one another, aerodynamic tests may be categorized into three categories:

1) Air movement, model immobility, such as wind tunnel experiment.

2) In experiments like flight, model free flight (which is conducted when a powered or unpowered aircraft model flies in the air), rocket sled (which is conducted when a model is carried by a rocket-propelled sled traveling at a high speed on the orbit), and rotary arm experiment, the air is still and the object or model moves (the experiment is conducted when the model is carried by the rotary arm).

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4. Aviation industry

4.1. The effect good stability brings on aviation industry

The stability of aircrafts indicates security and safety in Aviation industry, the two factors being the foundation and bottom line of any individual. Without highest level of safety standard, the aviation would not even grow as an industry, meaning no passenger, no employee, no goods, no supply chain, no investment, etc. Basically the stability of aircrafts would be taken as the most important factor for any air lines from day one of its establishment. Nobody will trust and take any flight with stability issues.

The stability is of great importance, since the world aviation industry also makes a lot of contribution to development in economy. Not only has it boosted world trade activity by providing more rapid and convenient movement of passengers and goods domestically and internationally, but has also created jobs and business opportunities to a large number of people and many companies. For example, in order to boost the local economy, the authorities would build or expand local airports to attract investment and people from the outside. The aircraft manufacturers would invest more research and development efforts to improve the technology advancement and thus the aircraft safety, enabling their competitiveness in the marketplace. By doing so, the industry will grow continuously, gaining reputation, attracting talents and investment, involving more companies on the supply chain, etc.

New players will join, new technologies will emerge, more investment will enter this industry, etc. The stability of the aircraft will, on the other hand, result in the stability of the aviation industry. This is a good eco-system.

4.2. Other factors needed to consider besides stability

Time-saving is always an issue to travelers, both business travelers and tourists. The evolution history of transportation states people want to save time spent on way. Therefore the high speed aircraft will most likely be the direction of the aviation industry development. However, for aircraft, high-speed makes sense only if the stability is not an issue, thinking about the sad curtain call of

supersonic Concorde Aircraft in 2003. Even so, the next generation of high-speed and ultra stable aircraft is still worth looking forward to.

5. Prospects and discussion

The usage of designs with good stability can lead to prosperity of the aviation industry. This article has already mentioned several aspects that contribute to the aviation industry. Nowadays, there are increasingly more companies that turn to more advanced designs of stability. For example, the Boeing Company's Boeing 777X has a lot of the design requirements went into the bezel (or frame). The new bezel features are designed to provide bracing and added stability in turbulence. Thus it enables the aircraft to fly in a more comfortable and smooth way.

6. Conclusion

In conclusion, an advanced design on aerodynamics brings various effects on many fields of aviation. The stability in the air marks the comfort of passengers, the less money on fuel, development on industry and so on. Therefore, it is expected that better and better aircraft design will emerge in the future, taking all factors into account and becoming a good design.

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