Review and Analysis of Variable Swept Wing Technology

YongyueYUAN
Binzhou University, China

ABSTRACT : *The wing sweep angle of a variable sweep wing aircraft is variable, and it can adapt to the better aerodynamic efficiency of the aircraft at different flight speeds. This is the greatest advantage of the variable sweep wing aircraft, which is different from the fixed wing aircraft. However, the variable swept wing aircraft also has the disadvantage of poor stability and large and complex actuator system. By reviewing the development history and research status of variable sweep wing aircraft, the advantages and disadvantages of variable sweep technology are analyzed, and several key executing agencies are listed. Finally, the development of variable sweep technology is prospected.*

KEYWORDS -*wing, aerodynamic characteristics, variable sweep law, variable sweep mechanism*

I. INTRODUCTION

The flight speed of aircraft has always been an important index to measure the flight performance of aircraft, especially for military fighters with high maneuverability requirements, so it is extremely important to improve their flight speed. In November 2018, the J-20 and J-10B military aircraft showed excellent flight performance at the Zhuhai Air Show in China. However, it is difficult for aircraft to maintain good aerodynamic characteristics in the process of increasing flight speed from low speed to high speed. Therefore, it has become the focus of academic research to improve this problem through the special design of aircraft shape, especially wing.

Flat-wing aircraft has better performance at low speed, but when the flight speed is in the transonic stage, the shock resistance will increase geometrically with the increase of speed. Swept-wing aircraft has the advantages of fast speed and smooth flight at high speed, but its flight efficiency is low at subsonic speed. In conclusion, this contradiction can be improved if the sweep angle of the wing can be changed during flight. Variable swept-wing aircraft emerged as the times require. The swept-back angle can be changed with the change of Mach number, angle of attack and other flight parameters, so as to achieve high adaptability. This type has the advantages of high integrated flight performance and low fuel consumption, and can play a higher operational efficiency in different combat missions. Therefore, variable swept wing aircraft has great research value.On the basis of summarizing scholars' research on variable sweep wing, this paper summarizes in detail the structural forms of different variable sweep wing, and analyses the flight principle of variable sweep wing. At the same time, the research status of variable sweep wing aircraft at home and abroad is summarized. Finally, the structural forms and flight of integrated wing are summarized.Based on the principle, the development of variable sweep wing is prospected.

II. DEVELOPMENT HISTORY OF THE WING

2.1 Variable Swept Wing Technology

In 1944, German designer Messersmitt put forward the concept of variable sweep wing, and designed the world's first variable sweep wing concept aircraft, Me P. 1101, which put forward a new direction for aircraft design and manufacture. After the end of World War II, Bell Laboratory in the United States designed the Bell X-5 which changed the sweep angle in flight on the basis of studying Me P.1101, and completed its test flight in 1951. But the change of pressure center of gravity will cause the nose to be pushed down and the stability is poor. In the mid and late 1960s, General Dynamics and Grumman co-developed the F-111 dolphin (Aardvark), which is known as a variable swept-back aircraft in the true sense of production and service, but was abandoned due to its far overweight.The F-14 developed by Grumman Company in 1968 is the most advanced. Its wing is

controlled by an airborne computer and can realize automatic step less change of sweep angle from 20 ~68. However, the shortcomings of high cost and maintenance limit its practicability.

After a long period of bottleneck and low tide of development, the idea of combining variable swept wing technology with UAV was put forward, this ushered in a new life for the development of variable swept wing. And new intelligent materials are constantly found, which provides a material basis for them.In 1980, China launched a large-scale ministerial variable swept wing technology research project, which took more than eight years to achieve significant results. However, due to the limitation of the level of science and technology, the attempt of Qiang-6 was forced to declare failure. Since then, there has been no substantial progress in the research of variable swept wing technology in China.

2.2.Application Status of Variable Swept Wing

The design of variable swept wing combines the aerodynamic advantages of the aircraft at low and high speeds.It can make the aircraft have excellent flight performance in both low and high speeds. At present, domestic research institutes and institutions of higher learning is continually carrying out in-depth research on this issue, mainly focusing on the research of optimal variable sweep law, new variable sweep mechanism, modeling method of variable sweep wing and computer solution calculation.

LU Jizhaoused genetic algorithm and CAITA and Fluent software to study the optimal variable sweep rule of variable sweep wing at mid-low altitude. LIU Lu and others used CFD numerical simulation method and MATLAB software to solve the optimal sweep law at specified height. WANG Zhao designed a spring adaptive variable rear wing mechanism, and simulated its variable sweep law with aerodynamics and kinematics, which verified the feasibility of the new mechanism. HUANGMinghe used Radau Pseudospectral Method (RPM) to conceptually design and optimize the trajectory of a variable swept wing tactical missile at hypersonic speed, and calculated the optimal value.In addition, other scholars have carried out detailed studies on gliding trajectory optimization design, drag characteristics analysis, dynamics control and simulation, UAV design and aerodynamics of variable swept wing missiles.

III. TECHNICAL ANALYSIS OF VARIABLE SWEPT WING

3.1. Technical characteristics

Because of the variable sweep angle of the wing, the variable sweep aircraft has better aerodynamic efficiency at different flight speeds, which is also the biggest advantage different from the fixed-wing aircraft. When a variable sweep wing aircraft is flying at low speed, it can use a smaller sweep angle, which increases the lift of the leading edge of the wing and increases the efficiency of the wing. When the aircraft is flying at supersonic speed, it can use a larger sweep angle, which can improve the acceleration performance and high-speed flight ability of the aircraft.

Therefore, variable swept wing aircraft also has the characteristics of short skiing distance and good landing performance. It has good gust response characteristics in low altitude flight. It is often used in fighter, fighter, heavy bomber and other aircraft, such as Tu-160 of the former Soviet Union, B-1 bomber of the United States and so on.At the same time, there are two main shortcomings: first, the change of wing sweep angle will result in the change of aerodynamic center position, which will affect the flight stability of the aircraft; second, the existence of variable sweep wing is driven by complex mechanisms and control systems, which increases the weight of the fuselage, reduces the flexibility, and also reduces the hanging point of the wing and reduces the maintainability. For example, F-14 fighters are still overweight at the expense of conventional design and manufacturing procedures, and the cost of manufacturing and maintenance is high. Therefore, the variable swept wing technology needs to continue to improve the driving mechanism and structure to ensure that the aerodynamic center changes within a reasonable range and reduces the weight for easy maintenance.

3.2. Mechanisms of variable swept wing

Since the concept of variable swept wing was put forward by Germany in 1944, the development of variable swept wing aircraft has been restricted by its complex structure, large weight, complex operation and high maintenance cost. Up to the last 20 years, new materials and technologies have been proposed, which are expected to make breakthroughs in adaptive aircraft and open up a new path for the

development of variable swept wings. Therefore, the design of variable swept wing structure is particularly important. Simplifying the structure form, reducing the volume and weight of the structure and reducing the maintenance cost have become an important task for the application and development of the wing. Hydraulic mechanism, crank rocker mechanism and slider mechanism are typical mechanisms used in variable sweep wing.

Hydraulic mechanism is mostly used in traditional large-scale and high-speed aircraft, and its sweep angle depends on the stroke of push rods on both sides. With higher output torque and transmission efficiency, the aircraft can have higher security and stability in the process of deformation. However, because of its large mass and volume, hydraulic mechanism is not suitable for adaptive aircraft.

The crank-rocker mechanism transforms the output force of the motor into the reciprocating swing of the rocker through the whole rotation of the crank. It has the advantages of lighter weight and lower complexity. It is easy to manufacture and manufacture. The construction of the motion forms has diversity and can realize different motion rules and requirements. However, because the inertial force and moment are not easy to balance, the synchronization is low, the error is large and the stability is poor, so it is not suitable for high-speed transmission

The slider mechanism is also a mechanism whose sweep angle depends on the stroke of the push rod. Synchronization depends on the installation accuracy of slider. The driving mode is screw nut drive, so the mechanism is more complex, but has better stability. Generally speaking, the ideal organization should be light and efficient. Compared with the ideal standard, the existing mechanisms are still of high quality, not suitable for small and medium-sized variable swept-wing UAVs, and at the same time, their stability and durability are not ideal. This is an urgent aspect for the future development of variable swept wing technology for small and medium-sized adaptive aircraft.

IV. CONCLUSION

In this paper, the development process of variable swept wing technology from its emergence to now is reviewed. At the same time, the technology of variable swept wing is analyzed. It is concluded that the existing technology is not enough to fully play the advantages of variable swept wing. At present, the application of variable swept wing technology in large aircraft has been relatively mature, but due to the continuous advancement of new technologies and materials, this technology still has great potential. If the technology of variable swept wing is popularized in small adaptive aircraft, it will certainly bring a new revolution in this field.

It can bring new development to the traditional large-scale man-made control aircraft. From the point of view of current development, the research of variable swept wing UAV is still in its infancy, and there are many aspects to be improved and deepened. For example, in the aspect of mechanism design, the existing mechanism schemes cannot fully achieve the ideal state of lightweight, precise and high transmission efficiency, which has great room for improvement. We should try to start with new materials, and change the sweep angle mainly by natural aerodynamic drag to make it sweep naturally, and then use computer micro-manipulation to reduce the influence of partial air flow interference, so as to obtain the best sweep angle more accurately.

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