Aircraft Braking System

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Abstract

Aerospace industry is evolving at an ever rapid pace. Earlier, aircrafts relied more on slower speeds and grassy runways than on brakes for stopping. With the advent of new and more powerful high speed aero-vehicles, the need for a more reliable and robust braking system increased, a braking system that would ensure minimum stopping distance, easy manoeuvring of the aircrafts and better heat dissipation. The paper presented provides an overview of the methods employed for effective braking in an aircraft. The system primarily consists of a number of interacting elements such as the disc brakes, thrust reversers, air brakes and spoilers. Disc brakes convert the excess kinetic energy into heat by friction. Thrust reversers redirect the airflow so as to increase the thrust in a direction opposite to that of flight travel, thereby assisting in deceleration of the vehicle. Spoilers and airbrakes are structures which help in increasing the drag. These elements altogether are responsible for providing necessary retarding force to the aircraft.

Keywords

Spoiler, Disc Brake, Thrust Reverser, Airbrake

I. Introduction

A. Forces on an Aircraft

An aircraft in flight is under the influence of many forces. The four primary forces acting on a straight and levelled aircraft are weight, lift, thrust and drag.

![Fig. 1: Forces on an Aircraft](image)

Weight is defined as the force acting on the aircraft due to gravity. Lift is the force acting perpendicular to relative motion and opposes weight. The wings of an aircraft are curved on top but flat at bottom. This cross sectional shape of wings is known as airfoil. When this shape moves through the air at a high speed, air velocity is higher at the top surface of the wing than the bottom. This causes the pressure on top of the wing to be lower than the pressure on the bottom of the wing. This pressure difference generate lift and increases with the increase in the angle of attack (it is the angle between relative wind and chord of airfoil). Thrust is the forward force that is created by the propellers or the engine and is responsible for forward movement of aircraft. Drag is the force acting in direction opposite to the thrust. There are two types of drag: parasitic and induced. Parasitic drag is caused due to air resistance to the aeroplane surface and its components. Induced drag is an inevitable part of lift caused due to redirection of air by the wings. The greater the angle of attack, greater the induced drag. For a particular plane the higher the speed the lower is angle of attack required to maintain its level. Induced drag is inversely proportional to square of the speed. Parasitic drag on the other hand increases with speed. The aerodynamic efficiency of an aircraft is maximum at a speed where the overall drag (sum of induced drag and parasitic drag) is minimum. This speed is known as the minimum drag speed.

B. Braking System

Brakes are responsible for conversion of excess kinetic energy into thermal energy by increasing the friction. Increasing the amount of friction (i.e. is the resistance offered to motion of a vehicle) reduces the speed of motion of the vehicle. Braking systems employ this principle for slowing down or stopping the vehicles. Braking systems in aircraft are of three basic types: mechanical, hydraulic and pneumatic brakes.

Mechanical brakes are those which are operated by the use of linkages, levers, cams etc. Hydraulic brakes make use of fluid pressure for transmission of pressure to the braking components while Pneumatic brakes use air pressure for transmitting brake power. These systems either increase the surrounding air drag with the help of airbrakes, spoilers, flaps, reverse thrusters, drag chutes, etc or increase the ground drag using anchors, skids etc for effective braking. Different types of entities used for braking have been explained further in this paper.

II. Spoilers and Airbrake

Spoilers are devices used to destroy the lift of an aircraft. These are flap like structure of rectangular cross-section whose leading edge is hinged to the wings (at an angle) disturbing the streamlined flow of air thereby changing the amount of lift. The net force on aeroplane in the vertical direction is equal to weight minus lift. Thus, when the spoilers are employed lift gets reduced as a result the net downward force acting on the body increases. Spoilers are of two types: flight spoilers and ground spoilers.

![Fig. 2: Spoiler Hinged on Wings](image)

Flight spoilers are used to reduce lift, without increasing speed to a very high rate. This allows easier descent of the aircraft. Ground spoilers also known as lift dumpers are deployed on landing. They slow down the vehicle by increasing the drag and also decrease the lift dramatically. As a result, weight of the aircraft is transferred from the wings to the undercarriage. This leads to ease of braking...
and also reduces chances of skidding. Maximum angle of the spoiler is kept about 50°-60° from the flush position. Spoilers are generally employed for rolling purposes instead of ailerons mainly because spoilers allow trailing edge of wing to be freed for other uses. When the pilot moves the control wheel to the right, the right wing spoiler extends and the right wing loses lift. The aircraft then rolls to the right. Similarly for the left roll, leftwing spoiler extends up. Spoilers can be also used in takeoff rejection i.e. when takeoff of an aircraft is aborted due to some technical failure or any other reason.

Air brakes also known as dive brake is a device which consists of a series of metal blades which when activated increase the drag on the aircraft. They are utilised in high performance aircrafts and are located above or below the wing or near the fuselage. Air brakes differ from spoilers that they have minimal effect on the lift. Rather they increase the drag by biting into the air. Another difference is that Air brakes are either fully stowed or fully deployed, while spoilers can be deployed at different positions.

Both air brakes and spoiler are when deployed ensure optimal power is available to the engine to prevent it from the danger of shock cooling (due to rapid descent).

III. Thrust Reversers

In addition to the normal brakes, thrust reversers are employed for decelerating the aircraft after touchdown especially when the runways are snow covered or icy. Thrust reversers work on the principle of reversal of the direction of the exhaust gases or changing the propeller pitch in order to create a drag force to oppose the motion of aeroplane. Thrust reversal is mainly used to reduce the stopping distance. It enables landing on smaller runways, reduction in the wheel brake wear and taxi distance. It is also used in case of Rejected take offs.

In case of wet or icy runways layer of water acts like a lubricating film between the wheel surface and the runway (Hydroplaning). As a result of this, friction reduces. Deployment of thrust reversers which are independent of the surface friction enables better braking in such conditions. Since reverse thrust is most effective at high speed, it is important both to initiate reverse early in the landing roll and to increase thrust promptly to the limits recommended for the specific airplane model [1]. Thrust reversers need to be operated just after touchdown and they have a minimum speed requirement below which there is a danger of re-injection of exhaust gases into the engine. Generally thrust reversers are retracted below a speed of 70mph.

In propeller aircraft thrust reversal is accomplished by changing the blade angle of the propeller to produce drag. It involves the use of a hydro mechanical system for actuation in order to slow the aircraft. In turbojet and turbofan aircrafts thrust reversal is achieved by redirecting the air flow of the exhaust gases from the engine. Because of aerodynamic restrictions, the discharge angle is kept 45 degree and as a result, the drag produced for both these systems is 40-60% of the forward thrust.

There are several methods for thrust reversals in turbojet or turbofan engine
- Clam shell type
- Bucket Target type
- Cascade type

Clam shell is a pneumatically operated thrust reversal system. In this system the doors are kept closed during the flight allowing the exhaust from the engine to flow straight out the rear. Upon activation by thrust reversal lever, the deflector doors on aft end of the engine rotate and closing the normal passage of gas flow and redirecting the air in forward direction via cascade vanes. As a result of this, drag is increased.

Bucket target type is a hydraulically operated thrust reversal mechanism which redirects hot exhaust gases from the engine. The thrust reverser doors are actuated by means of a conventional pushrod system [4]. The target doors are located on the outside surface of the engine nacelle, and when activated these lift outwards and rearwards to the rear of the engine forming a convergent-divergent nozzle. This system is comparatively more efficient than other thrust reversal because of this geometry which allows for maximum thrust to be reversed.

Cascade type consists of a series of vanes which are covered by blocker plate under normal conditions to allow annular flow of air from the engine. When reverse thrust is actuated the blocker doors slides towards the tail. This exposes the cascade vanes, redirecting the airflow in the forward direction. As a result the reverse thrust increases. Cascade thrust reverser system can be used for both cold and hot air stream. Although this system is being used in larger commercial aircraft because of its ease of integration with conventional engine nacelles but due to its severe weight and complexity, maintenance and fuel costs are high.

The main disadvantage of the use of thrust reverser in turbojet and turbofan engine is that the reverse airflow causes a large amount of noise associated with it due to increased turbulence.
IV. Disc Brake

Aircraft typically use disc and multi-disc brakes. It mainly consists of rotating disc attached to the wheel assembly, brake calipers which are held stationary and contains the brake pads made of material such as asbestos, ceramics, carbon etc. When brake pedal is pressed, brake fluid under pressure flows from master cylinder to the slave cylinder via tubes. The slave cylinder consists of piston which gets actuated by the force of incoming fluid pressure. The piston forces the brake pads against the rotating disc. The friction between the brake pad and disc surface, resist its rotating motion and stops it. Disc brakes used these days are differential type i.e. the left and right unit are independent of one another. This also provides increased manoeuvrability.

![Disc Brakes](image)

Multiple disc brakes consist of series of discs, the steel stators which is a stationary unit is keyed to the bearing carrier and the rotors form the rotating part and are keyed to the wheel. Automatic adjuster is used for providing clearance between the rotor and stator layers. Under the action of hydraulic pressure, these series of disc get compressed, forcing the wheel to slow down due to friction. These days the discs are provided with slots for better heat dissipation at high temperature. Also, Carbon fibre is being extensively used as rotor material for the brakes because of its low weight and the ability to withstand high heat and temperature. Although it requires lesser maintenance than the conventional brakes but the cost of manufacturing is comparatively high.

V. Conclusion

Braking system is one of the crucial elements in the aviation sector. The advent of technologies such as thrust reversers, spoilers, disc brake etc has transformed the commercial as well as military aviation extensively. Their use ensures better utilisation of energy which would otherwise go waste and also reduces the dangers of accidents due to skidding and shock cooling. These days materials with better thermal and mechanical properties are being used such as carbon fibre, ceramic etc. This ensures the longer life of brake parts, increased reliability and safety. Although proper adjustment, inspection and maintenance of these system from time to time is essential for effective operation.

References


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