

## **Preliminary Study of Aircraft Braking System with Emphasis on Fail-safe Technology**

**S. Vats<sup>1\*</sup>, Heena<sup>1</sup>, A. Katyal<sup>1</sup>, H. Kamal<sup>1</sup>  
S.K. Chaturvedi<sup>2\*</sup>, V.K. Patidar<sup>2</sup>**

*<sup>1</sup>B.Tech Student, <sup>2</sup>Faculty  
Department of Aerospace Engineering  
University of Petroleum & Energy Studies,  
Dehradun-248007, Uttarakhand, India.*

### **Abstract**

A brake is a device for slowing or stopping the motion of a machine or vehicle, or restraining it from starting to move again. Aircraft brakes are disc and are usually hydraulically or pneumatically operated. These brakes, for land based aircraft, are exclusively positioned on the main wheels although there have been some aircrafts over the years which have also had nose wheel brakes. A typical aircraft braking system uses links and cables that port some of the aircraft hydraulic pressure to the brakes after going through a valve that meters the amount of pressure. Operation of the brakes has evolved from a single lever applying all brakes symmetrically, to heel operated pedals, to toe operated brake controls incorporated into the rudder pedals. The foot operated controls has resulted in the ability to apply left or right brakes independently allowing use of differential braking system to steer the aircraft during ground operations and to maintain directional control during that portion of the takeoff or landing roll when the airspeed is too low for the aerodynamic controls to be effective. This paper also focuses on preliminary study of different types of aircraft braking which includes: Aircraft disc brakes in the landing gear, used to brake the wheels while touching the ground; Thrust reversers, that allow thrust from the engines to be used to slow the aircraft. Air brakes, dedicated flight control surfaces that work by increasing drag; Drogue Parachutes, used by several former and current military and civilian aircraft. The study carried out in this paper is therefore, the primary study of Aircraft Braking system; its various types and their

applications in different aircrafts depending upon the type of flight and the landing conditions available. Also, emphasis is laid on the fail-safe technology which includes a particular device or a system that prevents or mitigates unsafe consequences of the system's failure; that is, if and when a "fail-safe" system "fails", it is "safe" or at least no less safe than when it is operating correctly. The study regarding this technology will be useful for projects related to Aircraft Braking system applications in the sector where drogue parachute technology may be taken into consideration as a Fail-Safe system against a conventional braking system or a simple parachute (which could get caught in itself while unfolding and fail to inflate properly, thus not slowing the falling object as much as it should).

**Keywords:** Aircraft Braking system, Fail-Safe technology, Drogue Parachutes.

## 1. Introduction

A Braking system may be defined as the machine element for applying a force to a moving surface to slow it down or bring it to rest in a controlled manner. In doing so, it converts the kinetic energy of motion into heat which is dissipated into the atmosphere. The basic principle behind any braking operation is to create a controlled friction process that increases the rate of deceleration, acceleration converts heat energy into motion and deceleration converts motion into heat energy. An airplane while landing and takeoff also requires a system which helps in control. Also due to high speed it requires a system to reduce its speed while landing so that it can be brought to halt. For this purpose aircraft braking system was introduced. This system not only helps in slowing down the speed of the aircraft but also in maintaining its balance. . Also, on landing, skid phenomena is observed due to runway surfaces, pilot brake demand or due to other factors which creates unsafe for the aircraft while landing. Today, many aircraft-level functions are implemented using diverse and redundant system architectures and capabilities as mitigation techniques. These approaches contribute to an acceptable level of safety at the aircraft level.

## 2. Aircraft Braking System

An aircraft brake system consists of many systems and airbrake is an integral part of it. Air brakes or speed brakes are a type of flight control surface used on an aircraft to increase drag or increase the angle of approach during landing. Aircraft brakes, for land based aircraft, are almost exclusively located on the main wheels although there have been some aircraft over the years which have also had nose wheel brakes. Operation of the brakes has evolved from a single lever applying all brakes symmetrically, to heel operated pedals, to toe operated brake controls incorporated into

the rudder pedals. With the foot operated controls comes the ability to apply left or right brakes independently allowing use of differential braking to steer the aircraft during ground operations and to maintain directional control during that portion of the takeoff or landing roll when the airspeed is too low for the aerodynamic controls to be effective. Aircraft brake system plays a very important role in the safe takeoff and landing. However, Friction-induced vibrations are a major concern in a wide variety of mechanical systems. This is especially the case in braking systems, where friction is both the principal performance factor and a potential cause of detrimental vibrations, noise, and excessive wear. In aircraft braking systems friction induced oscillations can lead to excessively high loads in the landing gear and the brake structure, with consequences ranging from noticeable human discomfort to structural failure of the brake components. Thus, for maximum brake effectiveness, the friction between the tire and the runway surfaces should closely relate to the friction in the brake so that the peripheral speed of the tire will be just slightly less than the speed of the aircraft. In this way the tire will grip the runway surface and eliminate slipping of the aircraft to a large extent.

### **3. Classification of the Aircraft Braking System**

#### **3.1 Aircraft Disc Brakes**

Aircraft disc brakes in the landing gear are used to break the wheels while touching the ground. These brakes are operated hydraulically or pneumatically. In most modern aircraft they are activated by the top section of the rudder pedals ("toe brakes"). In some older aircraft the bottom section is used instead ("heel brakes"). Levers are used in a few aircraft. Most aircraft are capable of differential braking. One of the major advantages of disc brakes is their resistance to wear as the discs remain cool even after repeated brake applications. Also, brake pads are easily replaceable. In addition to this, the condition of brake pads can be checked without much dismantling of brake system. However disc brakes require more for their operation as the brakes are not self emerging. Also, excessive pad wear limits it's applications in many aircrafts.

#### **3.2 Thrust Reversers**

Thrust reversal, also called reverse thrust, is the temporary diversion of an aircraft engine's exhaust so that the exhaust produced is directed forward, rather than aft. This acts against the forward travel of the aircraft, providing deceleration. Thrust reverser systems are featured on many jet aircraft to help slow down just after touch-down, reducing wear on the brakes and enabling shorter landing distances. Such devices affect the aircraft significantly but are considered important for safe operation by airlines. A landing roll consists of touchdown, bringing the aircraft to taxi speed, and eventually to a complete stop. However, most commercial jet engines continue to produce thrust in the forward direction, even when idle, acting against the deceleration of the plane. In scenarios involving bad weather, where factors like snow or rain on the runway reduce the effectiveness of the brakes, and in emergencies like rejected take-

offs, this need is more pronounced. Reverse thrust is also available on many propeller-driven aircraft through reversing the controllable pitch propellers to a negative angle. However, this type of braking system is found to be less effective at low speeds. The use of reverse thrust at speeds below approximately 60-70 knots can cause engine damage through sand, stones and other foreign objects entering the intake having been initially lifted off the runway by the forward flowing air.

### **3.3 Anti-skid System**

High speed jet aircrafts usually have more than one wheel on each side, and all of the brakes on one side are controlled with one pedal. This prevents wheels from locking while braking heavily. The reason behind this is that when a wheel is locked, it cannot steer, which can lead to accidents. The point of this type of braking system is not to reduce the braking distance, but to allow this vital steering while emergency braking. The problem associated with this type of system is that the control valves do not operate fast enough resulting in loss of all braking action and Directional control for that particular wheel.

## **4. Fail Safe Technology**

Fail safe Systems are designed to minimize or prevent damage and safely terminate a flight when a radio controlled model aircraft loses radio signal. The factor of safety is usually expressed as a ratio of the “load carrying capability” of the Structure to the expected loading. Loading may be static, impact, fatigue, wear, et cetera. The purpose of using a safety factor is to assure that the design does not fail in the event of unexpectedly high loads or the presence of material/design defects. Factors of safety are applied to decrease the probability of failure, or in more positive terms, they increase the probability of success. Thus, Fail-safe designs are designs that incorporate various techniques to mitigate losses due to system or component failures. The design assumption is that failure will eventually occur but when it does the device, system or process will fail in a safe manner. The benefit of safe-life designs includes reducing the likelihood of unplanned maintenance and reducing the likelihood of any failure. Benefits of fail-safe designs include being able to manage the unexpected and mitigating damage if failure occurs.

## **5. Drogue Parachute**

A drogue parachute is a parachute designed to be deployed from a rapidly moving object in order to slow the object, or to provide control and stability, or as a pilot parachute to deploy a larger parachute. A drogue parachute is more elongated and has a far smaller area than a conventional parachute, and thus provides less drag. This means that a drogue parachute cannot slow an object as much as a conventional parachute, but it can be deployed at speeds at which conventional parachutes would be torn apart. Drogue parachutes are sometimes used to deploy a main or reserve

parachute by using the drag generated by the drogue to pull the main parachute out of its container. The most familiar drogue parachute is the one used in this manner in parachuting.

Drogue parachutes may also be used to help stabilize direction of something in flight, such as a thrown RKG-3 anti-tank grenade. It is often used to gain control of very fast descents, including those of spacecraft during atmospheric reentry, or nuclear bombs such as the B61 and B83. Some escape capsules used by supersonic aircraft deploy drogue parachutes to stabilize and slow down, allowing either a main chute to be deployed or the pilot to exit the capsule and use a personal chute.

## 6. Analysis of Stopping Distance of Mig-29 by Using Types of Brakes While Landing

### 6.1 For Dry Surface

Taking land friction coefficient =0.9

Velocity of an aircraft =250km/hr

### 6.2 For Icy Surface

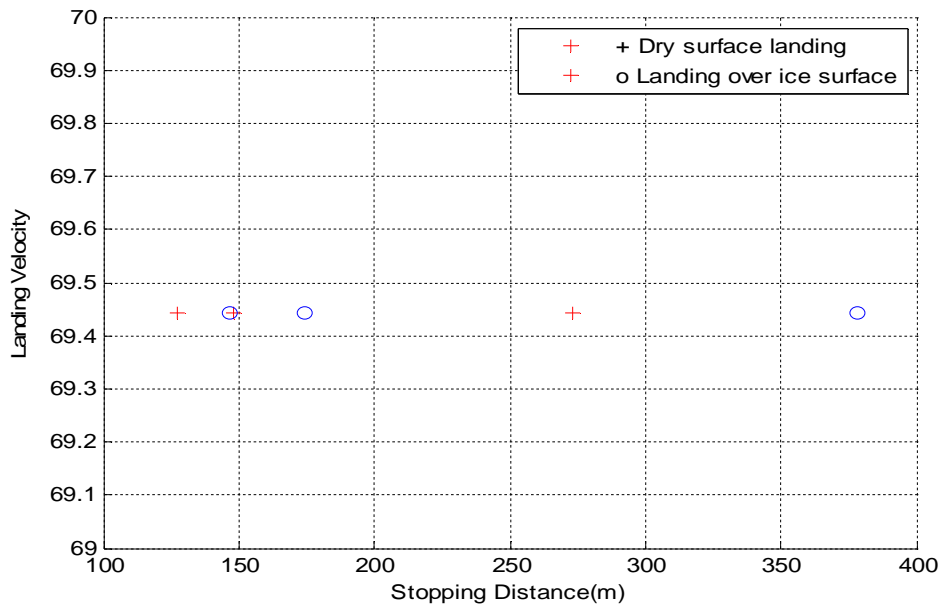
Taking average friction coefficient of ice =0.65

The equation for stopping distance calculation as given in equation 1

$$S = V^2 / 2\alpha \tag{1}$$

COMBINATION OF BRAKES WHILE LANDING	VELOCITY OF AN AIRCRAFT (km/hr)	FRICTION COEFFICIENT OF LAND	STOPPING DISTANCE (m)
Disc brakes	250	0.9	273.10
Disc brakes + thrust reversal	250	0.9	148.29
Disc brakes + thrust reversal+ drogue parachute	250	0.9	127.58

COMBINATION OF BRAKES WHILE LANDING	VELOCITY OF AN AIRCRAFT (km/hr)	FRICTION COEFFICIENT OF ICE	STOPPING DISTANCE (m)
Disc brakes	250	0.65	378.148
Disc brakes + thrust reversal	250	0.65	174.60
Disc brakes + thrust reversal +parachutes	250	0.65	146.67



**Fig. 1:** Variation of stopping distance with landing velocity using various combinations of breaks.

## 7. Conclusion and Future Aspects

The aircraft brake is dependent on the situation of the aircraft industry and influenced by the development of aerospace technology. Various modern equipments and processing methods are used for the manufacturing of new type of brakes. Some of them are Computer Numerically Controlled (CNC) machines, Laser cutting machinery and Chemical processing (anodize and conversion coating), EABS (Electrically Actuated Braking System) will be use in the future generation of aircrafts. This latest major technological innovation of utilization of Electrically Actuated Braking System is also representative of the revolution taking place in the aeronautical industry, where it is already taken for granted that the airplane of the future will be all-electric. Till now most of the airliner brakes have been actuated by means of a hydraulic system. An electrically-controlled braking system offers many advantages by comparison and a number of positive results: shorter delivery schedules, weight savings, reduced fuel consumption, reduced maintenance costs and improved aircraft availability. The graphical analysis shows that the stopping distance can be reduced to a large extent by using Drogue Parachute as the Fail safe braking system.

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