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PRINCIPLES OF FLIGHT IN MILITARY AVIATION

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ANNOTATION

This article enlightens the principles of flight in military aviation. It also discusses basic flight mechanics, types and roles of aircraft, safety considerations and design and certification procedures. Furthermore, this article aims to provide approaches in military aviation safety, effective regulatory control during design and development, operation and maintenance of the military aviation assets.

Keywords: military aviation, combat, mission, troop, attack, fighter, bomber, rotary-wing aircraft, fixed-wing aircraft, missile, cruise-missile.

I. INTRODUCTION

Military all over the world uses military aircraft in both offensive and defensive purposes. In offensive role, these aircraft are used in destroying enemy's vital installations, air strips, ordnance depots and supplies. In defensive role, it provides close air support to land-based army and also deters the threats of enemy air strike. Moreover, military aircraft plays a significant role to detect and neutralize submarines and warships to keep the seacoast free from enemy attack. Military aircraft also provides logistic supply to forward bases, conducting airlift (cargo and troops), and participates in rescue operations during national disaster. Military aviation includes both transport and warcraft and consisting of fixed wing aircraft, rotary-wing aircraft (RWA) and unmanned aerial vehicle (UAV). From the early days of world war, it has been realized that air power supremacy is vital for winning a war as well as maintaining the sovereignty of any country. It was realized that aviation had a great potential in transporting goods as well as passengers in large distances in minimum possible time. The military also realized the advantages of having an offensive and defensive air power during the war and peace time. Today air power has become the essence of military supremacy of any country for maintaining country sovereignty during peace time and offensive attack capability to win war by destroying enemy vital installations, deterring troop transfer and military supplies.

II. MATERIALS

The aircraft can be broadly categorized as lighter-than-air aircraft (balloons and airships) which generate lift due the buoyancy forces and heavier-than-air aircraft (aircraft, helicopters and UAV).

Military leaders seeking air superiority will turn to one type of aircraft: the fighter jet. Fighters are small, highly maneuverable, high-speed aircraft equipped with powerful weapons for air-to-air combat. Fighter pilots sit at the front of the aircraft in the cockpit beneath a transparent canopy. A fighter jet's fuselage holds one or more weapons bays containing bombs or missiles. Fighter jet engines use thrust nozzles to constrict airflow and cause jet propulsion that reaches Mach speeds. Many fighter jets have turbofan engines for quieter, more efficient flight. Most

have an afterburner for additional thrust during takeoff and in critical air-combat situations. Modern fighter jets are equipped with sophisticated weaponry and flight technology. Fly-by-wire controls automatically react to atmospheric conditions without pilot input. A front-firing cannon with several hundred rounds can destroy enemy aircraft. Electro-optical targeting systems track targets with deadly precision, and self-defense systems enable pilots to apply countermeasures against incoming missiles. These characteristics make fighter jets the primary weapons for maintaining air superiority in military conflicts.

Although fighter jets can carry many weapons, no fighter can match the destructive capability of a bomber. Bombers are military aircraft designed to drop bombs on enemy ground troops, facilities, and territories. There are several types of designs to meet the requirements of bomber missions. Almost all designs employ a bomb bay within their fuselage to carry the bombs before dropping them. Some bombers have a blended-wing body to carry a greater payload. Others have a swept-wing body for greater lift on shorter runways and faster, more efficient cruising during long-range flights. A long-range strike mission is usually a strategic bomber mission. This involves flying deep into enemy territory to drop bombs on strategic targets like supply bases, bridges, or even entire cities. A tactical bomber mission aims at bombing tactical targets, such as enemy troops and equipment. Though all bombers feature defensive weapons, some are better equipped for air-to-air operations. Fighter-bombers are designed to conduct air superiority operations in addition to completing bombing missions.

Some of the most important military aircraft don't fly combat missions. But without them, no combat mission could succeed. These cargo aircraft, called airlifters, are used for the deployment of troops and equipment into combat zones. They are also used for redeployment from one zone to another. Deployments by aircraft, or airlifts, often involve transporting cargo thousands of miles in intercontinental flights. For convenient loading and unloading, airlift cargo is often stacked and loaded on pallets. Airlift missions can be completed either by airland or airdrop. The ability to drop cargo without landing greatly increases the potential range and possible locations of airlift missions. Airlifts are often necessary for the sustainment of longer combat operations. Not all airlifts are for deployment or combat supply. An aeromedical evacuation is the transportation by aircraft of injured soldiers out of battles zones. Cargo aircraft are also required for military operations other than war (MOOTW). These may include the delivery of troops or humanitarian aid on peacekeeping missions.

Although nearly every military aircraft is armed, few present a greater threat to enemy ground units than gunships. These heavily armed aircraft use their massive firepower in various types of missions. They commonly serve in convoy escort, force protection, and air interdiction missions. They may attack preplanned targets or targets of opportunity. Two common gunships are the AC-130H and the AC-130U. These side-firing gunships can provide surgical firepower and area saturation even at night or in bad weather. Side-firing gunships often attack by circling targets in a banking turn while firing deadly munitions. This leaves the gunship vulnerable, so the maneuver usually requires the support of air superiority aircraft. Another attack method of gunships is strafing. In this type of attack aircraft supply heavy machine gun fire while flying past. Strafing leaves a gunship less vulnerable, and so it requires less air support.

Without information about the enemy, military leaders cannot plan effectively. Reconnaissance (recon) aircraft provide them with that necessary information. These relatively slow aircraft have a large wingspan, so struts are often needed to hold the wings steady. They fly at high altitudes to avoid ground fire. Recon planes are equipped with radar technology to detect enemy units. The radar antenna is located in the plane's radar dome. More advanced planes have a rotodome, which spins to provide better radar coverage. Recon planes can provide surveillance of enemy forces in nearly any theater. They are often responsible for airborne battle management, where real-time information about enemy units is passed to ground forces. Command and Control (C2) operations are even conducted from these airborne monitors.

The fighter jet may be fast, but it can't compare to the maneuverability of a helicopter. Helicopters are used effectively in low level operations, such as resupply missions or personnel recovery. Because they have a cargo hook which is capable of carrying an external load of up to 8,000 lbs (3,600 kg), they can transport heavy cargo to troops at ground level. Helicopters are ideal for special operations such as search and rescue (SAR). They are equipped with a forward-looking infrared system. This allows pilots to find people, even at night, by detecting their body heat. Furthermore, they can rescue troops in places where it cannot land, by hovering over them and using a hoist with a lift capacity of 600 lbs (270 kg). In combat search and rescue (CSAR) missions, pilots must take greater precaution due to potential hostile activity. For this reason, Helicopters are equipped with armor plating and .50 caliber machine guns.

If you combine the speed and maneuverability of a jet with the destructive power of a missile, you get the cruise missile. Although it has some of the capabilities of a jet, a cruise missile is not considered to be an actual aircraft. The aerodynamic fins that make up the tail assembly and wings of a cruise missile are almost identical to those of some fixed-wing aircraft. But these non-ballistic missiles are not designed for multiple flights. The rest of the missile is designed to support the warhead, which explodes upon impact with a target. Cruise missiles equipped with nuclear-capable warheads are among the most destructive weapons ever created. Cruise missiles use several methods to stay on course and hit their targets. A Global Positioning System (GPS) tracks the missile's location relative to the world. At the same time, an Inertial Navigation System (INS) calculates the missile's location according to the movement it has made. Terrain Contour Matching (TERCOM) prevents low flying missiles from colliding into prominent landmasses. When a target is near, the Digital Scene-Mapping Area Correlator (DSMAC) and the Automatic Target Recognition (ATR) system ensure that the intended target is engaged.

III. METHODS AND RESULTS

An aircraft is a complex machine using the application of multidisciplinary engineering sciences. The major engineering groups can be indicated as follows:

-Aerodynamics and flight mechanics determining aircraft shape, configuration and control law;

-Airframe structure (fuselage, wings, vertical and horizontal tail planes and control surfaces) Mechanical system (hydraulics, pneumatics, landing gear, fuel and flight control systems);

-Engine/power plant system;

-Electrical system (power generations, distribution and emergency power);

-Avionic (communication, navigation, weapon aiming, displays and warnings and utility management system) and instrument system;
-Environmental systems (air-conditioning, life support system and cabin pressurization systems) Armament system (for military aircraft);
-Air egress (ejection) system;
-Software (embedded as well as operational software).
For the aerodynamic study, air is considered an ideal gas which follows gas laws. Therefore, the variation of air properties with respect to altitude is important. The International Standard Atmosphere (ISA) is used for comparison of performances of aircraft designed by different countries. The ISA is defined as:
-Altitude (H):sea level (0 m)
-Temperature (T):288.15°K
-Pressure (P): 1.01325 MPa (14.7 psi)
-Density (ρ):1.225 kg/m3
The atmosphere is divided in two layers. The lower layer is called 'troposphere' where temperature decreases linearly with altitude (6.5°C/km altitude rise, known as lapse rate). Air pressure decreases with altitude as shown in Figure 1. Air density can be estimated from gas equation (ρ = P/RT, where R is universal gas constant). Figure 1 also shows the different types of clouds in the atmosphere [1, 2, 3, 4, 5].

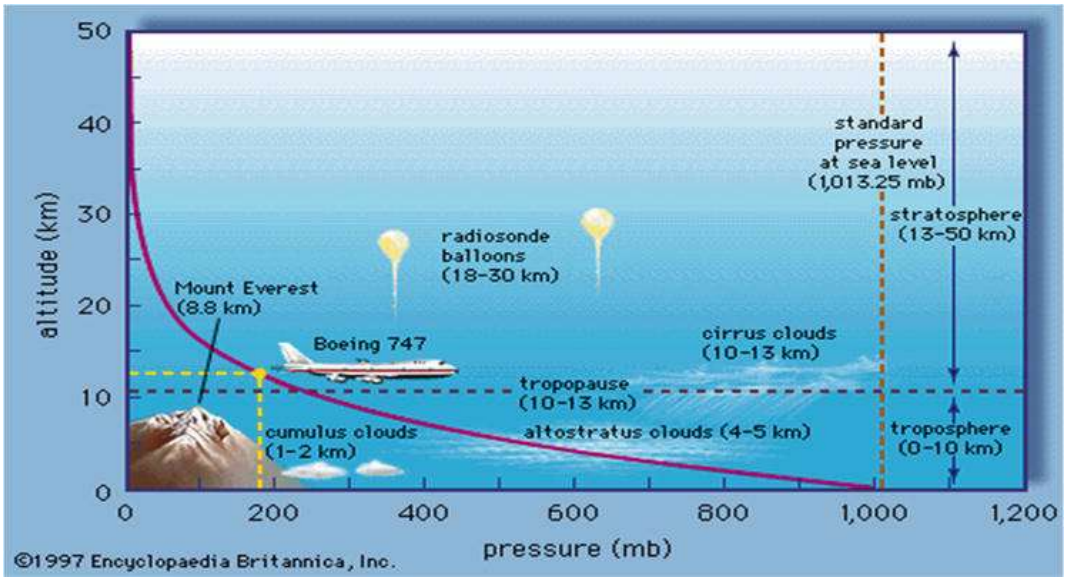


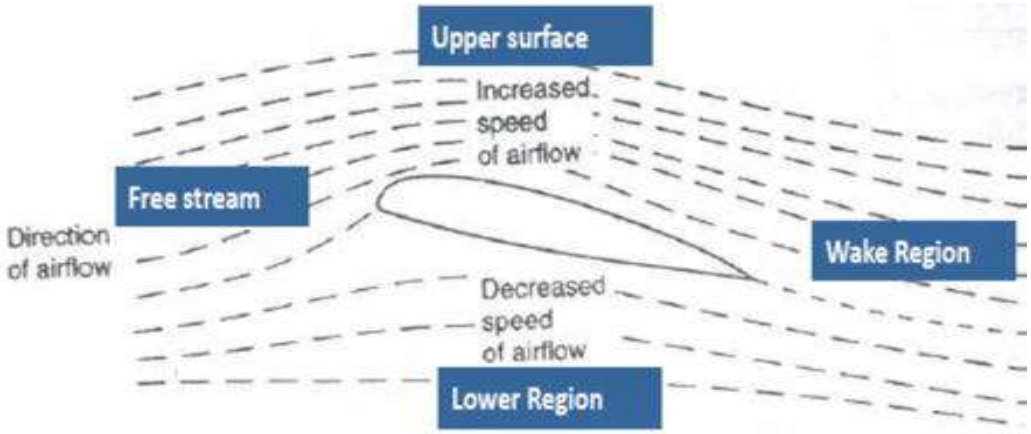
Figure 1. Variation of pressure of atmospheric pressure with altitude.

The upper layer of the atmosphere is called 'stratosphere' where T remains constant at −56°C (ISA condition). In troposphere, with increase in altitude, both pressure and temperature decrease reducing the density, thus lowering engine mass flow reducing thrust, lift and drag. These values optimize at 10–12 km which is known as cruise altitude for jet aircraft. Due to decrease in mass flow, jet engines cannot operate at very high altitude.
Movement of air over an aircraft generates aerodynamic forces and moments. Due to change in the air properties, the aerodynamic forces and moments also vary with altitude. Flight dynamics looks at these aerodynamic forces and includes thrust and gravity forces to study aircraft motion. Further the aerodynamic forces generated due to deflections of control surfaces are added as applied control forces to study the dynamics of the flight path including stability

and controllability of the aircraft [1, 5].Airflow over a body obeys three basic aerodynamic equations: these are conservation of mass, conservation of momentum and conservation of energy. Solving these equations, we obtain velocity distribution over the aircraft surfaces from which forces and moments can be estimated.

Airflow over an airfoil (cross section of wing) is shown in Figure 2. Due to the airfoil camber, air particles traveling over the upper surface have to cover longer distance than the air flowing on the lower surface. In order to comply with the law of conservation of mass, air particle on the upper surface speeds up to cover longer distance (due to camber) than the airflow over the lower surface. According to the law of conservation of momentum, the increase in speed is compensated by the decrease in pressure. This creates differences in pressures with lower surface air pressure being more than that of the upper surface. This differential pressure gives rise to upward force. The vertical component of this upward force is the wing lift, and axial component is the drag. Further the resultant of the air pressure of the upper surface and lower surface does not pass through the same point, which creates a turning moment known as pitching moment. An airfoil of unit thickness will produce lift, drag and pitching moment coefficients.

Figure 2. Subsonic flow over.



The lift, drag and pitching moment produced by the wings can be written as [Math Processing Error] where S is the total wetted wing area and C is the mean aerodynamic chord length. The force and moments acting on an aircraft in x-z plane during flight are shown in Figure 3.

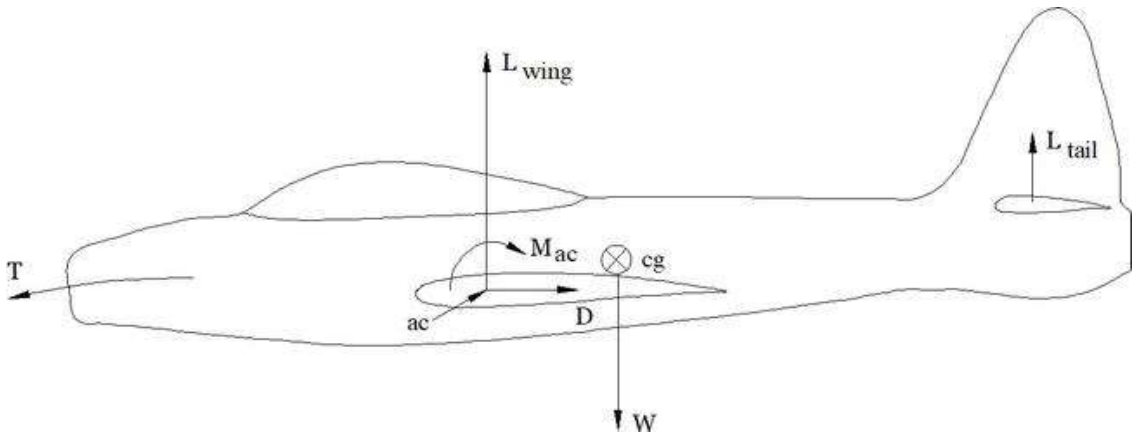


Figure 3. The force and moment system working on an aircraft in flight [2].

The lift, drag and pitching moments act at the aerodynamic centre of the aircraft. The forces and moments are in equilibrium. If the equilibrium is disturbed, the aircraft will move from its flight path. For example, if the lift is increased more than weight, the aircraft will float up, and if the thrust produced is more than the drag, the aircraft will accelerate. The reverses are also true. Similarly, if any control surface is deflected, ΣM about the axis will be disturbed, and the aircraft will rotate about that axis. The degrees of turn of flight path achieved per degree of deflection of control surfaces are the measure of controllability of the aircraft.

IV. CONCLUSION

In the modern warfare, air power plays a very significant role in both offensive attack role and defending the country's land and water space. Judicious mix of various types of combat and noncombat aircraft increases the war power of both army and infantry. Competition to develop more effective air weapon is thus never-ending. Huge research effort is being spent on development of sophisticated military aircraft with precision navigation, weapon aiming and targeting along with improvement of air armament lethality.

Aviation is also associated with various safety issues. While in civil aviation, ICAO regulations take care of aviation safety issues of the member states, military aviation safety is controlled by each state according to their own military doctrine. To make military aviation safe, the authorities must exercise effective regulatory control during design and development, operation and maintenance of the military aviation assets.

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