UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS TESIS*

JUDUL: A study on corrosion behaviour of aircraft components' material: Anodized aluminium 2024-T3

SESI PENGAJIAN : 2007/2008

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I hereby, declare this thesis entitled "Study of Corrosion Behaviour of Aircraft Components' Material: Anodized Aluminium 2024-T3" is the result of my own research except as cited in the references.

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APPROVAL

This PSM submitted to the senate of UTeM and has been as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Materials Engineering). The members of the supervisory committee are as follow:

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ABSTRACT

This report presents a study on corrosion behaviour of aircraft components' material: anodized aluminium 2024-T3. Aluminium 2024-T3 is an aircraft material with high damage tolerance and it is normally used for aircraft fuselage and wings structure. However, the natural of Al 2024-T3 is very susceptible to many types of localized corrosion such as pitting corrosion, crevice corrosion and intergranular corrosion. Anodizing process is a process where the bulk metal is corroded purposely using oxidizer to construct a protection layer that can prevent corrosion. In this study, the anodized aluminium 2024-T3 is prepared using chromic acid anodizing and hardcoat anodizing under controlled solution's temperature, concentration, times and current. Later, the prepared samples were studies using anodic polarization curve, Tafel plot (corrosion rate) and morphology analysis. Data such as critical corrosion potential of anodized Al 2024-T3 with their passivity can be obtained and it is useful to characterize the corrosion behaviour the specimen. Meanwhile, the Tafel slope that been generated experimentally can used to calculate the corrosion rate of specimen. Lastly, through the SEM, the morphology of the corroded specimen is observed to determine what types of corrosion might be responsible for the deterioration of anodized Al 2024-T3. The result of this study had shown pitting corrosion and uniform corrosion on the specimens. This is further characterized with some metastable pitting and micropitting that commonly found in aluminium pitting process. As the Cl- ion concentration increase, the specimens' E_{corr} and E_{bd} had become more negative and more susceptible to corrosion. As conclusion, the Al 2024-T3 is very susceptible to pitting corrosion and it become more critical when the Cl^- ion in the environment increased. With anodizing process, the Al 2024-T3 aircraft components can increase its corrosion resistance and extend the service life of aircraft components about 25 years minimum.

ABSTRAK

Laporan ini adalah berlandaskan kepada satu kajian yang berkaitan dengan kelakuan kakisan pada bahan pembinaan komponent-komponent pesawat: Aluminium 2024-T3. Al 2024-T3 adalah sejenis bahan yang amat rentan kepada banyak jenis kakisan setempat seperti kakisan pitting, kakisan crevice dan kakisan intergranular secara semulajadi. Proses penganodan adalah satu proses,dimana aluminium dikakiskan secara sengajanya untuk mendapatkan satu lapisan pelindungan kakisan yang terdiri daripada oksida aluminium. Dalam kajiaan ini, Al 2024-T3 telah dianodkan dengan menggunakan cara penganodan asid kromik dan penganodan hardcoat dalam larutan yang dikawal ketat parameternya seperti suhu, kepekatan, masa dan arus. Diikuti dengan itu, sampel-sampel yang telah disediakan dikaji dengan menggunakan alat-alat seperti "anodic polarization curve", "Tafel plot", dan morfologi analisis. Dari situ, data penting seperti keupayaan kakisan dan kelakuan kepasifan Al 2024-T3 boleh diterima dan digunakan untuk mengaji dengan mendalam ciri-cirinya. Selain itu, Tafel plot juga boleh digunakan untuk medapatkan kadar kakisan spesimen secara ekperimen dalam masa yang singkat. Melaui gambar mikroskop SEM, morfologi spesimen dikaji untuk mengenalpasti jenis kakisan yang berlaku pada Al 2024-T3. Keputusan kajian menunjukkan kakisan pitting and kakisan uniform pada permukaan spesimens dan kakisan ini diperwatakan lagi selanjutnya dengan metastabil pitting dan mikropitting. Apabila kepekatan ion Cl^- meningkat, E_{corr} dan E_{bd} Al 2024-T3 menjadi semakin negative dan proses kakisan menjadi lebih mudah berlaku. Sebagai kesimpulannya, Al 2024-T3 adalah amat rentan kepada kakisan pitting dan kelakuan ini menjadi semakin kritikal apabila ion Cl^- sekitar meningkat. Dengan proses penganodan, rintangan kakisan komponent Al 2024-T3 boleh ditingkatkan dan jangka-hayat komponent ini boleh diperpanjangkan minima 25 tahun.

DEDICATION

For my beloved mother and family.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

ℓ	-	liter
μ	-	Micron
%	-	Percent
A	-	Ampere
AGARD	-	Advisory Group for Aerospace Research and Development
Al	-	Aluminium
Al_2O_3	-	Alumina
ASTM	-	American Standard Testing Methods
Cl^-	-	Chloride ion
cm	-	centimeter
Cr	-	Chromium
CR	-	Penetration rate
CrO_3		Chromic acid
Cu	-	Copper
E_{corr}	-	corrosion potential
FAA	-	Federal Aviation Administration
Fe	-	Ferum
g	-	gram
gal	-	gallon
H_2O	-	water
H_2SO4		Sulfuric acid
HCl	-	Acid hydrochloric
ICAO	-	International Civil Aviation Organization
i_{corr}	-	corrosion current density
$K_2Cr_2O_7$	-	Potassium dichromate
M		Molar
Mg		Magnesium

MMC	-	Metal Matrix Composite
Mn	-	Manganese
MR	-	Mass loss
n.d	-	no date
NAARP	-	National Aircraft Aging Research Program
NaCl	-	Natrium Chloride
^{o}C		degree Celsius
ppm		part per million
PSM	-	Projek Sarjana Muda
Rp	-	Polarization resistance
s	-	Second
SCC	-	Stress-Corrosion-Crack
SEM	-	Scanning Electron Microscope
Si	-	Silicon
SO_4	-	Sulphate
Ti	-	Titanium
US		United State
V	-	Volt
wt %	-	weight percentage
Zn	-	Zinc

CHAPTER 1
INTRODUCTION

1.1 Background of study

Commercial aircraft transportation is one of the world largest transportation platforms to transfer human, goods, and properties. It been reported that, the commercial airline worldwide had carried about 2.2 billion passengers and 38 million tones of freight in 2005 (ICAO, 2006). Both of these numbers has showed the severity of aircraft safety to the community and worldwide. After the explosion of Aloha Airlines Flight 243, on April 1988, the corrosion problems on aircraft's structure and components started to appear on the desk. Aware of the risk for corrosion to cause massive disaster to the community, the Federal Aviation Administration (FAA) had launched the National Aircraft Aging Research Program (NAARP) (Pappas, 2006). This started the new page for research and development in aircraft application corrosion study.

In 2005, about one third of the worldwide commercial scheduled flights are classed into international flight that required crossing some marine environment (ICAO, 2006). Marine environment is the most structurally hostile of environments that can cause serious corrosion to aircraft. This is because the marine environment is salty and high in moisture. Both of these conditions are main contributors to Cl^- ions and water. These elements reacted with the metal and cause the material to deteriorate and corrode. The examples of aircraft components that exposed the most to the marine environment included aircraft engine, wings and fuselage.

Most of the aircraft components are built used aluminium alloy, nickel alloy, titanium alloy, steel and composites. Currently, 75 % of the Boeing 747-400 aircraft constructions are still using aluminium and its alloy. In the most recent years, the usage for laminated composites has rise up to challenge the position of aluminium alloy. This is due to its high strength-to-weight ratio and low material cost (Matthews and Rawlings, 1994). Even though the composites are started to be recognized; however, this material is still cannot overtake the roll of aluminium alloy in aircraft application. This is because most of the composite processing methods are still in the pre-mature stage and it is too expensive.

1.2 Problem statements

For now, the most economical material that used for aircraft components application is aluminium 2024-T3. However, this material is susceptive to many types of corrosion, especially crevice corrosion and pitting corrosion. So, the anodized 2024-T3 aluminium has been developed to solve this problem. The ability of this material to withstand the corrosion in rural area is unquestionable. But, its ability to resist corrosion under marine environment is still under investigation. Until now, there is still lack of strong evidences that shows that the anodized 2024-T3 aluminium have high corrosion resistance in marine environment. In addition, the corrosion behaviour of anodized 2024-T3 aluminium under environment with differences sodium chloride (NaCl) concentration is not well studied. All these factors have bring together and act as the prime mover for the researchers to start their study on corrosion behaviours of anodized 2024-T3 aluminium and moving the milestone for corrosion engineering one step forward.

1.3 Objectives of research

The main objectives of this study are:-

(i) To prepare anodized Al 2024-T3 materials using chromatic acid anodizing method and hardcoat anodizing method.

(ii) To study corrosion behaviour of anodized Al 2024-T3 in a solution with differences Cl^- concentration.

(iii) To compare the morphology of anodized Al 2024-T3 before and after corrosion.

1.4 Scope and limitation of research

In this research, it is interest of study, in detail, corrosion behaviours of the anodized Al 2024-T3. The corrosion behaviours that been stated here are included anodic polarization measurement, corrosion rate measurement and morphology studies. For the anodic polarization measurement, anodic polarization curve will be plotted after the experiment. Next, each corrosion stages that observed will be discussed. Following by that, the corrosion rate of the specimen also will be measured using potentiostat assisted with the Tafel plot. Lastly, the morphology of the specimen will be compared before and after corrosion test to study the product and changes that though the microscale observation. The equipments needed for this analysis are included light microscope, axioscope and scanning electron microscope (SEM).

Somehow, in this study, the mechanical properties studies such as tensile test, fatigue test and impact test are not going to be covered.

CHAPTER 2

LITERATURE REVIEW

2.1 Aircraft

According to the oxford dictionary, the definition of aircraft is any machine or structure that can fly in the air and is regarded as a vehicle or carrier. The examples of aircrafts are included commercial aircraft (Figure 2.1), military aircraft and helicopter.

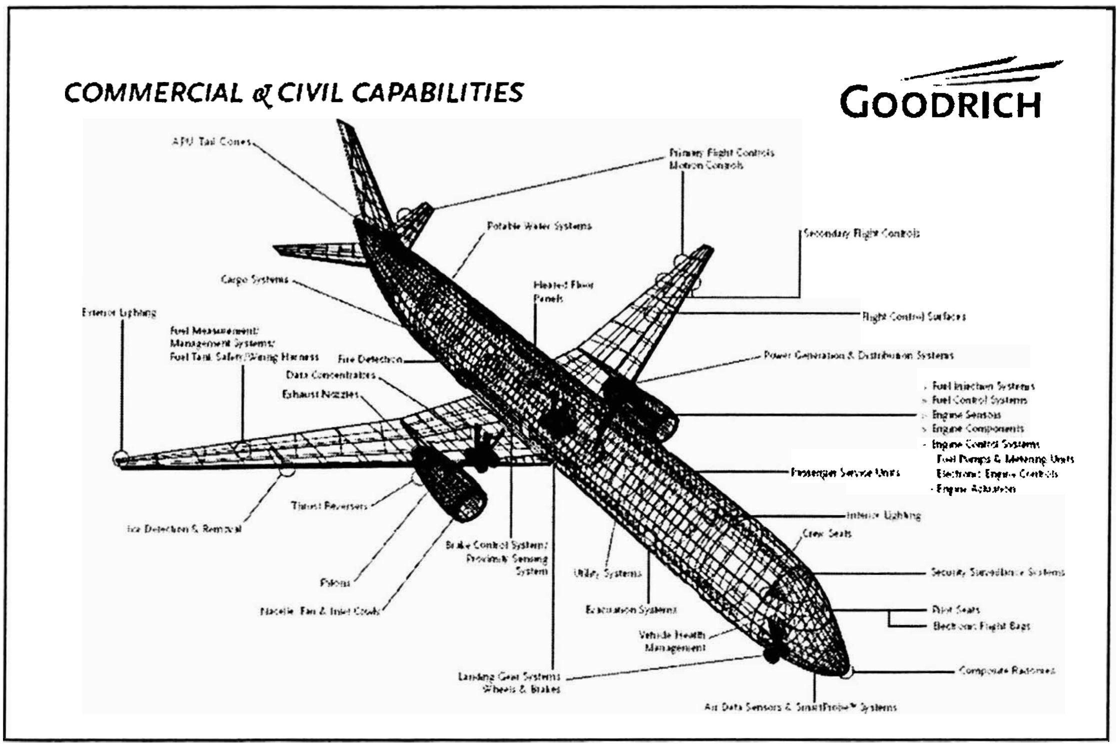

Figure 2.1: Commercial aircraft main structure and components

Source: Goodrich (2006)

2.1.1 Introduction

The commercial aircraft is normally pointed as civil aircraft because they are normally owned by airline companies that provided public transportation service. The statistic of International Civil Aviation Organization (ICAO) Annual Report showed that more than two billion passengers had travelled around the world using civil aircraft on 2005. Generally, the commercial aircraft structure is divided into 5 main parts which are fuselage, wings, empennage, landing gear and power plant.

2.1.2 Fuselage

The body of the airplane is called as fuselage. The functions of fuselage are as the main attachment body for other major components and also act as the storage for the cargo, passengers, flight crew and other accessories. The fuselage is normally constructed from very strong material and streamlined, to enable it to withstand the forces that are created in flight. For the last generation aircraft, the primary material that used to construct airplane fuselage is aluminium alloy. The evolution of aircraft has focused on the need to enhance basic capabilities, including range, payload, speed, and operating cost, all of which have been served by improvements in structural materials (Greenwood, 1989).

For the new generation aircraft, graphite epoxy material is used in order to reduce the aircraft weight-to-volume ratio and at the same time maintain the safety and physical performance of fuselage. The world aviation fuel price is the most important factor that determines the path of future aviation. According to a statistic done by Air Transport Association of America, Inc, it been found that the world market aviation fuel's price had increased from US$0.81/gallon to US$1.93/gallon in the period of 2000 till 2007, or in short the price had doubled. It been estimated that, the new Boeing 777 can save up to US$2 billion for fuel consuming for a typical fleet over its normal lifetime by shifting most of its aircraft structure material to composite (Boeing,2007) (Figure 2.2). Besides that, the Boeing 777 is also takes advantage of new composite materials and aluminium alloys to decrease the weight and improve corrosion and fatigue resistance (National Research Council, 1996).

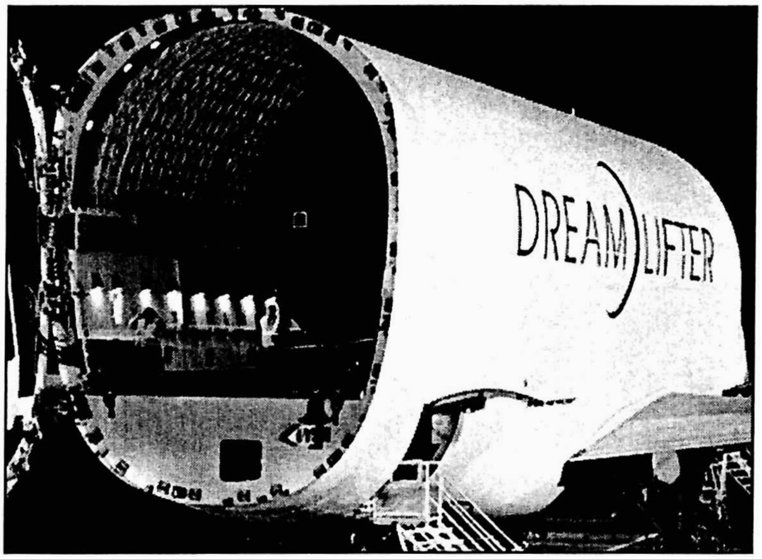

Figure 2.2: Section of Boeing 777's composite fuselage

Source: Boeing (2007)

2.1.3 Wings

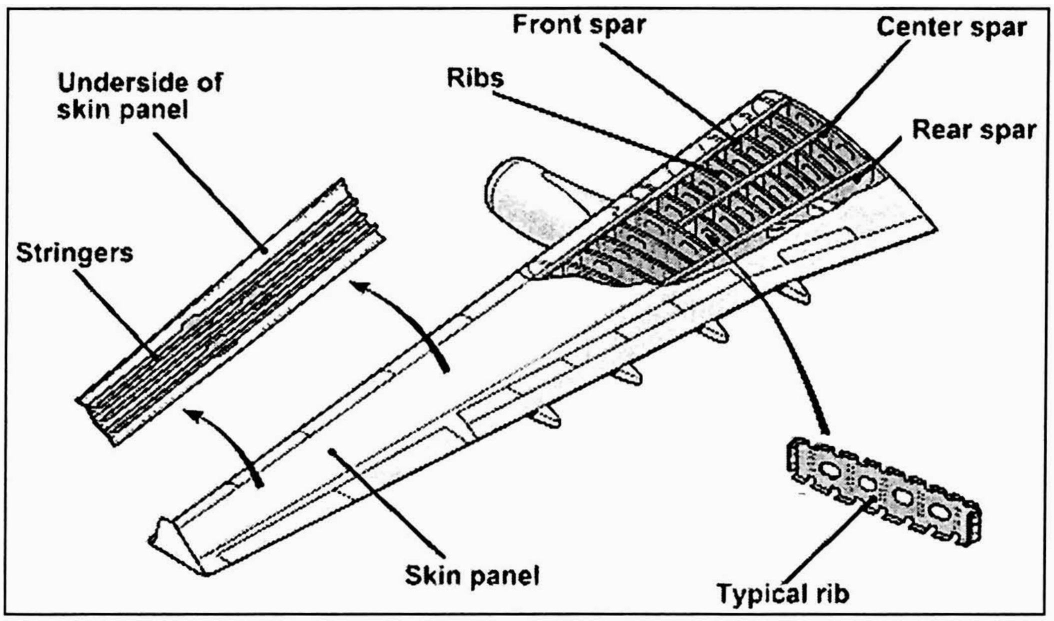

Figure 2.3: Aircraft wing structures

Source: Airbus (2007)

Wing is a rigid horizontal structure projecting from both sides of an aircraft and supporting it in the air and it is in airfoil shape. The aircraft's wing is divided into spars, ribs, stringers and skin panel (Figure 2.3). The spars are the main strength members of the wing and run along the length of wing. Ribs are run from the leading edge to the rear of the wing and support the skin panel and provide the airfoil shape that allows the wing to create lift. Stringer is a longitudinal component that used to reinforce the skin. Meanwhile, the skin panel is used to cover up the aircraft components to avoid environmental attack and create an aerodynamic stream flow around the aircraft wing.

2.1.4 Empennage

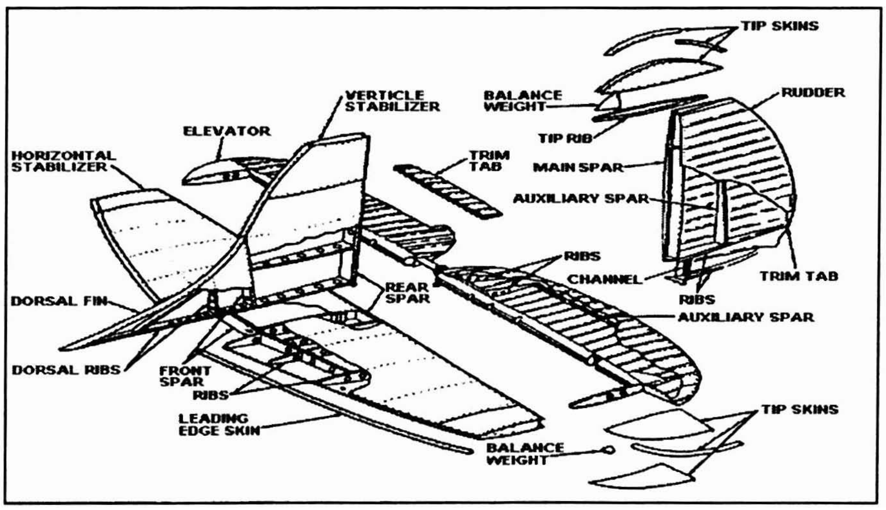

Figure 2.4: Empennage structure and its components

Source: SweetHaven Publishing Services (2007)

The empennage or commonly called as aircraft tail is a very important component that used to control the aircraft stability. The empennage major components are included vertical stabilizer, horizontal stabilizer, rudder, the elevator, and one or more trim tabs. Figure 2.4 shows the empennage structure and it components. The vertical stabilizer is used to pilot the direction of flight and to support the rudder. Rudder is used to counter adverse yaw when turning the aircraft.

Meanwhile, the horizontal stabilizer is used to maintain stability about the airplane's lateral axis, and it is the base for attaching the elevators. Eventually, the function of elevator in a standard flight is to control the up-and-down motion of the aircraft. Lastly, the ribs are used to develop the cross-sectional shape, and fairings are used to streamline angles between these surfaces and the fuselage.

2.1.5 Landing gear

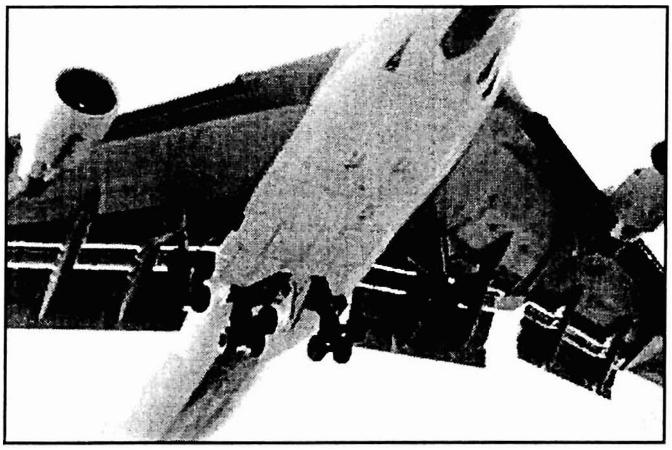

Figure 2.5: Landing gear of Boeing 747

Source: Boeing (n.d)

The landing gear is the principle support of the airplane when parked, taxing, taking off, or when landing. The most common type of landing gear consists of wheels, but airplanes can also be equipped with floats for water operations, or skis for landing on snow. They are commonly three types of landing gear used in aircraft, which are tandem, triangle and "taildragger". Generally, tandem is used for large aircraft. Tandem has two sets of wheels located one behind the other on the fuselage. Figure 2.5 shows the example of tandem landing gear that used for Boeing 747 commercial aircraft. Meanwhile, triangle has two main wheels and a nose wheel and it is used for most of the modern light aircraft. Lastly, "taildragger" is conventionally used for older light aircraft. It has two wheels forward and a third small wheel at the tail.

2.1.6 Power plant

The commonly used aircraft power plants are categorized into two classes which are engine-propeller power plant and jet-propeller power plant. The engine-propeller power plant is used for most of the light weighted aircraft because it is light in weight and produced medium thrust force. In the other hand, the jet-propeller is used for most of the modern aircraft. There are four types of jet-propulsion engines: the rocket, the ramjet, the pulsejet, and the gas turbine jet engine. The rocket engine is a jet propulsion system that does not use atmospheric air and normally it is used for aerospace spacecraft. The ramjet is a continuous combustion system that used atmospheric air to generate trust force. The pulsejet is an intermittent impulse duct engine, where its combustion is controlled by the flapper valves. Gas turbine jet engine is operates as a continuous turbine-compressor combustion machine. The compressed air is mixed with the fuel and combustion is done under high pressure in the combustion chamber. Figure 2.6 has shows the illustration of gas turbine jet engine's components.

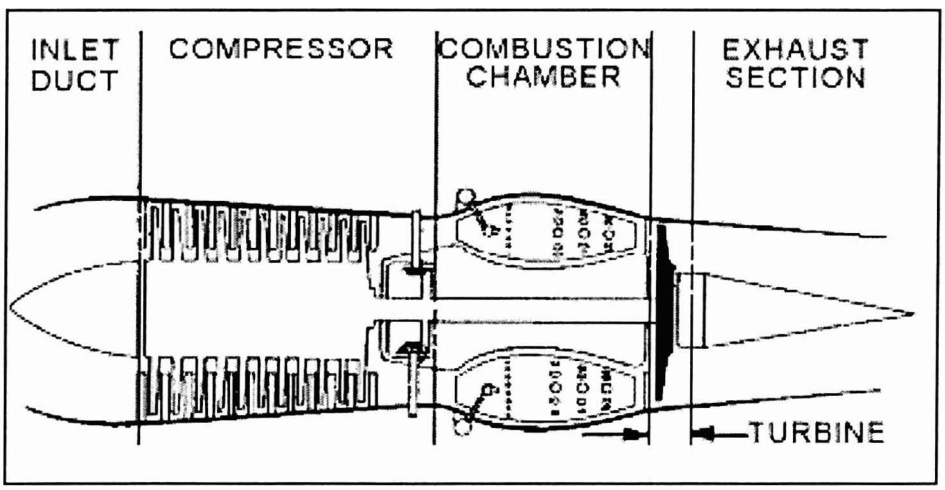

Figure 2.6: Illustration of gas turbine engine's components

Source: U. S. Naval Sea Cadet Corps (n.d)