Comparing piston, turboprop, turbojet, and turbofan engines in terms of mechanism, fuel consumption, optimal cruising conditions, and opportunities for future development.

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Abstract

Aviation is a significant sector in engineering. It directly influences the lives of millions through its influence on different sectors, including transport, global trade, and military use. Aviation witnessed a long history of progress and development, especially during periods focused on engineering, such as WWII. It was in that period that the first ever jet engine was introduced. The transition from propeller-powered piston engines to jet engines was the definition of a breakthrough. This paper focuses on reviewing the mechanism by which every type of engine works. It is most concerned with four significant engine types: piston engines, turboprop engines, turbojet engines, and turbofan engines. It is necessary to understand the mechanism by which each engine operates to analyze its performance and efficiency. To understand how every design and model were built to satisfy different purposes, it was necessary to review the aspects and variables related to each design, including their speeds, fuel consumption, and optimal cruising conditions. This paper and its content were gathered from credited reviews and sources. By understanding historical and present trends in engine design and construction, we can capture a glimpse of the future. This paper looks to leak an aspect of the future concerned with improving propellers and jet engines. It reviews strategies that are being studied to improve the engines, including tip loading and improving fuel efficiency of jets.

I. Introduction

The Wright brothers created, built, and launched “The Flyer” on Dec. 17, 1903, near Kitty Hawk, North Carolina [1]. Since this time, the aircraft industry has been developing till now. The Flyer was powered by a propeller engine, an engine with blades radiating from a central hub that is rotated to produce thrust to the propeller aircraft [1]. This propulsion has high fuel efficiency and cheap cost. However, a drawback of this propulsion is its massive slow speed that cannot reach supersonic speeds [2].

During World War 2, the speed at which propellers could fly peaked, meaning that even an extremely efficient propeller engine had a built-in limit. That limit was decided by several factors, such as the specific design of the propellers and the shock waves created on the tips of the propellers as the plane approached the speed of sound. Those shock waves produced enormous drag and reduced the engine’s efficiency above a certain speed [4]. As a result, airplane designers shifted their eyes to rocket and thrust technology, which was starting to emerge recently as a potential answer to the quest for more speed after realizing the limitations of propeller-powered engines.

After 36 years had passed since the first aircraft production, on Aug. 27, 1939, Hans Von Ohain developed the world's first jet plane. The jet engine takes air from one end and forces it through different stages: compression, combustion, and exhaust, and then shoots the gasses from the other end. As the jets of gas shoot backwards, the engine and the aircraft are thrust forward. Jet planes have lower fuel efficiency than propeller ones and require massive construction, design, and material costs, but their speeds are much higher, breaking three times the speed of sound [2].

In WW2, Germany's Me-163, the world's first jet fighter, was mainly rocket-driven, giving the pilot minimal control [4]. This design was not successful. That distinction goes to the Me-262, a German aircraft that was also produced and included turbojet engines. This aircraft's design gave the pilot far more control and allowed it to carry much more ordnance [4]. Of course, engineers were attempting to exceed the speed of sound for the sheer purpose of developing weapons and increasing the payloads of aircraft. As a result, on Oct. 14, 1947, at the height of 45,000 feet, Chuck Yeager is credited with becoming the first person to break the sound barrier in level flight (13.7 km) [3]. During World War II, technology advanced significantly, particularly in aviation engineering.

Later improvements resulted in creating a system that combined both techniques, utilizing both jets and propellers within a single engine. An enormous efficiency improvement resulted from the turbofan engine's creation, which produces thrust by combining a jet blast from the back with propeller-like fan blades on the front. The power of the bursting fuel/air mixture is employed twice, leading to a tremendous gain in efficiency. Turbines drive the fan on the front and rear of the engine, which is rotated by the blast [5].

Due to flaws existing in both types of engines, they require further research. Both have drawbacks; whilst jet engines are inefficient in terms of design, construction, and fuel consumption, propeller engines struggle to exceed the speed of sound. "In the longer term, the continuing growth of civil aviation is unsustainable given current technologies and operating systems." [6].

Research can contribute to solving such problems as it goes on to solve different engine-related flaws. For example, ongoing research includes improving propeller engines by curving the tips of the blades (tip loading), which can increase efficiency [7]. Meanwhile, improving jet engines includes increasing fuel consumption efficiency by working on thrust-specific impulse, a parameter describing the amount of thrust extracted from a certain amount of fuel per a specific period.

At this moment, it is impractical to try and design a propeller engine that aims for supersonic flight. The absence of a single engine better than the rest is why this paper focuses on comparing the mechanism by which different engines work, the results achieved by the different types of engines, the evolution of aviation and how WWII accelerated it, and what the future holds for aeronautical engineering.

The piston engine

Light aircraft still employ piston internal combustion engines as their power source. With the help of one or more piston-powered engines and a propeller, piston airplanes may travel both on the ground and through the air. Piston-powered aircraft typically fly below 15,000 feet and burn 100 octane low-leaded gasoline.

i. The Piston engine structure and mechanism

An airplane's power plant includes the engine propeller and engine accessories; not only does it provide thrust, allowing the airplane to accelerate and climb without assistance. Nevertheless, it also powers the various aircraft systems by providing electrical power and driving fuel-air and often hydraulic pumps. The piston engine components are provided in figure (1). The piston engine produces power by burning gasoline inside its cylinders; this causes the back-and-forth or reciprocating movement of a piston inside each cylinder. Each piston is connected to a rod which translates this back-and-forth motion into the spinning of the engine's crankshaft.

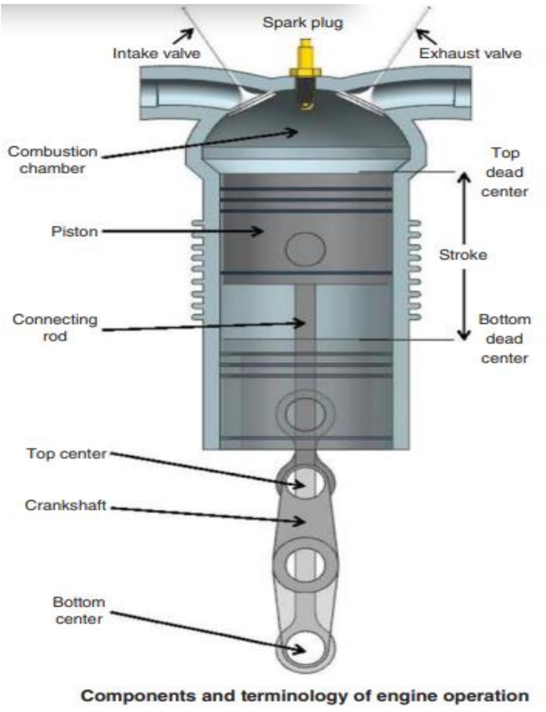


Figure 1:Main Components and terminology of piston engines

The engine operates on a four-stroke cycle; the first is the intake. An intake valve opens, allowing a highly flammable mixture of vaporized fuel and air to rush into the cylinder. When the cylinder is filled, the intake valve closes. Next is compression, as the piston is driven upward by the motion of the rest of the engine. It tightly squeezes the flammable mixture into a small space near the top of the cylinder. The third is the ignition or power stroke, a carefully timed firing of the spark plug ignites. The fuel-air mixture results in great heat and pressure inside the cylinder, which powerfully forces the piston down the exhaust stroke. This finishes the cycle by allowing spent exhaust gases to escape through the exhaust valve as the piston rides to the top of the cylinder. Once again, when the piston reaches the top of the cylinder, the exhaust valve closes, and the cycle starts over. The intake and exhaust valves are closed by springs and opened by a camshaft [3].

As the engine turns, it drives the camshaft, which is shaped with strategically placed lobes along its length. These lobes open the intake and exhaust valves on the cylinders as the camshaft rotates. Piston engines are described by the number and arrangement of their cylinders. Standard cylinder arrangements are radial inline, v type, and opposed. Opposed engines are the most common on small airplanes since they produce good power pound-for-pound without creating a significant drag.

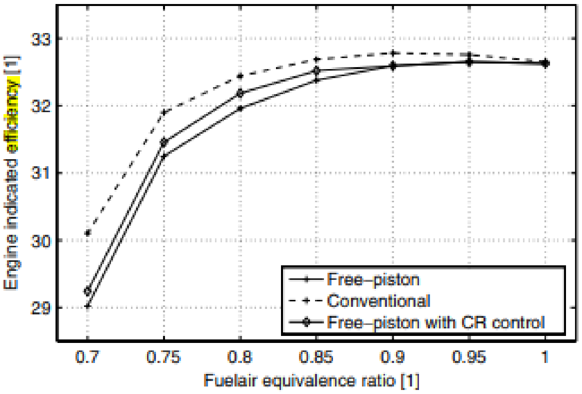
As the airplane flies, in contrast to automobiles, airplane engines are air-cooled by outside air, routed by baffles across the cylinders and engine. Each cylinder has fins that allow the air to cool the cylinder more effectively. When an engine is air-cooled, a combination of high engine power and low airflow tends to cause the engine to run hotter. This situation is typically encountered. During climb out, the engine temperature gauge should be scanned to ensure the engine's temperature limitations are not exceeded excessively. High engine temperature will cause a loss of power, excessive oil consumption, and possible permanent internal damage. Operating an engine at a higher temperature than designed will cause loss of power, excessive oil consumption, and detonation. Detonation occurs when the fuel explodes inside the cylinder instead of burning evenly as designed. This sudden detonation of the fuel is often described as engine knocking.

Engine pre-ignition occurs when the fuel spontaneously ignites inside the engine before the proper time for standard ignition. Pre-ignition can be caused by hot spots inside the engine or an overheating spark plug. It changes the engine’s timing and is referred to as engine knocking to prevent detonation [9][1].

ii. Engine efficiency:

Engine efficiency is lowered for lean mixes (mixtures having fuel-air equivalency ratios of less than one) since the flame speed is decreased. Although a mixture’s flame speed often peaks for somewhat leaner mixes than its stoichiometric conditions, this is because efficiency also depends on things like heat transfer losses and the chemical makeup of the burned gases.

The estimated part load performance of the engine types is shown in graph (1). The efficiency penalty for the engines happens right away on the lean side of stoichiometric, and this is because the combustion chamber’s low compactness penalizes even little decreases in flame speed [8].



Graph 1: Piston engine types efficiency

II. Turboprop engine

i. Turboprop engine structure and mechanism

The turboprop has played a significant but unnoticed role in aviation propulsion for many years. Recent years have seen a significant increase in interest in advanced turboprops for usage at higher speeds than were previously feasible because of growing worries about fuel supply and prices [10]. Turboprop engines are a compromise between turbojet engines and reciprocating powerplants. Turboprop engines are most efficient at speeds between 400 and 650 kph and altitudes between 5,500 and 9,000 meters. In addition to being fuel-efficient, they operate effectively at the low airspeeds needed for takeoff and landing. At altitudes between 7,500 meters and the tropopause, the turboprop engine’s minimal specific fuel consumption is often available [11].

The thrust principle must be understood to understand the mechanism of turboprop engines. According to Newton’s second law, F = mA, with F being the force, m is the mass, and A is the acceleration. This law is applied to the turboprop thrust. The thrust force is equal to the mass of the air multiplied by its acceleration (Thrust force = mA). In turboprop engines, a large quantity of air or mass of air is accelerated by a small value which causes an increase in the thrust force. In other engines like turbofan, the thrust can be increased by increasing the acceleration of the air, but in the turboprop, there is a limitation on the mass of air being accelerated, so it produces lesser thrust [12].

The turboprop engines can be divided into two major sections, the engine core, similar to a gas turbine, and the propeller, which is connected to a turbine-driven shaft.

The engine core consists of a compressor, burner, turbine, and a turbine-driven shaft, as shown in figure (2). The compressor is used to compress the air and increase its pressure. The high-pressure air then travels to the burner. The burner consists of fuel injectors, igniters, and a combustion chamber. The fuel is sprayed, which mixes with the high-pressure air and gets burnt inside the combustion chamber. In the combustion chamber, the pressure and the temperature of the gases increase. The high pressure of the gases is then allowed to expand in the turbine section, which causes the turbine to rotate, rotating the compressors too, as shown in figure (2). These components are like the gas turbine engine. On the turboprop engine, there is an additional turbine called the drive turbine, as shown in figure (2). However, in the drive turbine, the gases expand further, causing a decrease in the pressure and the rotation of the turbine. This turbine extracts almost all the pressure energy from the incoming gases. So tiny thrust is generated at the exhaust. This turbine rotates at a very high speed, so it cannot connect directly to the propeller, as this can cause the blades to stall, so the turbine is connected to a reduction gearbox which reduces the speed of the shaft, so the propeller operates more efficiently [12].

As the drive turbine rotates, it extracts most of the energy from the high-pressure gases, so the tiny thrust is created at the exhaust (approximately 20% of the total thrust). Moreover, the drive turbine rotates the propeller, which creates most of the total thrust force (approximately 80%).

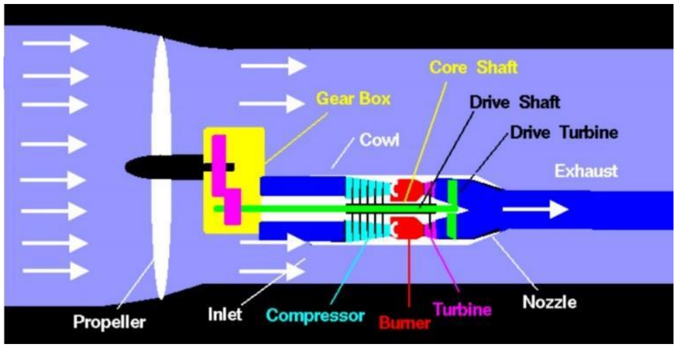
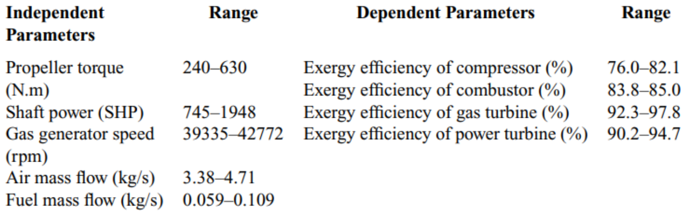


Figure 2: Structure of a turboprop engine

ii. Engine efficiency:

Data was gathered during an engine test when the engine was accelerating above idle conditions. Small transport aircraft with two turboprop engines powered the plane. Its most excellent range is 5000 km, and it can transport up to six tons. The average cruising speed of an aircraft is around 0.36 Mach. An engine may produce up to 1950 shaft horses. A gas generator, a free turbine, and a propeller gearbox are all present. The gas generator, or core engine, featured a two-stage cooled turbine, a through-flow annular combustor, and an axial-radial compressor. Two stages make up the free turbine, which is uncooled. Variable pitch propellers can do reverse thrust. A computerized engine controller and a hydro-mechanical fuel control unit are used to operate the engine. The created energy is captured and sent to the propeller gearbox using a free turbine. While the engine is running, shaft torque and speed are monitored. This makes it possible to calculate the power sent to the propeller. Air mass flow, fuel flow rates, engine speed, shaft power, and propeller torque have all been monitored and used as input data. The energy efficiencies of the engine parts have been computed, and the input data has been used to apply the Artificial Neural Network (ANN) learning process. Table (1) lists the parameters and their ranges.



Independent Parameters	**Range**	**Dependent Parameters**	**Range**
Propeller torque (N.m)	240–630	Exergy efficiency of compressor (%)	76.0–82.1
		Exergy efficiency of combustor (%)	83.8–85.0
Shaft power (SHP)	745–1948	Exergy efficiency of gas turbine (%)	92.3–97.8
Gas generator speed (rpm)	39335–42772	Exergy efficiency of power turbine (%)	90.2–94.7
Air mass flow (kg/s)	3.38–4.71		
Fuel mass flow (kg/s)	0.059–0.109		

Table 1: Parameters of a turboprop engine

Each engine parameter has a precision of six decimal places. The only independent parameter that the engine controller can change is the fuel mass flow, and all other parameters depend on it. Component matching and efficiency, however, disclose an underlying link that may not be directly linear. Finding a formulation that will enable regeneration of the efficiency numbers using the input parameters is necessary because the manufacturer does not give the engine characteristics. Spline modeling offers a fix for this issue. A small number of fitting points can accurately represent hundreds of data points.

The accuracy of the spline function will rise along with the number of fitting points, and the goal is to utilize the fewest possible points while maintaining the necessary precision. Two alternative point distributions and two different optimization techniques were used to apply spline modeling. The objective function is the mean of the squared errors (MSE), and the optimization task is to minimize the error when locating the points. Functions for constraints are not utilized [14].

III. Turbojet engine

i. Turbojet engine structure and mechanism

The turbojet engine would be set up in a modern combat aircraft, as shown in figure (3) [15]. In a typical jet engine, the air is sucked in from the front and then compressed. Afterward, that air is streamed to the combustion system, where it is mixed with fuel and ignited into flames. Rapidly expanding gases are exhausted through the rear. The gases produce equal forces in different directions providing forward momentum as they rush to the rear. Leaving the engine, they pass through the turbine and the turbine shaft. This shaft is responsible for rotating the compressor and resupplying the engine with air. The turbojet engine is a reaction engine [16]. It belongs to reaction engines because the expanding gases are used to exert forces that act on the front section of the engine. The engine sucks in and squeezes the air, which flows through the turbine, causing it to spin. That stream of air jets out of the rear of the engine, thrusting the plane forward. The mechanism of the turbojet engine can be divided into four processes. Intaking the air, compression, combustion, and finally shooting out the air in the form of a jet or a stream.

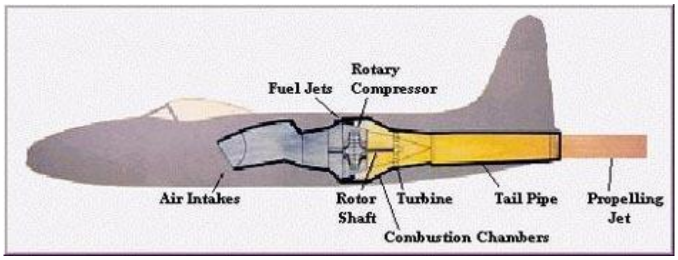


Figure 3: Model of a turbojet engine in a modern combat aircaft

The fan and compressor are responsible for the intake process. A typical commercial jet engine takes in 1.2 tons of air per second during takeoff [15]. In most engines, compressors are responsible for both sucking in the air and compressing it; however, some engines are provided with an additional fan unrelated to the compressor to increase air intake [16]. Compressors are designed to achieve ratios over 40:1. At full power, the compressor of a primary commercial jet rotates its blades at 1600kph and takes in 1200kg of air per second.[15]

The air is driven in the combustion room, which is supplied by fuel through spray nozzles. The combustion chamber is responsible for igniting the mixture and releasing the resulting heat so that the air is expanded and accelerated to give a smooth stream of uniformly heated gas. It is necessary to perform this operation with the least pressure loss and maximum temperature possible [18]. Fuel consumption is determined by the rise of heat required; however, the maximum temperature is defined by the materials from which the turbine blades and nozzles are made. The combustion chamber must provide stable and efficient burning of the mixture during all operations performed by the engine due to the fact that the temperature of the gases decides the thrust of the engine. The expanding heated gas provides the thrust on its way out while spinning the turbine and the compressor.

Thus, the turbine is tasked with operating the compressor and its attachments [18]. It qualifies for the task by absorbing heat produced by the combustion system and transporting them to lower temperatures and pressure. The gases stream through the turbine at temperatures ranging from 850 to 1700 °C, which significantly exceeds the melting points of some of the materials used in the engine. To produce a high-efficiency engine, a high-temperature inlet into the turbine is required, which causes problems for the turbine blades that are demanded to operate for long periods in temperatures exceeding their melting points [15]. Cool air is ejected out of numerous tiny holes in the blade to allow it to run under these conditions. This air which remains close to the blades, allows it to keep operating without massively detracting from the overall engine efficiency. Materials with good performance under such temperatures, such as nickel alloys, are used to construct the turbine blades and nozzle guide vanes [15].

Percentages reaching about 60% of the overall airflow are not streamed through the engine's core. They also are not used in the combustion process. Instead, they are directed into the flame tube to cool off the combustor walls [15]. If the turbine and compressor are efficient, the pressure at the turbine discharge will be near twice the atmospheric pressure, and this excess pressure is sent to the nozzle to produce a high-velocity stream of gas which produces a thrust [17]. Substantial increases in thrust can be obtained by employing an afterburner. A second combustion chamber is positioned after the turbine and the nozzle. The afterburner increases the temperature of the gas ahead of the nozzle. The temperature increase achieved by the afterburner amounts to about 40% of the thrust during takeoff, which reaches much higher percentages during high speeds once the plane is in the air [17].

ii. Engine efficiency

In describing the performance of jet engines, it is necessary to describe different efficiencies and parameters. Most parameters that describe an engine's performance are associated with fuel consumption and the valuable energy produced during different parts of the engine cycle [19]. In describing the efficiency of a turbojet engine, we can review two parameters to describe the efficiency of the engine. These two indicators are thermal efficiency and propulsion efficiency. When both parameters are combined, they can output an engine's overall efficiency. [20]

Thermal efficiency:

A turbojet engine is a heat engine that depends on thermal energy to produce work. Thermal efficiency η_{th} is the percentage of heat turned into practical work. Due to practical limitations, heat engines often operate at around 30% to 50% efficiency [21]. Heat engines cannot achieve 100% thermal efficiency according to the Second Law of Thermodynamics, and this is because the engine must produce some waste heat that cannot be used, as shown in Figure (4) by the Q_L term. The output of a turbojet engine is primarily shaft power. Accordingly, thermal efficiency is defined as: $\boldsymbol{\eta_{th}} = \frac{\boldsymbol{P_s}}{\boldsymbol{m_f Q_r}}$ (Equation (1)). Where P_s is the shaft power, and $m_f \times Q_r$ is the total energy consumption rate [20].

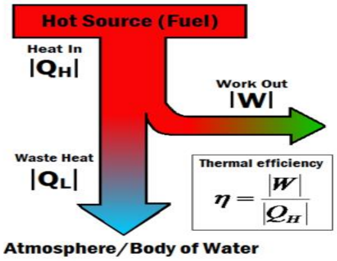


Figure 4: Resulting work of a specific amount of input heat

Propulsion efficiency:

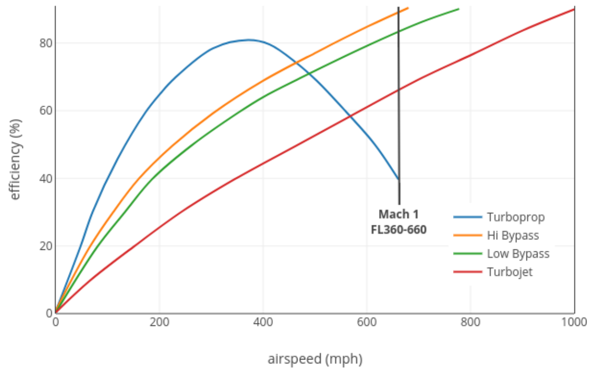
The performance of propulsion of an engine, Known as the propulsion efficiency, can be measured from the ratio of the thrust power to the rate of production of propellent kinetic energy. It can be put in the following form: $\boldsymbol{\eta_p} = \frac{\boldsymbol{Tu}}{\boldsymbol{P_s}}$ (Equation (2)) [20]. Where $T \times u$ is the product of thrust and flight velocity, called thrust power, and P_S is the propellent kinetic energy production rate. It is impossible to ultimately convert the kinetic energy into thrust power because that requires the jet velocity to equal the free stream velocity; however, there would be no thrust under this condition [19]. Hence, it is unavoidable to have residual kinetic energy in the jet wake. Any effort to improve the propulsive efficiency reduces the residual kinetic energy.

Overall efficiency:

Neither thermal nor propulsion efficiency can honestly describe an engine's performance. Thus, the overall efficiency has been introduced and is a product of thermal and propulsion efficiency. $\boldsymbol{\eta_p} \times \boldsymbol{\eta_t} = \frac{\boldsymbol{T \times u}}{\boldsymbol{m_f Q_r}}$ (Equation (3)). Multiplying the propulsion efficiency with the thermal efficiency leaves behind a ratio of the thrust power to the thermal energy consumed, which is the overall efficiency [20]. The engine's thermal, propulsive, and overall efficiency depend on various engine cycle parameters. Therefore, improving the engine efficiency essentially means varying the associated design variables to achieve minimum fuel consumption [19].

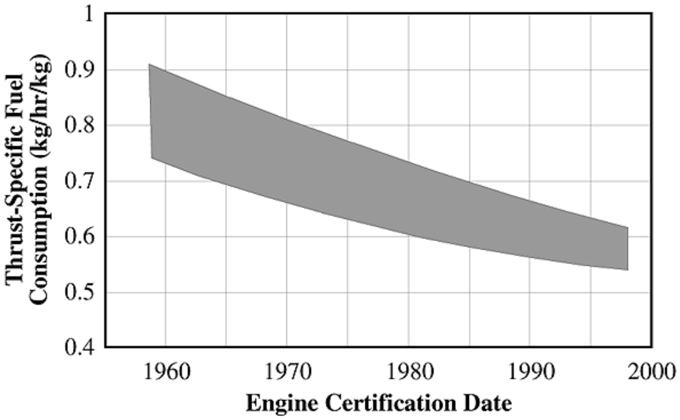
The previous is the mechanism by which the performance of turbojet engines is measured. There are countless numbers of designs and a variety of models created to satisfy different purposes. Turbojet aircraft work on the principle of accelerating a relatively small mass of air to a high speed. As optimum efficiency is achieved when the accelerated air speed approximates the aircraft's speed, turbojet engines do not reach peak efficiency until speeds approach Mach 2 [22]. A turbofan engine is significantly more efficient and quieter for sub-Mach speeds due to the greater mass and lower speed of the exhaust stream leaving the engine [24].

The preceding discussion briefly reviewed how primary engine cycle considerations can influence design trends of gas turbines. Experimental confirmation of such trends may be obtained by looking at historical trends of principal parameters affecting the performance of gas turbines since they were first introduced. Graph (2) shows impressive progress in reducing thrust-specific fuel consumption over time [23]. Thrust-specific fuel consumption (TSFC) is the fuel efficiency of an engine concerning the thrust output [28]. The 1960 to 1970 vintage engines were either turbojets or first-generation low bypass ratio turbofans with relatively high fuel consumption levels. 1970 to the mid-1980s saw the introduction of second-generation turbofan engines, generally referred to as high bypass ratio engines, which had significantly better fuel consumption than the earlier ones. Improvements in fuel consumption for third-generation engines were minor [23].



Graph 2: Comparison between propulsive efficiencies of various engines

Graph (2) compares the propulsive efficiency of different jet engines, including the turbojet engine. The graph shows that turboprop engines reach peak efficiencies in low sub-Mach speeds before their efficiency drops. Meanwhile, turbojet engines are very efficient for high Mach speeds [24].



Graph 3:Thrust specific fuel consumption from 1960s to 2000s

IV. Turbofan engine

A turbofan engine, also known as a fanjet or a bypass engine, generates thrust using a mix of bypass air and jet core efflux that has been accelerated by a ducted fan powered by the jet core. Due to their powerful thrust and excellent fuel efficiency, turbofan engines are used in most modern aircraft [25].

i. Turbofan mechanism

The turbofan can be considered a high-tech propellor inside a duct called a diffuser driven by a gas generator. It consists of three major components: the core, the turbine, and the fan.

The core:

The core of a jet engine is a gas generator that creates high-pressure gas to power a turbine. This setup has a compressor, combustor, and turbine sections, as illustrated in figure 5. There are two types in the compressor section: high-pressure compressors and low-pressure compressors. They Compress the air making for a much more powerful combustion reaction relative to engine size. Compression happens in stages that force incoming air into an increasingly narrow chamber. A single compressor stage consists of a connected core casing, a rotating rotor, and a ring of stationary stator vanes. As the air is forced through the compressor, rotor blades swirl it. Stator vanes reduce air pressure while reducing their spinning motion. This compressor has eight high-pressure and four low-pressure stages. As the air moves through the combustor, the combustible air is combined with fuel and ignited, causing a jet of extremely powerful gas to be released. This design is known as an annular combustor or “ring-shaped” method. The intake nozzles receive compressed air. Each nozzle is connected to a fuel injector to provide a uniform mixture of incoming fuel and air. A couple of ignitor plugs, not unlike the spark plugs found in car engines, ignite this mixture, and the reaction spreads evenly around the ring. Once started, combustion continues as long as air and fuel are supplied [25],[26].

The turbine:

The turbines at the rear of the jet engine are powered by exhaust gasses exiting the combustor. The fan is powered by a large portion of the turbine’s power. In contrast, the compressor stages are powered by a smaller portion. As a result, turbine fins heat up a lot. Special coatings are used to lower temperatures, and some air from the compressor is redirected for cooling. The exhaust cone is explicitly designed to mix and speed up exhaust streams. The sensitive internal engine components are likewise covered [26].

The fan:

Early jet engines were turbojets, where all incoming air flows through the core. But now, most contemporary winged aircraft engines are turbofans, in which only a small amount of air enters the core or gas generator, and the energy produced rotates a specifically made fan, as shown in figure (5). The fan might once more be compared to a sophisticated propeller inside of a duct [26].

Bypass ratio:

Bypass air is described as the air that does not penetrate the core. Similar to how air flows through a propeller, this air passes through the fan and avoids, or goes around, the engine. However, the air's velocity as it passes through the fan is slightly higher than the free stream. Consequently, a turbofan receives some of its thrust from the fan and some of it from the core. The bypass ratio is the ratio of air passing through the core to air passing around the engine [27`].

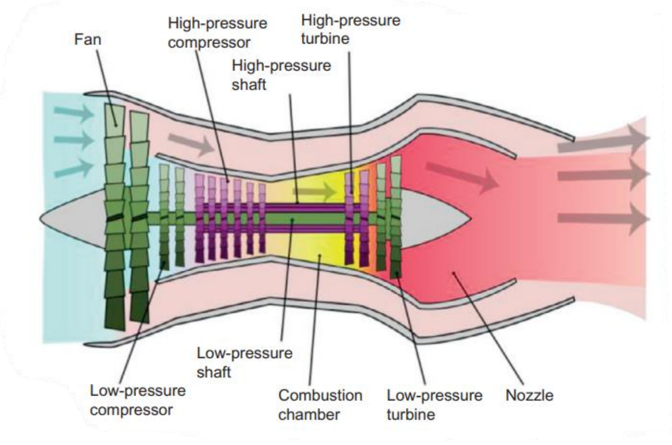


Figure 5: The Turbofan engine internal components

i. Fuel efficiency

Since the addition of the fan only slightly changes the fuel flow rate for the core, a turbofan generates more thrust for virtually the same amount of fuel used by the core. This reveals the fuel efficiency of a turbofan. The overall efficiency of large turbofan engines, which produce thrust, is approximately 40%. The fuel efficiency of high bypass ratio turbofans is comparable to that of turboprops. Since the fan is surrounded by the intake and contains several blades, it may operate more effectively at higher speeds than a straightforward propeller. Due to this, turbofans are used by high-speed aircraft while propellers are used by low-speed aircraft [25],[27].

V. Ongoing research

Over time, it became more and more obvious that no engine was ideal for all tasks. With or without propellers, piston-to-jet engines all had their advantages and disadvantages. As a result, upgrading current engines to make them operate more effectively in harder conditions soon became a priority. The performance of the engine can be enhanced, its speeds can be raised, its fuel consumption can be reduced, and the materials the engine is composed of can all be changed.

In both piston and turboprop engines, the propeller is a common component that may be enhanced to assist boost both efficiencies. Propeller efficiency rapidly declines after they reach a particular speed. This causes the propellers to operate poorly and is mostly caused by shockwaves on their tips [1]. When compared to typical designs, turbojet and turbofan -fuel diesel engines run rough, and the unequal torque distribution creates vibrations that eventually wear out the propeller. This shortens its life expectancy and raises the possibility of failure. The second issue is that the engine type and propeller design must be precisely matched. In addition to being inefficient, using a propeller made for a gasoline engine in a diesel engine worsens the fatigue issue [32]. Therefore, engineers used various designs and tactics to reduce the decline in efficiency while increasing the top speeds that propellers might attain. Over the past ten years, there have been several attempts to increase propeller efficiency by drastically altering the shape of the blade's tip. The blade tip of the tip-fin propeller is softly bent towards the suction side thanks to a tip fin or winglet that is connected to and incorporated into the blade. Current attempts have prioritized both high efficiency and good cavitation qualities. In contrast, past efforts have primarily focused on improving the propeller's efficiency. This has resulted in a design combining skew and tip fin [31].

Meanwhile, turbojet, turbofan, piston and turboprop engines have a feature in common that may be upgraded to raise the engine's total performance. Fuel use is that aspect. Engineers need to change how aircraft engines have historically been developed, notably in terms of core size, given NASA's focus on extremely efficient hybrid-electric aircraft. Adding the more substantial inlet fan only marginally alters the fuel burn rate since shocking the core raises the engine's bypass ratio. As a result, the engine is more efficient since it produces greater thrust for about the same amount of gasoline burned [29].

VI. Conclusion

Since the first aircraft was invented, The Flyer, the world has sought more speed. So many engines were invented to achieve this goal. Those engines include four main engine types, the piston, turboprop, turbojet, and turboprop fully demonstrated in the review. Their mechanisms, fuel consumption, and engine efficiency were discussed to understand each engine's optimum cruising conditions, peak speeds, efficiencies, and optimum operational performance.

A turbojet engine is a jet engine that gets all of its thrust from the high-energy gas stream it exhales out of the exhaust nozzle. It is the most reliable and fastest of the three engines, but its fuel efficiency is the lowest. On the other hand, at low to medium altitudes, turboprop engines combine the reliability of jet engines with the effectiveness of propeller-driven aircraft. Its mechanism is almost the same as a turbojet but with a propeller. The piston engine consists of a fixed cylinder and a moving piston. The piston is propelled by the expanding combustion gasses, which turn the crankshaft, propelling the aircraft. It has the best efficiency and price but the least reliability. Also the turboprop engine is a type of jet engine that generates thrust using a mix of bypass air and jet core efflux that has been accelerated by a ducted fan powered by the jet core. It is very fuel efficient and reliable as It provides a middle ground between fuel efficiency, speed and reliability. As a result, it is the most used engine type globally.

Finally, it was found that the jet engines (Turbojet and Turbofan) has the best structure and mechanism that helped humankind to reach the speed of sound rather than the propeller propulsion (piston, turboprop), which is better for short-distance travel.

VII. References

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