I'm not a robot

The turboprop engine was designed to give the turbojet engine superior performance by adding the propelling function. Initially, the turbojet engine was designed to have efficient and superior performance at high speeds and high altitudes. While its initial climb and takeoff performance were not exemplary, the addition of propellers to these turbojet engines, turning them into turboprops, enabled them to provide a much better performance at medium speed and altitude as well. All in all, a turboprop engine brings together the performance attributes of a turbojet and propeller engine. This combination makes it one of the top engines in the market in terms of performance. Compared to other types of engines, a turboprop engine offers several advantages that can visibly improve the flight performance of an aircraft. The major advantages of using this engine include the following:Turboprop engines are lightweight so they can provide a better performance during takeoff while maintaining fuel efficiency.There are fewer moving parts in a turboprop engine compared to other engines, making it more reliable in terms of mechanical aspects.The power output of this engine per unit of weight is higher, while the engine carries a minimum vibration system.The use of the propeller enhances the initial climb and takeoff performance quite remarkably while ensuring that the operation of the engine remains simple. The best and most efficient performance a turboprop engine can deliver is when the speed lies between 250 and 400 mph and the altitude is between 18,000 and 30,000 feet. However, they give a substantially good performance at low altitudes, as well during takeoffs; and most importantly, they are fuel-efficient. Within the altitude range of 25,000 ft, the engine can function at a minimal fuel consumption level. The power of a turboprop engine is defined in shaft horsepower which depends on not just the RPM, but also the torque applied to the shaft of propeller. Being gas turbine engines, these turboprop engines produce jet thrust using the exhaust leaving the engine. The total engine power is calculated by adding this thrust power to the shaft horsepower. However, the performance of a turboprop engine might suffer if the speed is increased considerably. A turboprop engine is undoubtedly one of the best performing engines used in aircrafts today and gives a balanced performance managing speed and altitude perfectly. However, the limitations of this engine should be well understood by the pilot if they dont want to cause damage to the engine parts.link to Why Do Pilots Say Niner?(How Pilots Count to ten)link to Can Helicopters Fly Above Clouds?link to Does a Jet Engine Push or Pull?link to Can a Fighter Jet Survive a Missile Hit? (Missile Speed Vs Fighter Jet Speed)link to How Much Fuel Does a Helicopter Use? (With Statistics!)link to Why Dont Airplanes Fly Faster? The turbofan and the turboprop are two variations of the primary gas turbine engine, sharing certain design similarities. They are both variations of the primary turbine engine, so their thermodynamics are based on the Brayton cycle. Similarly sized engines deliver power similar to that of the fan or propeller. The turbofan features a large fan stage at the front of the engine core, as illustrated in the cutaway below. The turbofan is a highly efficient way of producing thrust, particularly when it utilizes a high bypass ratio, where most of the mass flow passes through the fan and the fan generates the majority of the thrust. Turbofans have been used to power commercial airliners, such as the Boeing 747, Boeing 767, Airbus A300, and A330, as well as many other aircraft. The turboprop utilizes a propeller driven by a power turbine, equivalent to a propulsion system with a very high bypass ratio.Cutaway drawing of the Pratt & Whitney PW4000 turbofan, a family of high-bypass turbofan aircraft engines with thrust ratings ranging from 52,000 to 99,040 lb (230 to 441 kN), depending on the application.The performance and analysis of turbofans and turboprops share many similarities. However, the propellers propulsive characteristics and aerodynamic limitations affect the operation of a turboprop as a system. Turboprops and turbofans have much better efficiency than turbojets in producing thrust for a given quantity of fuel. Turbofans are commonly used on many commercial airliners, although turboprops are often employed on smaller commuter aircraft. Turboprops are also used on some general aviation aircraft and military training aircraft. A turboshaft, which has the same essential core as a turboprop, can power helicopters and other machinery, as well as aircraft.Understand the functionality and characteristics of a turbofan engine andhow it differs from a turbojet engine.Appreciate the concept of bypass ratio for a turbofan and how it contributes to its overall propulsive efficiency.Understand the characteristics of turboprop andturboshaft engines. The flow in a turbofan engine is split into two paths, as shown in the figure below:The flow through the engines core is similar to that of a turbojet engine.The fan produces the surrounding axial bypass flow.The flow in a turbofan engine is split into two paths. The bypass ratio is the ratio between the mass flow through the fan and the mass flow through the core.The fan spins much slower than the inner core of the engine, which contributes to its efficiency and reduces noise. A cowl surrounds the fan stage, guiding the airflow into the fan and the engine core. It is found that the thrust-producing efficiency of this type of engine is increased significantly by increasing the bypass ratio. Recall that the bypass ratio (BPR) is the area or mass flow through the fan divided by the area or mass flow through the core itself, i.e., (1) Like all engines, the thrust of a turbofan and its fuel consumption characteristics vary with flight conditions, i.e., with airspeed or Mach number and flight altitude. Such characteristics are determined from engine performance measurements, supported by mathematical modeling of the engines characteristics. However, remember that altitude typically refers to the density altitude, i.e., the altitude corresponding to the local ambient air density.Thrust ProductionThe thrust-producing capabilities of turbofan engines are found to be significantly affected by the airspeed and the corresponding Mach number , and their thrust production decreases at higher airspeeds. The typical takeoff and climbing phase behavior is shown below, which occurs at relatively low airspeeds, typically below about 300 kts (flight Mach numbers less than 0.5). Notice the reduction in thrust with increasing flight Mach number, a characteristic of this engine type. At higher Mach numbers, the thrust curves tend to flatten out at higher altitudes; however, at lower altitudes, thrust production diminishes quickly at transonic Mach numbers.Representative variations in thrust and specific fuel consumption for aturbofan engine at higher flight Mach numbers.For design purposes, equations representing the characteristics of an engine are often helpful. During the takeoff and climb phase, the thrust for a turbofan engine is often approximated using the empirical equation (2) The thrust from a turbofan can also be approximated using the equation (3) where the values of the coefficients and depend not only on the engine type but also on its operational altitude.Notice that the variations of thrust with and are relatively large at lower altitudes. However, the assumption that thrust is almost constant is reasonable in the cruise range (say, between flight Mach numbers of0.7 to 0.85 at higher flight altitudes). The same basic variation of thrust with altitude holds for turbofan engines, i.e., (4) where is the thrust produced at MSL. Notice that in most cases, although the value may depend on the engine design.An aircraft flying at a true airspeed, of 200 m/s, is powered by a turbofan engine with a bypass ratio of 5:1. The mass flow rate into the engine core is 20 kg/s, and the fuel consumption is 2 kg/s. The average discharge flow velocity from the engine core, , is 410 m/s, and from the bypass fan, , it is 270 m/s, both with respect to the engine. Using conservation principles, show an appropriate control volume and control surface to analyze this problem. Determine the thrust and equivalent power developed by this turbofan engine. Neglect all pressure difference effects.Show solution/hide solution.The control volume analysis of this problem is shown below.The mass flow of air into the core of the engine is and with a bypass ratio of 5:1, the mass flow into the fan will be The mass flow rate of fuel is Therefore, the thrust from the engine core is From the fan, the thrust is The total thrust is then In this case we are given that = 20 kg/s, = 2 kg/s, and also that = 410 m/s, = 270 m/s, and = 200 m/s. Therefore, substituting the numbers gives and The total thrust is The equivalent net power that is developed is Propulsive EfficiencyThe net propulsive efficiency of a turbofan engine can be defined as (5) Therefore, for the engine core and the fan together, then (6) It will be apparent that the higher the bypass ratio, , all other factors being equal, the higher the net propulsive efficiency. Introducing the into the previous equation gives (7) By substituting into the previous equation gives (8) and so (9) This form of the equation for propulsive efficiency further highlights the important contribution of the bypass ratio. The term shows that increasing the (all else being equal) increases the fraction of the fan contribution, which tends to be more efficient if is closer to , i.e., accelerating a large mass flow rate at a relatively low velocity.Thrust Specific Fuel Consumption (TSFC)A representative thrust-specific fuel consumption (TSFC) map for a turbofan engineis shown in the figure below. For modeling purposes, the variation of the TSFC for aturbofan follows the relation (10) where the values of and depend on the engine and its operational altitude. This latter equation has good validity in the cruise condition between flight Mach numbers of 0.7 to 0.85. The effect of altitude on the TSFC of a turbofan engine is fairly small (notice the greatly expanded scale), so the assumption that TSFC is constant is reasonable for use in a first-level aircraft flight performance analysis.The effects of flight altitude on the specific fuel consumption of aturbofan engine are relatively small. Afterburning turbofans, such as the Pratt & Whitney F100 and the General Electric F110, are designed explicitly for supersonic-capable fighter airplanes, where a balance between subsonic fuel economy and transonic/supersonic thrust is crucial. These engines typically operate with a bypass ratio in the range of 0.3 to 0.9, making them distinct from both high-bypass commercial engines and zero-bypass turbojets. In engines like the F100-PW-229, used on the F-15E and F-16C, the bypass ratio is approximately 0.36, while in the F110-GE-129, also used on the F-15 and F-16, the ratio is closer to 0.87. These bypass ratios are not selected for low noise or subsonic cruise performance as in commercial turbofans, but rather to increase the specific thrust (thrust per unit airflow) while gaining some propulsive efficiency and lower fuel burn during loiter and subsonic cruise.From a flowpath perspective, the afterburner is downstream of the turbine and acts only on the core exhaust stream. The bypass stream does not pass through the burner but enters the nozzle annulus and mixes with the core flow before or within the variable-area convergent-divergent nozzle. This mixing increases the mass flux through the nozzle and helps cool the afterburner liner. The net jet velocity in afterburning mode typically exceeds Mach 2.2 at the nozzle exit. The thrust of a low-bypass turbofan can be expressed as (11) where only the core stream has the afterburner. This configuration offers a compromise between the high specific thrust of a turbojet and the improved propulsive efficiency of a turbofan, particularly in the subsonic regime.The nozzle design is critical because the exhaust nozzle must accommodate a significant increase in total volume flow when the afterburner is lit because of the addition of fuel mass and thermal expansion. As a result, variable-area nozzles are required. These nozzles adjust the throat and exit areas in real time to maintain proper pressure matching and prevent choked flow or separation. On engines such as the F119 used in the F-22, the nozzle also incorporates thrust-vectoring capability with two-dimensional geometry, enabling pitch and yaw control at high angles of attack.In dry mode (non-afterburning), these engines produce thrust levels on the order of 16,00018,000 lb (71.280.1 kN), with a total specific fuel consumption (TSFC) of around 0.75 to 0.80 lb/lb/hr (76.5 to 81.6 kg/kN/hr). When the afterburner is engaged, thrust increases by 60% to 70%, with the F100-PW-229 reaching 29,000 lb (129.0 kN) of thrust at sea level static conditions. However, this comes at the cost of a TSFC that typically exceeds 1.9 lb/lb/hr (193.8 kg/kN/hr) and may reach over 2.1 lb/lb/hr (214.2 kg/kN/hr) at high altitudes and Mach numbers. The high fuel burn rate is acceptable for tactical scenarios that require short-duration bursts of power, such as intercepts, combat maneuvering, or takeoffs from short runways. A turboprop is a turboshaft engine at its core, as shown in the figure below. However, a low-pressure power turbine drives a propeller through a shaft, and only a small amount of jet thrust is produced, i.e., by design, is relatively low, which also helps keep the noise lower. In fact, in this type of design, approximately 95% of the thrust comes from the propeller, while only 5% comes from any residual jet thrust generated by the exhaust nozzle. The most common application of turboprop engines is for smaller, commuter-class aircraft. The turboprop engine is similar to the turboshaft, which is used extensively to supply power for helicopters. Examples of standard turboprop engines include the Pratt & Whitney PT6, used in many small commuter aircraft, and the Allison T56, which powers the Lockheed C-130 Hercules and the Lockheed P-3 Orion.A typical turboprop engine features a power turbine located at the end of the gas generator, which drives a propeller.In the turboprop/shaft engine, the first three stages of the engine core are essentially the same for all gas turbine engines. However, in this case, the high-pressure turbine is followed by a low-pressure turbine, which powers the high-pressure compressor. The low-pressure power turbine, in turn, drives the propeller through a concentric shaft. The power turbine may be integral to the gas generator section, although most modern engines have a free power turbine on a separate concentric shaft that drives the propeller. This latter type of design enables the propeller to rotate freely, independently of the compressors rotational speed. Additionally, because of the increased expansion and energy extraction in the low-pressure power turbine stage, the exhaust jets residual energy is low, resulting in a small jet thrust at the exhaust nozzle, as previously discussed.Propeller ContributionThe propeller may be coupled to the power turbine through a speed-reduction gearbox, which is necessary to keep the propeller tip speeds below the speed of sound. This approach maintains the overall propulsive efficiency and lowers the propellers noise. This gearbox is mounted on the front of the engine behind the propeller. However, the free-turbine design is more commonly used today, eliminating the penalties associated with weight and other issues related to the speed-reduction gearbox.Because turboshaft engines are used to power high-performance airplanes, the propeller is always of the constant-speed (variable-pitch) type, similar to that used with higher-powered reciprocating engines. A constant-speed propeller allows the angle of the blades to adjust dynamically during operation. This ensures that the engine operates at its most efficient rotational speed, regardless of changes in power demand or airspeed. This propeller type is similar to those used in high-powered reciprocating engines. Still, it is optimized in terms of blade area and number of blades to handle the power output of a turbine engine, i.e., to deliver the power at the engine shaft as useful propulsive work.An advanced propeller design for a turboprop airplane. Recent advancements include lower weight, reduced fuel consumption, less noise, increased reliability, and better performance.Turboprop engines, which often power regional and utility aircraft, rely on this configuration to deliver high efficiency at lower speeds, making them ideal for short-haul flights. Adjusting the propeller blade pitch also enables reverse thrust during landing, improving braking performance and reducing wear on the aircrafts wheel brakes.Propulsive EfficiencyRegarding efficiency, the turboprop falls between the propeller and reciprocating engine combination and the turbofan or turbojet. Regarding airspeed capabilities, the maximum airspeed (or flight Mach number) for a turboprop-powered aircraft is limited by the propellers loss in efficiency when the blades begin to operate at higher helical Mach numbers. This characteristic results from compressibility losses and the onset of shock waves at the propellers tips. For this reason, turboprops tend to be limited to flight at lower airspeeds than turbojet or turbofan-powered aircraft and also to lower operational altitudes where the speed of sound is higher.The performance of the turboprop can be analyzed using the basicconservation principles. The total thrust from the turboprop is , where is the propeller thrust and is the jet thrust, and so the power from the turboprop is (12) Defining theshaft power as the power available from the engine, then (13) where is the propulsive efficiency of the propeller and is the power produced by jet thrust. Defining equivalent shaft power as an overall power that includes jet thrust gives (14) or (15) Thrust Specific Fuel Consumption (TSFC)The TSFC for the turboprop will be (16) which is measured in terms of weight per hour per unit thrust, e.g., in units of lb hr lb or kg kN hr. Again, remember the anomaly of the SI system where mass (kg) is often used for TSFC instead of weight (N), and this difference should be accounted for in calculations as needed. However, other definitions for TSFC for a turboprop can also be based on the net available power , the shaft power , or the equivalent shaft power , i.e., (17) The equivalent shaft power includes the small contribution from the jet thrust.Both power and TSFC will vary with airspeed and altitude. For a turboprop, is approximately constant with up to a typicaloperational value of 0.6 or 0.65. The variation of with altitude followsthe relationship (18) where is typical, although the exact value depends on the specifics of the engine design. The specific fuel consumption of a turboprop is found to be relatively constant with both airspeed and altitude. Turboshaft engines are very similar to turboprops in that they are designed to deliver power to a shaft, with only minor differences in their detailed design. Many engine manufacturers use a basic engine core customized as either a turboprop engine or a turboshaft engine. The differences in the various engines are typically confined to the compressor stages, which are optimized to achieve the best pressure ratios for different operational flight scenarios, resulting in the highest power output and lowest specific fuel consumption.Turboshaft engines are commonly used in helicopters, which drive the rotor(s) through a gearbox and transmission system, as shown in the figure below. The advantage of a turboshaft engine for a helicopter is that it is both powerful and lightweight, offering a significantly better power-to-weight ratio compared to a piston engine. Turboshaft engines are used exclusively on helicopters, except for smaller general aviation (GA) helicopters, where piston engines are often a more cost-effective alternative. Turboshaft engines are also used as auxiliary power units, driving an electrical generator, on larger airplanes. On ships, turboshafts are used for propulsion and can also be found on various other ground-based equipment.A turboshaft engine is often used to power a helicopter.A unique application of the turboshaft engine is the 29,000 hp (21,300 kW) Pratt & Whitney F135-PW-600 afterburning turbofan engine for the STOVL version of the F-35B, as illustrated in the figure below. In conventional (airplane) mode, the engine operates as a turbofan. However, when powering the lift fan for VTOL operation, it operates in turboshaft mode, sending power through a shaft (i.e., similar to a turboprop). At the same time, the engine simultaneously continues to produce propulsive thrust as a turbofan.The 29,000 hp Pratt & Whitney F135-PW-600 afterburning turbofan enginefor the STOVL version of the F-35 B. Open rotor engines, also known as unducted fans, represent a propulsion concept that seeks to deliver significantly higher propulsive efficiency than conventional turbofans by eliminating the nacelle and increasing the bypass ratio beyond what is practical in ducted configurations. As shown in the figure below, this type of engine uses one or more large-diameter, unshrouded fans, typically arranged in a single or contra-rotating pair, to accelerate a large mass of air at low velocity. By doing so, the open rotor minimizes the kinetic energy lost in the exhaust stream, thereby increasing propulsive efficiency in accordance with the ideal relation , where is the jet velocity and is the flight speed. Because can be made only slightly greater than , especially in cruise, propulsive efficiencies well above 0.80 are theoretically attainable.An open-rotor design has a specific fuel consumption that is better than that of a turbofan, with reduced weight.In most implementations, the open rotor employs two contra-rotating high-bypass fans mounted on a common axis and driven by a low-pressure turbine. The second stage recovers swirl energy from the first, improving axial thrust and reducing net torque. The configuration not only achieves higher bypass ratios, often exceeding 30:1, but also delivers a high thrust-to-weight ratio and fuel burn reductions on the order of 20% to 30% compared to existing turbofans. Cruise thrust-specific fuel consumption is expected to fall in the range of 0.45 to 0.55 lb/lb/hr (45.9 to 56.1 kg/kN/hr), making the open rotor attractive for future medium- to long-range transport aircraft operating at Mach 0.75 to 0.78 and altitudes of 35,000 to 38,000 ft.Despite its aerodynamic advantages, the open rotor faces significant challenges related to aeroacoustics and integration. The absence of a duct exposes the rotor blades directly to the freestream, resulting in high tonal noise from periodic blade-passage interactions and broadband noise from turbulent wake-blade interactions. These effects are exacerbated in contra-rotating configurations, where the trailing rotor operates in the unsteady wake of the leading stage. Tip vortexshock interactions at high blade-tip Mach numbers further contribute to acoustic emissions. As a result, open rotors produce significantly more noise than ducted turbofans, posing a significant certification barrier under current FAA and EASA regulations. To address these concerns, designers employ scimitar-shaped blades with high sweep and compound curvature to delay compressibility effects and reduce shock strength. In contrast, blade spacing and rotation speed are optimized to minimize interaction tones.Another design consideration is the difficulty of integrating the open rotor onto existing aircraft platforms. The lack of a nacelle necessitates alternative installation strategies, such as rear fuselage-mounted pylons or over-wing pusher arrangements. These configurations impose structural penalties, potential center-of-gravity shifts, and aerodynamic interference from the empennage. Blade containment in the event of failure is also problematic in an unshrouded configuration, raising safety concerns that must be addressed through structural shielding or reduced blade-tip energies.Historically, open rotor designs were explored extensively in the 1980s, most notably in the GE36 UDF (Unducted Fan) program, which demonstrated the viability of contra-rotating free propellers at transonic speeds. More recently, the Safran/GE RISE (Revolutionary Innovation for Sustainable Engines) initiative has revived interest in the configuration, targeting entry into service by the mid-2030s with a projected 20% fuel savings over current LEAP engines. Flight test articles have demonstrated competitive thrust levels in the 20,000 to 35,000 lb range while achieving significantly lower cruise TSFC. Although the acoustic and integration challenges remain formidable, the potential gains in fuel economy and emissions reduction ensure that the open rotor will continue to be a focus of future propulsion research and development. One important design decision for an airplane, especially an airliner, is the number of engines to use. One benefit of using two or more engines is redundancy, in that, in the event of an engine failure, the aircraft can still safely fly and make an emergency landing. Aircraft engines, however, are costly to purchase and operate; therefore, airlines typically prefer to use twin-engine airliners. However, for some extremely large Jumbo aircraft, four engines may be required to provide sufficient thrust and power to propel the airplane, ensuring good climb performance and adequate one-engine inoperative performance. Twin-engine aircraft, however, are still subject to restrictions on long-distance, over-water operations under ICAO rules, known as ETOPS, which isan acronym for Extended-range Twin-engine Operations Performance Standards.Aircraft with fewer engines will have lower fuel burn and better economics. For a jet engine, a good approximation of the thrust produced is (19) where is the pressure ratio at that altitude and is the corresponding absolute temperature ratio, which can be found from the ISA model.Because jet engines will operate at or close to their rated thrust for much of the flight, a first-level approximation is to assume that their TSFC remains independent of power output. Of course, a better approximation is to calculate the actual fuel flow rate from the TSFC curve for the engine. By multiplying the TSFC by the thrust output, it will be apparent that the fuel flow rate is a linear function of the thrust output. This relationship can be generalized as (20) where is the number of engines and the coefficients and , depend on the characteristics of a particular engine.It will be apparent that the total fuel flow will always be greater by approximately for a multi-engine installation. Therefore, an aircraft design will generally aim to use the fewest number of engines consistent with flight performance, flight safety, and other relevant considerations. The recent retirement of the Boeing 747 and the A380 from many of the worlds airline fleets, as well as the cessation of production of both models, reflects an airlines emphasis on cost. Turbofans and turbojets both operate on the same fundamental gas turbine cycle and generally use kerosene-based jet fuels, most commonly Jet A or Jet A-1. However, turbofan engines have become the dominant propulsion type in modern civil aviation, particularly for subsonic transport aircraft, which has introduced practical differences in fuel selection, specification, and operational constraints.Turbofans are optimized for long-duration, subsonic cruise at high altitudes and moderate Mach numbers, typically around . Consequently, the freezing point of the fuel becomes a more critical parameter, particularly for extended intercontinental flights. Jet A-1, with a certified freezing point of , is preferred in international operations, while Jet A, which freezes at , is common in domestic flights within the U.S.Turbojets, in contrast, are often employed in military or supersonic applications and experience higher thermal loads from elevated turbine inlet and exhaust gas temperatures. Under such conditions, fuel stability and resistance to thermal degradation become more critical than low-temperature properties. Jet fuels used in turbojet-powered aircraft may include military grades such as JP-8, which contain additives for corrosion inhibition, anti-icing, and thermal oxidative stability.Fuel system sensitivity is another distinguishing factor. Modern turbofans are highly susceptible to contamination from water or microbial growth in the fuel tanks, which can block filters or affect engine performance. This necessitates rigorous filtration procedures and the potential use of biocides or anti-icing additives in commercial aviation operations. Turbojets may operate with broader tolerances, especially in hardened military applications.From a performance standpoint, turbofans are designed for high propulsive efficiency and low thrust-specific fuel consumption (TSFC) at cruise. As a result, combustion stability, emissions compliance, and compatibility with lean-burn technologies place tight constraints on allowable variations in fuel properties. In contrast, turbojets are less sensitive to slight differences in specific energy or combustion efficiency, but are more dependent on high energy release rates and the operability of the afterburner, where applicable.Finally, modern turbofans are increasingly certified for use with sustainable aviation fuels (SAFs) or biofuels, such as synthetic paraffinic kerosene (SPK) or hydroprocessed esters and fatty acids (HEFA), which meet ASTM D7566 specifications. These fuels are blended into conventional Jet A or Jet A-1 to reduce lifecycle carbon emissions. Compatibility with SAFs is a critical development in commercial aviation. Turbojets, especially older military engines, may require additional testing and qualification for SAF usage because of differences in material tolerances and combustion characteristics. Turbofans or turboprops are used on many aircraft types because of their high propulsive efficiency. Turboprops, however, are generally limited to smaller commuter aircraft or those that do not need to cruise at transonic flight conditions. A cowl around the large fan helps the turbofan perform better than a propeller at higher speeds and reduces noise. However, the propeller, too, has aerodynamic limits, including the loss of propulsive efficiency at high helical tip Mach numbers. At supersonic flight speeds, such as those of a military fighter, turbojets are generally more suitable; however, low-bypass turbofans are increasingly being used. While the base fuels are nominally the same, turbofans demand stricter control over freezing point, thermal stability, contamination, and sustainable fuel compatibility. Turbojets, by comparison, place greater emphasis on thermal resilience and additive support for extreme operational profiles. Discuss why the propulsive efficiency of a turboprop system generallydecreases at higher flight altitudes.Increasing the fan diameter of a turbofan engine can dramatically increaseits thrust. Explain.Take a look at photographs of the large turbofan engines used on the Boeing 787. Why are there chevrons at the end of the bypass section of the engine?Research the Open Rotor concept and list itsrelative advantages and disadvantages compared to a turbofan.What are the advantages and disadvantages of a high bypass ratio in a turbofan engine?Explain the principle of reverse thrust and its significance for turbofan and turboprop engines.What factors determine the propulsive efficiency of a turboprop engine?Compare and contrast the fuel efficiency of turbofan and turboprop engines.How do the size and design of the propeller affect the performance of a turboprop engine?Discuss the factors that influence the selection of a turbofan or turboprop engine for a specific aircraft.To learn more about turbofans and turboprops, check out some of these online resources:A series of videos on how to build a jumbo-jet engine. See the playlist here.A tutorial on turbofan engines by CFM.A series of videos on the B-777 GE90 turbofan. See the playlist here.A great video tour of the Rolls-Royce Engine factory, where they build the XWB engine for the Airbus A350.GE90 maximum thrust test!King Air turboprop demonstration starting and varying blade pitch.Excellent video demonstration of a turboprop engine using a cutaway.Fascinating tour of a propeller overhaul facility!Video on how a turboshaft engine is used to power a helicopter.First tests of a new open rotor propulsion system.Airbus is getting ready to test an open-rotor design on an A380. Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit , provide a link to the license, and indicate if changes were made . 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For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. eLearning | Computer Based Training | Systems Simulation eLearning | Computer Based Training | Systems Simulation Interactive Training and Simulation Sphaera has expertise in the design of interactive CBT courseware and elearning covering gas turbine engines for both commercial and military aircraft. For example, the package described on this page contains clear schematic diagrams of 5 different gas turbine engines that can be built-up in a series of easy to understand steps to form the basis for many important introductory lessons to gas turbine engines such as discussing the purpose of each section of the engine or each phase of the Brayton cycle (induction, compression, combustion and exhaust): The engines below provide good examples of a turbojet, turboprop and different types of turbofans (low-bypass, high-bypass, twin-spool and multi-spool) therefore developing the students' appreciation of the different approaches to engine design: Avon Turbojet The turbojet was the first type of jet engine developed and the Avon is a good example. Introduced in 1950 it was used as the powerplant for many well-known military aircraft such as the English Electric Lightning, Hawker Hunter and Saab 35 Draken. In a turbojet all the air passes through the core engine (with no bypass) where it is compressed and ignited to provide all the thrust when it exits the rear of the engine in the form of a high-velocity jet. As turbojets are noisy and are not the most fuel efficient of turbine engine types, they are not suitable for use on airliners but ideal for high altitude, high speed flight. Adour Low-Bypass Turbofan In a turbofan, some of the air is diverted around the core of the engine to provide additional thrust. In comparison to turbojets, this reduces noise and increases fuel efficiency. Turbofan engines are generally classified as either low-bypass or high-bypass. Some low-bypass turbofan engines are used in speed ranges associated with military aircraft (above Mach 0.8) and the Adour is a good example. It provides propulsion for the many variations of the Hawk and also the SEPECAT Jaguar. CFM56 High-Bypass Turbofan Almost all large passenger aircraft use high-bypass turbofan engines, which have a large fan at the front of the engine which produce about 80 percent of the thrust. This results in reduced noise and better fuel consumption for the speed range associated with passenger aircraft. Like most turbofan engines, the CFM56 is a twin-spool design. The first spool, known as the low-pressure (LP) spool, features a fan and three-stage low-pressure compressor (LPC) driven by a four-stage low-pressure turbine (LPT). The second spool, known as the high-pressure (HP) spool, supplies HP air to the combustion section of the engine and features a nine-stage high-pressure compressor (HPC) driven by a single-stage high-pressure turbine (HPT). The CFM56 is used to power the Boeing 737, the Airbus A320 family (A318, A319, A320 and A321) and Airbus A340. RB211 High-Bypass Turbofan The RB211 is included as a good example of a multiple-spool turbofan. It is a triple-spool design featuring the usual LP and HP spools with an additional intermediate-pressure (IP) spool. The RB211 was the first production triple-spool engine, entering service on the Lockheed TriStar and powering the Boeing 747, 757 and 767. It has since developed into the Trent family of engines. PW150A Turboprop The selected example of a turboprop is the PW150A from the Bombardier Dash-8 Q400. This engine features a low-pressure (LP) spool and a high-pressure (HP) spool with centrifugal compressor, but, as this is a turboprop design it has additional stages to extract as much of the gas energy as possible and turn a propeller. On this engine this is a two-stage power turbine driving a third shaft connected to the propeller through a reduction gearbox. Do You Have a Training Requirement? If you wish to use any of our CBT within your training school, or require any bespoke gas turbine training material to be created, simply contact us! BACK TO AVIATION TRAINING Turbine engine driving an aircraft propellerNot to be confused with propfan or turbofan.GE T64 turboprop, with the propeller on the left, the gearbox with accessories in the middle, and the gas generator (turbine) on the rightA turboprop is a gas turbine engine that drives an aircraft propeller.[1]A turboprop consists of an intake, reduction gearbox, compressor, combustor, turbine, and a propelling nozzle.[2] Air enters the intake and is compressed by the compressor. Fuel is then added to the compressed air in the combustor, where the fuel-air mixture then combusts. The hot combustion gases expand through the turbine stages, generating power at the point of exhaust. Some of the power generated by the turbine is used to drive the compressor and electric generator. The gases are then exhausted from the turbine. In contrast to a turbojet or turbofan, the engine's exhaust gases do not provide enough power to create significant thrust, since almost all of the engine's power is used to drive the propeller.[3]Schematic diagram showing the operation of a turboprop enginePropulsive efficiency for different engine types and Mach numbersExhaust thrust in a turboprop is sacrificed in favor of shaft power, which is obtained by extracting additional power (beyond that necessary to drive the compressor) from turbine expansion. Owing to the additional expansion in the turbine system, the residual energy in the exhaust jet is low.[4][5][6] Consequently, the exhaust jet produces about 10% of the total thrust.[7] A higher proportion of the thrust comes from the propeller at low speeds and less at higher speeds.[8]Turboprops have bypass ratios of 50100,[9][10] although the propulsion airflow is less clearly defined for propellers than for fans.[11][12]The propeller is coupled to the turbine through a reduction gear that converts the high RPM/low torque output to low RPM/high torque. This can be of two primary designs, free-turbine and fixed. A free-turbine turboshaft found on the Pratt & Whitney Canada PT6, where the gas generator is not connected to the propeller. This allows for propeller strike or similar damage to occur without damaging the gas generator and allowing for only the power section (turbine and gearbox) to be removed and replaced in such an event, and also allows for less stress on the start during engine ground starts. Whereas a fixed shaft has the gearbox and gas generator connected, such as on the Honeywell TPE331.The propeller itself is normally a constant-speed (variable pitch) propeller type similar to that used with larger aircraft reciprocating engines, except that the propeller-control requirements are very different.[13] Due to the turbine engine's slow response to power inputs, particularly at low speeds, the propeller has a greater range of selected travel in order to make rapid thrust changes, notably for taxi, reverse, and other ground operations.[14] The propeller has 2 modes, Alpha and Beta. Alpha is the mode for all flight operations including takeoff. Beta, a mode typically consisting of zero to negative thrust, is used for all ground operations aside from takeoff.[14] The Beta mode is further broken down into 2 additional modes, Beta for taxi and Beta plus power. Beta for taxi as the name implies is used for taxi operations and consists of all pitch ranges from the lowest alpha range pitch, all the way down to zero pitch, producing very little to zero-thrust and is typically accessed by moving the power lever to a beta for taxi range. Beta plus power is a reverse range and produces negative thrust, often used for landing on short runways where the aircraft would need to rapidly slow down, as well as backing operations and is accessed by moving the power lever below the beta for taxi range.[14] Due to the pilot not being able to see out of the rear of the aircraft for backing and the amount of debris reverse stirs up, manufacturers will often limit the speeds beta plus power may be used and restrict its use on unimproved runways.[14] Feathering of these propellers is performed by the propeller control lever.[14]The constant-speed propeller is distinguished from the reciprocating engine constant-speed propeller by the control system. The turboprop system consists of 3 propeller governors, a governor, and overspeed governor, and a fuel-topping governor.[14] The governor works in much the same way a reciprocating engine propeller governor works, though a turboprop governor may incorporate beta control valve or beta lift rod for beta operation and is typically located in the 12 o'clock position.[14] There are also other governors that are included in addition depending on the model, such as an overspeed and fuel topping governor on a Pratt & Whitney Canada PT6, and an under-speed governor on a Honeywell TPE331.[14] The turboprop is also distinguished from other kinds of turbine engine in that the fuel control unit is connected to the governor to help dictate power.To make the engine more compact, reverse airflow can be used. On a reverse-flow turboprop engine, the compressor intake is at the aft of the engine, and the exhaust is situated forward, reducing the distance between the turbine and the propeller.[15]Unlike the small-diameter fans used in turbofan engines, the propeller has a large diameter that lets it accelerate a large volume of air. This permits a lower airstream velocity for a given amount of thrust. Since it is more efficient at low speeds to accelerate a large amount of air by a small degree than a small amount of air by a large degree,[16][17] a low disc loading (thrust per unit disc area) increases the aircraft's energy efficiency, and this reduces the fuel use.[18][19]Propellers work well until the flight speed of the aircraft is high enough that the airflow past the blade tips reaches the speed of sound. Beyond that speed, the proportion of the power that drives the propeller that is converted to propeller thrust falls dramatically. For this reason turboprop engines are not commonly used on aircraft[4][5][6] that fly faster than 0.60.7 Mach,[7] with some exceptions such as the Tupolev Tu-95. However, propfan engines, which are very similar to turboprop engines, can cruise at flight speeds approaching 0.75 Mach. To maintain propeller efficiency across a wide range of airspeeds, turboprops use constant-speed (variable-pitch) propellers. The blades of a constant-speed propeller increase their pitch as aircraft speed increases. Another benefit of this type of propeller is that it can also be used to generate reverse thrust to reduce stopping distance on the runway. Additionally, in the event of an engine failure, the propeller can be feathered, thus minimizing the drag of the non-functioning propeller.[20]While the power turbine may be integral with the gas generator section, many turboprops today feature a free power turbine on a separate coaxial shaft. This enables the propeller to rotate freely, independent of compressor speed.[21]Drawings of the Hungarian Varga RMI-1 X/H the world's first working turboprop-powered aircraft.Alan Arnold Griffith had published a paper on compressor design in 1926. Subsequent work at the Royal Aircraft Establishment investigated axial compressor-based designs that would drive a propeller. From 1929, Frank Whittle began work on centrifugal compressor-based designs that would use all the gas power produced by the engine for jet thrust.[22]The world's first turboprop was designed by the Hungarian mechanical engineer Gyrgy Jendrassik.[23] Jendrassik published a turboprop idea in 1928, and on 12 March 1929 he patented his invention. In 1938, he built a small-scale (100 Hp; 74.6kW) experimental gas turbine.[24] The larger Jendrassik Cs-1, with a predicted output of 1,000 bhp, was produced and tested at the Ganz Works in Budapest between 1937 and 1941. It was of axial-flow design with 15 compressor and 7 turbine stages, annular combustion chamber. First run in 1940, combustion problems limited its output to 400bhp. Two Jendrassik Cs-1s were the engines for the world's first turboprop aircraft the Varga RMI-1 X/H. This was a Hungarian fighter-bomber of WWII which had one model completed, but before its first flight it was destroyed in a bombing raid.[25][26] In 1941, the engine was abandoned due to war, and the factory converted to conventional engine production.A Rolls-Royce RB.50 Trent on a test rig at Hucknall, in March 1945The first mention of turboprop engines in the general public press was in the February 1944 issue of the British aviation publication Flight, which included a detailed cutaway drawing of what a possible future turboprop engine could look like. The drawing was very close to what the future Rolls-Royce Trent would look like.[27] The first British turboprop engine was the Rolls-Royce RB.50 Trent, a converted Derwent II fitted with reduction gear and a Rotol 7ft 11in (2.41m) five-bladed propeller. Two Trents were fitted to Gloster Meteor EE227 the sole "Trent-Meteor" which thus became the world's first turboprop-powered aircraft to fly, albeit as a test-bed not intended for production.[28][29] It first flew on 20 September 1945. From their experience with the Trent, Rolls-Royce developed the Rolls-Royce Clyde, the first turboprop engine to receive a type certificate for military and civil use,[30] and the Dart, which became one of the most reliable turboprop engines ever built. Dart production continued for more than fifty years. The Dart-powered Vickers Viscount was the first turboprop aircraft of any kind to go into production and sold in large numbers.[31] It was also the first four-engined turboprop. Its first flight was on 16 July 1948. The world's first single engined turboprop aircraft was the Armstrong Siddeley Mamba-powered Boulton Paul Balliol, which first flew on 24 March 1948.[32]The Kuznetsov NK-12 is the most powerful turboprop to enter serviceThe Soviet Union built on German World War II turbopr