Jet propulsion cycle

Technology, Development

Name: Instructor: Course: Date: Jet propulsion cycles The jet propulsion cycles refers to a series of complex combustion processes that occur in gas turbines, which gives them the ability to propel a machine. Gas turbines are commonly used in powering aircrafts because of two features: their high power-to-weight ratio and their compact weight, which makes them easy to mount on airplanes. A few differences exist between gas turbines and jet propulsion cycles, in that; for the gases are combusted in the turbine under pressure, just enough to equal the turbine work to that of the compressor, which leads to a zero, work output. Gases are also expunged at a high rate, which gives the aircraft substantial thrust. These operations of a gas turbine are normally summarized as the Brayton cycle. The Brayton Cycle Brayton-type engines comprise of three main components: the gas compressor, the mixing chamber and the expander.

The Brayton works by drawing in ambient air into the compressor where it is compressed. The compressed air then goes through a mixing chamber and fuel is injected in an isobaric process. The compression also creates heat and the combination of the heat, air and fuel is ignited in a cylinder, which results in production of energy. This energy causes the heated air to expand through the piston in an isentropic process. Some of the energy produced also moves other crankshaft arrangements. Thus, the four key processes in an actual Brayton cycle include two adiabatic and isobaric processes (Lenoble & Ogaji 172). Brayton Cycles typically take one of two forms.

The open cycle is where the working air and combustible material enters and exits the machine. A jet propulsion engine operates in this way. The alternative is a closed cycle that takes in the air-fuel mixture but recirculates the mixture in the machine. These kinds of closed cycles are found in space power generators.

The Brayton Cycle has four main processes that result in the thrust of the airplane. The first process involves the compression within the inlet and the compressor. Efficiency in the Brayton cycle In determining the efficiency, the goal is to analyze the heat absorbed, the work done and eventually, the efficiency of the cycle. Following the path round the Brayton cycle from a to b to c to d and then back to a, the first rule offers; The net work is then calculated with the assumptions that any cycle returns to its original state and that u is a function of state. The net work done is w= q2+q1where q1 and q2 are interpreted as the heat received by the device (Sforza 29).

Ramjet cycle Ramjets are air-breathing jet engines that use the vehicles' motion to compress air and as such, they lack a rotary compressor. Ramjets and scramjets depend on the momentum of the engine to compress the air in the inlet cylinder instead of using the mechanical compressor to push the air. In the free stream condition, the inlet slows the air stream to compress it into the inlet. Slowing down the air speed increases the pressure. Ramjets cannot produce thrust when there is no airspeed so they cannot move a stationary aircraft. Weapon manufactures, for instance, use ramjet systems in their missiles and weapons to give an increased range of propulsion. The ramjets use the high pressure to force air through the cylinder and through the nozzle that accelerates the air to supersonic velocities creating a thrust (Qin et al 46).

Ramjets also apply the Brayton technology in their operations. An example of a ramjet engine has a subsonic diffuser to handle larger volumes and rates of combustion and compression. The change in temperature in the diffuser is related to the Mach number M5. In these engines, the maximum efficiency can be achieved if the temperature in the combustor is kept low (Sforza 49). Efficiency in ramjet engines Efficiency can be defined as the ratio of the output to the input.

It can also be interpreted as an expression of the level of perfection of an engine. A form of efficiency, thermal efficiency refers to the ratio of increasing the kinetic energy to the working fluid to that of the rate of heat addition. The calculation of thermal efficiency for one single-flow jet engine is: Another form of efficiency, propulsive efficiency refers to the ratio of force power to the speed of increment of kinetic energy.

The propulsive efficiency is dependent on how similar the exit velocity and the flight velocity are. The overall efficiency is a product of the two efficiencies (Sforza 29). Scramjet Scramjets are a variation of the normal ramjets but have the advantage in that the combustion takes place in supersonic airflow.

A scramjet depends on the high speed of the aircraft to aid in compression and slow down the incoming air before it is combusted. This is similar to a ramjet, but the difference occurs in the compression. Scramjets do not decelerate the airflow but instead allow it to be supersonic throughout the whole device. One of the best examples of a fast breathing SCRAMjet is the NASA X-43A that reaches Mach 9. 6. The scramjet is made up of three components: the covering inlet that decelerates and compresses the air, the combustor that burns the gas-air mixture to produce heat and the diverging nozzle that accelerates the heat to produce thrust. The scramjet however does not use rotating fans to compress air but instead lets the high speed do the compression. Because of this structural difference, scramjets are limited to high supersonic velocities as they lack mechanical compressors.

They may use turbojets or rocket for the initial propulsion. Scramjets have been used in special aircrafts such as Lear jets that drastically reduces the time taken for traveling. However, issues have arisen over whether such planes can carry enough fuel to last long journeys as scramjet engines consume more fuel than the normal ramjets. These aircrafts also create a sonic boom due to their high velocities and these booms may have negative side effects on the hearing of the passengers. These engines have been used for navigation on the NASA Mars project where vehicles fitted with the system move payloads. The engines produce an impulse of up to 4000s while rockets only give out 450s.

This provides a faster and cheaper way to navigate space (Qin et al 39). The turbojet cycle Turbojets are developed by adding compressors to turbine-powered ramjets in the exhaust. This allows for increased temperature at the combustor inlet and a consequent increase in the thermal efficiency.

The amount of temperature limits the activity of the turbine and the maximum power output. Some models of the turbojets are modified with an afterburner. These devices serve to increase the thrust for supersonic takeoff and in combat situations where a large amount of power may be required in a very short period. To achieve afterburning, additional fuel is injected into the jet pipe of the turbine. While it increases the thrust, afterburning is disadvantageous in that it has higher fuel consumption. Turbojets were the first air-breathing engines to be developed by engineers. Turbojets comprise of air compressors, combustion chambers, air inlets and gas turbines.

Cycle improvements on the turbojet engines Turbojets can be improved by slightly boosting the overall pressure ratio of the compression system. In doing so, the combustor temperature is also raised. By controlling the fuel and air supply, the result is an overall increase in temperatures at the inlet. This will not affect the nozzle temperature but will increase the nozzle pressure. Accordingly, the overall thrust increases while fuel consumption decreases or remains constant. Therefore, the thrust can be increased by simultaneously raising the turbine inlet temperature and the pressure ratio.

These improvements have to be accompanied with improved turbine materials such as vanes and cooling systems (Lenoble & Ogaji 178). The turbofan cycle A turbofan is an air-breathing engine that has a special extension for the turbo section that utilizes the mechanical energy at the combustion stage. The engine has a fan component that creates thrust using the mechanical energy in the turbine too accelerate the airflow speed toward the nozzle. Turbofans therefore create thrust using a combination of these two mechanisms in varying degrees. Engines depending on more turbo than fans are called low bypass turbofans, while those using more fan thrust than jet are high bypass turbofans. The turbofan engine works in the following way.

The operation of the engine has four main stages that have been labeled as " Suck-Squeeze-Bang-Blow". The air is sucked into the air intake and is compressed by an axial compressor to increase the temperature and pressure. The compressed air is then fed into the combustion chamber, mixed with kerosene and combusted that raises the temperature of the air. The hot, compressed air is passed through the turbines to convert the heat into mechanical energy (Cumpsty 23). The mechanical energy is used to turn the compressor that finishes the engine cycle.

Cycle improvements on the turbofan engines Performance in the turbofan engines can be increased by increasing the pressure ratio of the compression system and consequently, the combustor temperature. The overall pressure is also increased by improving the fan blades pressure ratio. The turbine blades of turbofan engines also need to be modified as they undergo stress and high temperatures. New metallic elements have been developed through sciences that are lined with crystals that allow blades to work at higher temperature without distortion.

Modern engines use nickel-based super alloys in their turbine blades. The development in the materials used to make blades however is not the main cause of improvement in the thrust. The improvement in the blade and vane cooling system also contributes toward increased performance. If the ratio of the turbine rotor temperature and the compressor delivery is kept constant, the high-pressure turbine throat area can be kept.

This principle is the most applied system in most high-pressure turbines that drive compressors.