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DEPARTMENT OF AEROSPACE ENGINEERING

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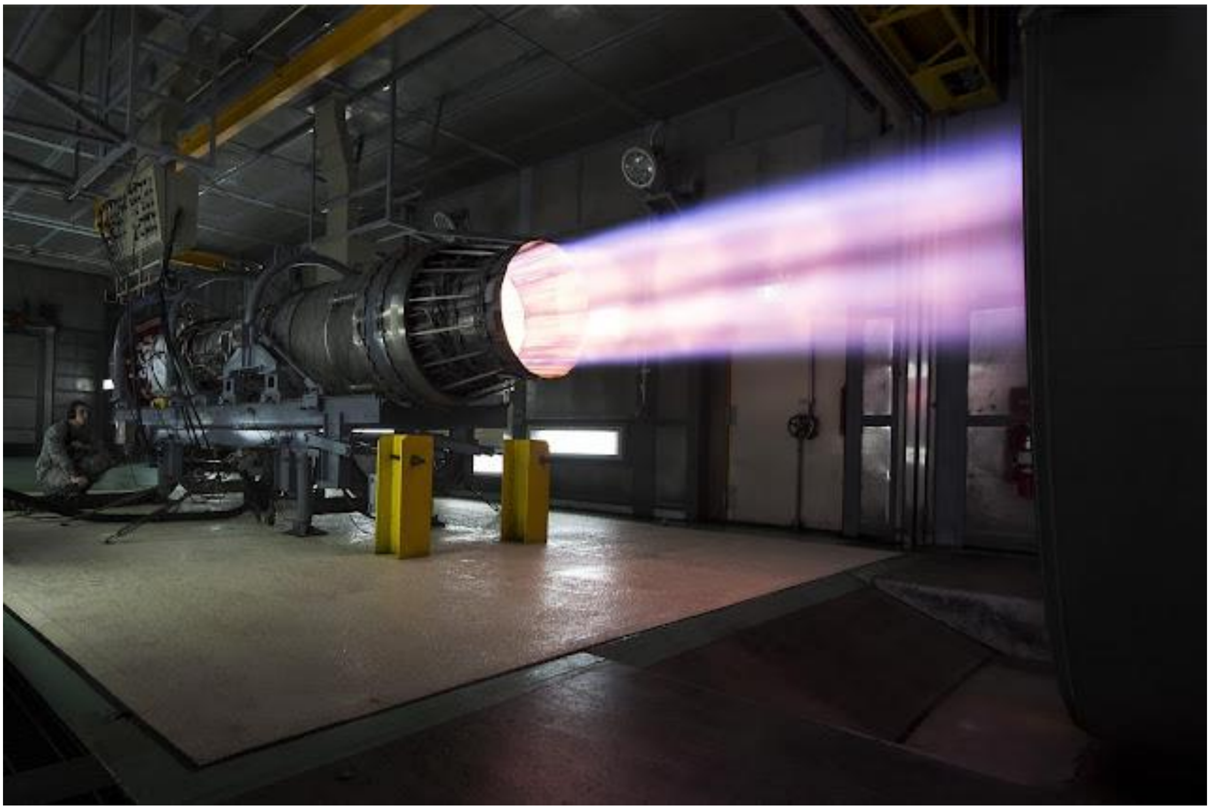
UNIT III - FUNDAMENTALS OF GAS TURBINE ENGINES

Thrust Augmentation Methods



Among the various types of jet engines, the turbojet engine is the one that produces the least amount of thrust for a given engine size. This is because the thrust generated by a turbojet engine is only by the exhaust gases. Any aircraft equipped with a turbojet engine will be enabled with the basic thrust (nominal thrust). With the basic thrust, an aircraft will be able to perform all the conventional maneuvers like take-off, cruise, land, etc. But there are certain circumstances wherein an aircraft has to perform special missions for which the basic thrust is not sufficient.

Missions that require excessive thrust

- Take-off from a short runway or a reduced runway-Ex Naval vessels
- A take-off on a hot summer day
- Combat maneuvers-Ex- Dogfight

To perform all these maneuvers, a turbojet engine has to generate a large amount of thrust. Higher thrust can be generated by using a large-sized engine. But using a large-sized engine will have its concurrent weight penalties. Hence, in such critical conditions, to meet the thrust requirements, a method called thrust augmentation is preferred. Thrust augmentation is a technique by which the basic thrust of a jet engine can be increased without increasing the size of the engine. There are two methods by which the thrust of a jet engine can be augmented.

Thrust Augmentation methods

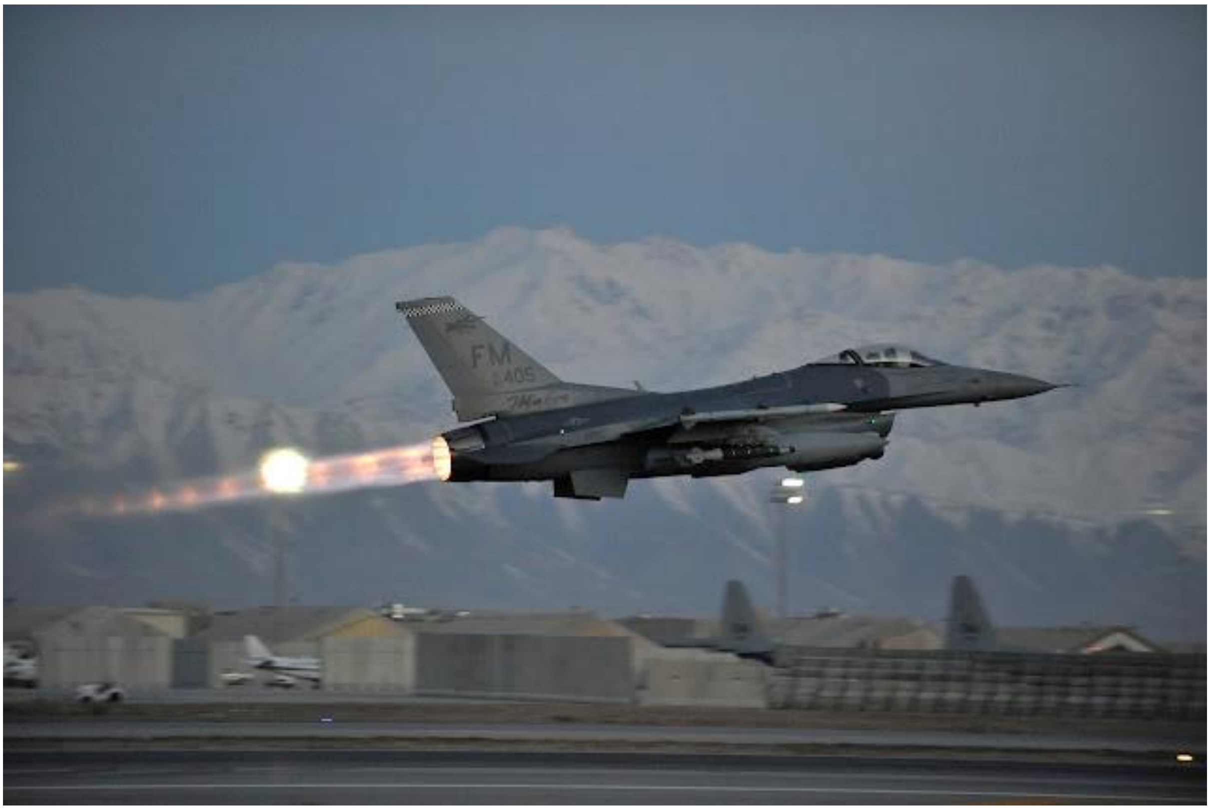
1. Afterburning Technique
2. Water or Water-Alcohol Injection Technique

Afterburner Technique

Afterburner is one of the widely used thrust augmentation techniques by which the basic thrust of the jet engine can be periodically augmented to improve the thrust during take-off, climb, and combat maneuvers. Afterburner is the common method of thrust augmentation and is a characteristic feature of all supersonic aircraft. The use of an afterburner is made possible because the main combustion chamber consumes only 25 % of the total oxygen passing through the engine. As a result, the remaining 75% of the air can be burnt with additional fuel in a secondary combustion chamber located downstream of the turbine i.e., in an afterburner.

Thus afterburner may be defined as an auxiliary burner attached to the tailpipe of the jet engine. By using the afterburner, an additional fuel can be burned downstream of the turbine which increases the temperature of the exhaust gases and consequently the thrust of the exhaust gases.

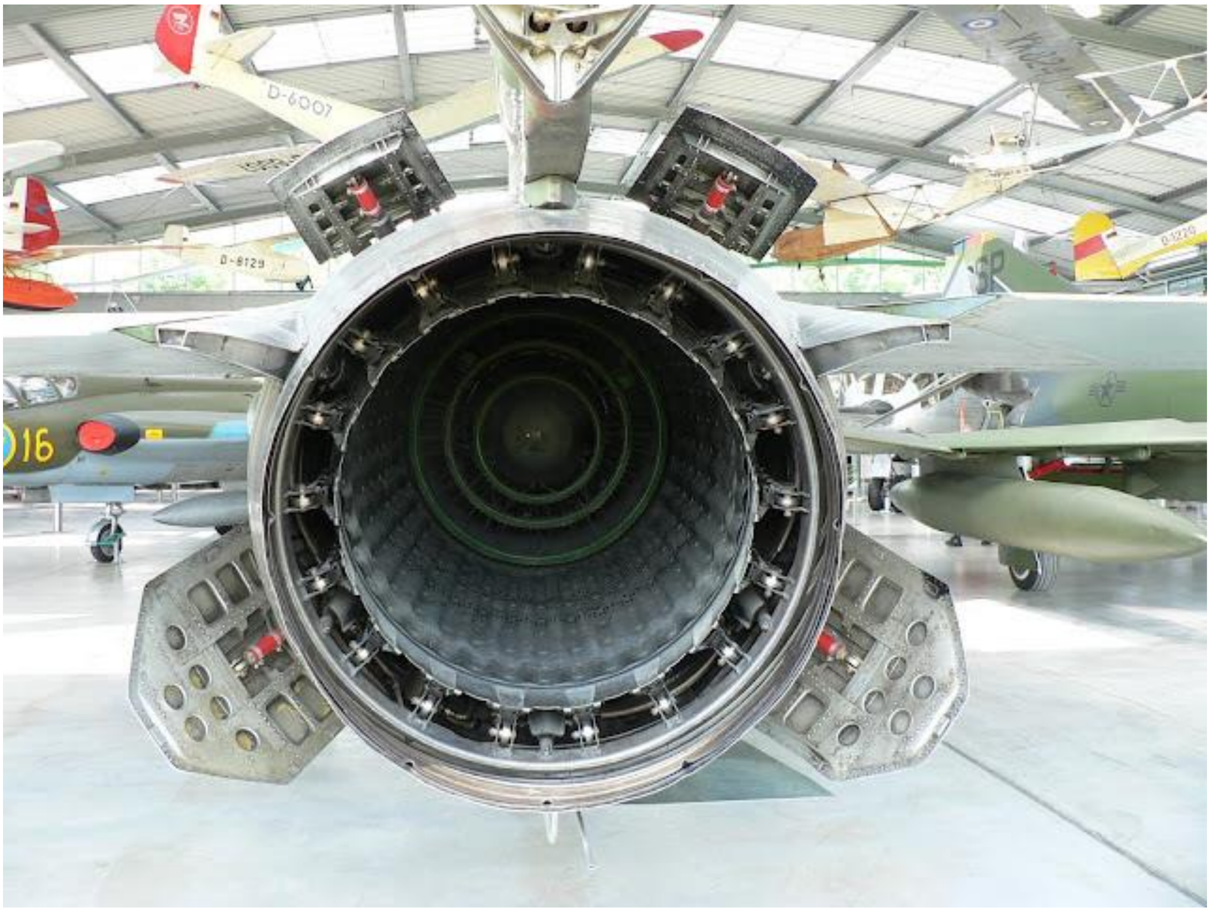
By using an afterburner, an additional thrust of up to 50% can be increased. An afterburner is nothing but a combination of a simple gas turbine engine and a Re-heater, where the expansion of the exhaust gases is accomplished in two stages, and reheating of the gases to the maximum permissible temperature between the stages.



Components of Afterburner

1. Diffuser
2. Spray Bars
3. Torch Igniter
4. Flame Holders
5. Screech Liners
6. Fuel Valves and Pumps
7. Variable Area Nozzle

Working on the afterburner

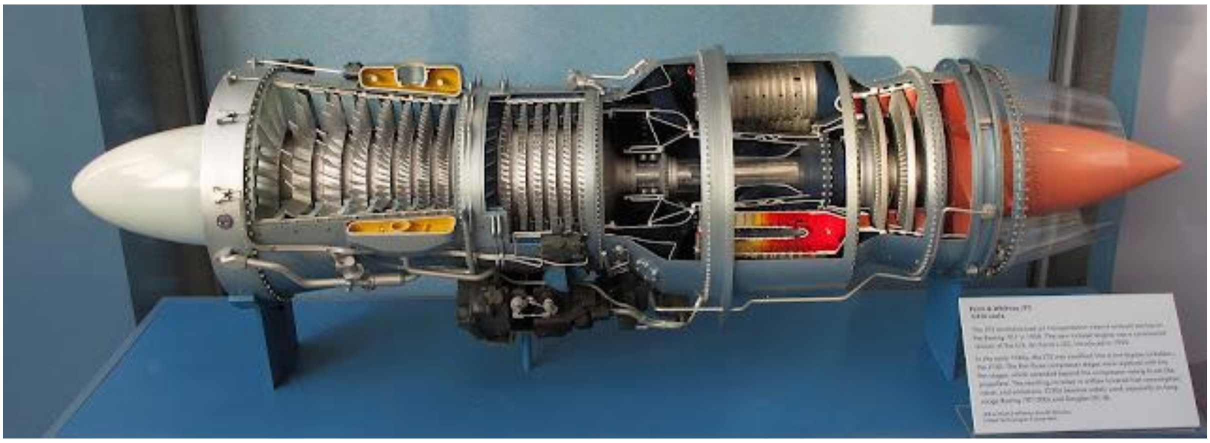


During the working of an afterburner, the hot exhaust gases from the turbine will be made to pass through the diffuser, where the gases are first deswirled and diffused and then made to enter the combustion chamber of the afterburner. Simultaneously, the fuel will be injected into the afterburner through multiple fuel spray bars. Further, the combustion process is initiated with the help of torch igniters or pilot burners which are placed in the wake of the number of flame holders. The process of combustion results in the generation of hot exhaust gases.

During combustion, the temperature of the exhaust gases increases rapidly and can reach up to 2200 C. Since, the temperature of the exhaust gases is very high, the flame is made to concentrate around the jet pipe axis, thereby maintaining a safe wall temperature. Most of the afterburner will be provided with a specialized liner which acts as both a cooling liner and screech liner. The liner is generally corrugated and perforated with thousands of small holes. This liner prevents the high frequency and amplitude pressure fluctuations resulting from excessive noise, vibrations, and other combustion instabilities from causing physical destruction of the afterburner components. All engines incorporating an afterburner must be

equipped with a variable nozzle to accommodate the large changes in the temperature produced by the afterburner.
During the non-afterburning operation, the nozzle will be in minimum position, but when it is switched ON, the nozzle will automatically open to provide an exit area suitable for the increased volume of the gas stream. The opening of the nozzle prevents any increase in the back pressure from occurring which tends to slow down the turbine as well as the compressor and will ultimately lead to the stalling of the compressor.

Water or water-alcohol injection technique



The water injection technique is one of the simplest methods of augmenting the thrust of a jet engine. This technique is mainly used during take-off and when there is a drop in the thrust due to changes in the atmospheric pressure or temperature. Using this technique, power or thrust up to 30 % can be boosted for take-off. The thrust developed by the water injection technique is termed as Wet Thrust and the thrust developed without the use of water injection is termed as Dry Thrust.

During the working, the water-alcohol mixture or just water is added into the engine through a series of spray nozzles. The principle by which this method produces extra thrust is by creating a cooling effect. When water is injected into the compressor inlet, the temperature of the compressed air decreases which increases the density and eventually the mass of the air. This further increases the discharge pressure ratio at the exit of the compressor. When this cooled compressed air is passed into the combustion chamber, the turbine inlet temperature will be reduced. To increase the combustion temperature in the combustion chamber, the mass flow rate of the fuel has to be increased.

The water provides additional thrust in one of two ways, depending on where the water is added. Some engines have the coolant sprayed directly into the compressor inlet, whereas others have fluid added to the diffuser. When water is added at the front of the compressor, power augmentation is obtained principally by the vaporizing liquid cooling the air, thus increasing density and mass airflow. Furthermore, if water only is used, the cooler, increased airflow to the combustion chamber permits more fuel to be burned before the turbine temperature limits are reached, thus increasing the turbine inlet temperatures. Higher turbine temperatures will result in increased thrust.

Water added to the diffuser increases the mass flow through the turbine relative to that through the compressor. This relative increase results in a decreased temperature and pressure drop across the turbine which leads to an increased pressure at the exhaust nozzle. Again, the reduction in turbine temperature when water alone is used allows the fuel system to schedule an increased fuel flow, providing additional thrust.

Water alone would provide more thrust per kg than a water-alcohol mixture due to the high latent heat of vaporization and the overall decrease in temperature. The addition of alcohol adds to the power by providing an additional source of fuel, but because the alcohol has a low combustion efficiency, being only about half that of gas turbine fuel, and because the alcohol does not pass through the central part of the combustion chamber where temperatures are high enough to efficiently burn the weak alcohol-air mixture, the power added is small.

The increased thrust results because of the cooling effect of the water or the increased flow through the fixed area turbine that effectively increases the operating pressure ratio of the engine. All of the preceding depends on where in the engine the water is injected. The water injection system is not without penalty. Water and the injection system are very heavy; there is a thermal shock to the engine, and compressor blade erosion can occur when the system is activated. An important limiting factor is, that compressor stalls can also be a problem with water injection.