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Thrust Augmentation and its Control Methods: Short Overview

[1]Nikkisha S, [*2]Ankit Kumar Mishra
[1]Astroex Research Association, Deoria, Uttar Pradesh, India
[2]REST LABS, Krishnagiri, Tamil Nadu, India
[*]Corresponding author Email:ankitkumarm1998@gmail.com

Abstract. Augmentation plays a crucial role in many aircrafts and jet engines to elevate the thrust. Thrust is oe of the four fundamental forces of an aircraft. Augmentation methods are used in certain cases to increase the thrust to perform better landing and take-off. There is various augmentation methods in which afterburner is mostly used over other augmentation methods because of its advantages. In this paper an overview has been provided for thrust augmentation and its different control methods.
Keywords: Augmentation, Control, Propulsion, Review

1. Introduction

There are four fundamental forces acting on an aircraft. An aircraft moves through the air by thrust. Different kinds of engines will develop thrust in many ways. Anyway, Thrust works through Newton's Third Law. With an average thrust, an aircraft can perform takeoff, landing, etc.., but in some circumstances, average thrust is not enough. For instance, taking off from a short runway, Normal thrust n When the thrust of an engine can be increased without any variation in engine size is widely known as Thrust Augmentation. There are various methods to perform augmentations such as afterburning, water injection and air bleed off method. After Burner is the most commonly used method in augmentation whereas water injection method uses a coolant to increase the thrust. This paper completely elaborates the concept of thrust augmentation and its types for better understandings.

2. LITERATURE REVIEW

Melvin J.Bulman (et.al, 2000) said we can increase the rocket's thrust by adding mass and releasing chemical energy in the rocket's nozzle. In this paper, they discussed hot-fire testing and compared CFD performance. This LANTR is a hypothesis, in which, Thrust from an NTR can either be tripled or quadrupled. The main benefit of this concept is higher thrust will be provided with a small nuclear reactor. At last, This LANTR concept increases thrust by over 40% to arouse nuclear-heated hydrogen.[1]

Scott Forde (et.al, 2005) have discussed the TAN (Thrust Augmentation Nozzle) hypothesis. The authors patented this concept to authenticate elevation sea-level thrust. This TAN concept is a supplement to augmented Nuclear Thermal Rocket (LANTR). This concept allows for a high lift-off thrust.[2]

Lt. Col Timothy Lawrence (et.al, 2005) said many developed systems which were used in the olden days are currently in use. Added to a conventional chemical rocket, The higher resultant thrust, and specific impulse will not be feasible. If we consider a nuclear reactor, which can directly heat the propellant or create nuclear electricity.[3]

Samit K. Bhattacharya (et.al, 2011) discussed the basic idea of developing a Nuclear Thermal Rocket. He has said some challenges of developing nuclear rockets. Apart from challenges, The main purpose is an overview sense to approach the basic layout of NTR.[4]

David R. McCurdy (et.al, 2012) conveys a nuclear thermal rocket generates high thrust and high specific impulse around 900 seconds than chemical rockets. It's been considered as next step in evolution. They have discussed how this NTR propulsion is going to be the next evolutionary step for Human Space Exploration.[5]

Stanley K. Borowski (et.al, 2013) discussed past achievements, current efforts, and future expectations of Nuclear Thermal Propulsion. Especially, this paper focused on the use of NTP for Human Space Exploration. He further discussed controlling NTR during its start-up, full thrust, and shutdown. He concluded with the future testing of small, scalable NTR.[6]

V. Krishnamurthy (et.al, 2013) said, currently, this chemical and electric propulsion technology is limiting the chances of inspecting the other planets. He also said the operating fundamental for gas core Nuclear Thermal Rocket propulsion. Thrust to Weight ratio will be increased by supersonic combustion of oxygen and this triggers to augment and thrust will be varied.[7]

Michael L.Blair(et.al, 2013) created 4 NTR Model in NPSS Which has been further divided into 2 categories. They analyzed the working factors like thrust augmentation, specific impulse and etc…, The main aim of this work is to analyze operation and system performance.[8]

John. R.Bucknell (et.al, 2015) proposes a new Nuclear Thermal Turbo Rocket for eath orbit applications. He said the propellant thermal flow of a chemical rocket is comparably high to the thermal power of a reactor. Therefore, Thrust to the ratio is far low. The early Nuclear Thermal Rocket project demonstrated 5:1 Thrust- Weight. At low Mach numbers, sufficient thrust will be produced in this NTTR.[9]

Seung Hyung Nam(et.al, 2015) said nuclear propulsion is one of the best ways to conquer the hard environment of space. Due to its high thrust and efficiency, NTR is a choice for space missions to Mars. This paper introduced some principles of nuclear thermal propulsion and they also introduced a concept with the help of NTP'S design features.[10]

Francisco J. Arias (et.al, 2016) see the advantage when pulsing NTR in respect of thrust and specific impulse. The proposed postulation is to evaluate the NTR. By increasing propellant mass flow rate, There will be excessive use of energy in thrust augmentation. The author said, In a static mode, the rising thrust will not be a good idea when the power is limited.[11]

Paolo Venneri (et.al, 2017) describes the design of LEU-NTR. They have also compared the two thrust classes. In this paper, the authors have given the methodology to implant low-enriched uranium in NTR. In the end, they compared and showed how LEU-NTR is applied for different thrust levels.[12]

Steiling (et.al, 1975) explored thrust augmentation of various afterburner ejectors. Using H/o2 sonic rocket as primary gas generator, static test were conducted.[13]

Green C J(et.al, 1963), experimente has been conducted by injecting liquids into supersonic region to get the thrust vector.The author presented the study of various injections of liquid combined with different physical parameters.[14]

3. Thrust Augmentation

Thrust augmentation is received through addition of chemical power to the nuclear rocket in preference to through an boom withinside the reactor power [15]**.** National Advisory Committee for Aeronautics (NACA) sought a way to increase the thrust as a very short-term period. This thrust augmentation includes bleed-off, afterburner, and coolants to increase an aircraft's thrust when necessary. In a simple way, Thrust augmentation is a way to boost the thrust in a brief period of time. Water injection, Bleed off, and After burning are the methods of thrust augmentation. In this method, after burn is mostly the preferred method for boosting the thrust. Afterburner is also known as Tailpipe Burning. The name ejector has been given to many devices as they are dependent upon the quantity of fluid. To calculate the performance of any flight and gas conditions, it is vital to keep the ideal, no-loss situation in mind and to evaluate the geometry ejector on thrust augmentation. The ideal performance of thrust augmentation includes a huge number of independent parameters. These independent parameters can be reduced by considering the inlet and outlet geometry of the ejector. It has been said that the augmenting ejectors always work at a pressure ratio of 1[16].

Considering a fully pulsed jet, it is essential to differentiate the measurement of the time average thrust from fully pulsed jet from an equivalent jet thrust. The thrust is given as:

$$F_s = \rho\ AU^2 \text{……………} [1]$$

For an aircraft VSTOL can be achieved by thrust augmenting ejector. The hyper mixing nozzle was developed to improve ejector's performance. The thrust of the combined flow usually surpass the primary jet alone. Anyway, this can be used in aircrafts applications which will augment the thrust to accomplish landings and short take offs [18].The ratio of thrust generated by the ejector to the thrust of the primary steam is known as thrust augmentation [19]. In VSTOL aircraft, Thrust augmentation will be providing power requirements with those of landings and take off. Practically, Thrust augmenting ejector as well as lift should attain compactness and higher performance simultaneously. With compact ejectors, aircrafts can easily attain higher level of static thrust augmentation [20]. A thrust will be developed in every fluid propulsion devices by momentum to a fluid stream. The thrust is equal to the momentum. The ratio of thrust augmentation elevates with diffuser area ratio and ejector inlet [21].

4. Thrust Augmentation Methods

Methods to augment the thrust are:

- After-Burner.
- Water Injection.
- Air Bleed Off.

After Burner: Afterburning could be the best way to increase power for jet turbines by using a larger engine, but this would come with an increase in weight, frontal area and fuel consumption. Jet engine afterburners boom center thrust thru the addition of gasoline downstream of the low pressure turbine and combustion that will increase the temperature of the exhaust [22]. Afterburning provides short-term benefits over utilizing a larger engine. The excess air supplied by the fuel in a turbine engine is used to provide oxygen for future combustion. This enables more fuel to be injected into the exhaust pipe, increasing the thrust and power of the jet engine. An afterburner (A/B) has to offer a flame preserving place and be of enough length for the combustion to be completed.[23]

The intense heat of an afterburner can cause the flame to be concentrated near the jet pipe's axis. This allows some of the engine discharge gas to flow along the jet pipe's wall, which helps maintain a safe temperature.

An afterburning jet pipe is larger than a normal jet pipe in order to obtain a reduced velocity gas stream. This allows the afterburner nozzle on the end of the pipe to open or close, providing an exit area that is suited for the size and speed of the gas being expelled. Pressure will not increase inside of an afterburning jet pipe as this type of engine operates under all conditions.[24]

Devices that use gas turbines take advantage of the structural limitations placed on turbine inlets by combustion temperatures exceeding half the stoichiometric fuel-air ratio. As a result, the gas leaving the turbine contains most of its original concentration of oxygen. This oxygen can be burned with additional fuel in a secondary combustion chamber located downstream of the turbine where the temperature constraints are relaxed. The increased total temperature produced at the nozzle by this additional heat addition results in an increased exit velocity and thrust.[25]

Generally, operability for afterburners involves both static and dynamic stability. Static stability is associated with the ability of the system to hold flame steadily on the flame holders over the entire range of operating conditions related to the aircraft flight envelope. Dynamic stability speaks to the unsteady character of the flame where strong oscillations or instability of the flame can create problems. Operability has always been a problem for afterburner designers because they often have to operate under a wide variety of conditions to satisfy the flight envelope of their specific aircraft, but this challenge also presents an opportunity for newer engines with more refined afterburners that augment, rather than replace, traditional thrust.[26]. Afterburners in which the volatile region would cover the entire range of useful mixture ratios.[27].

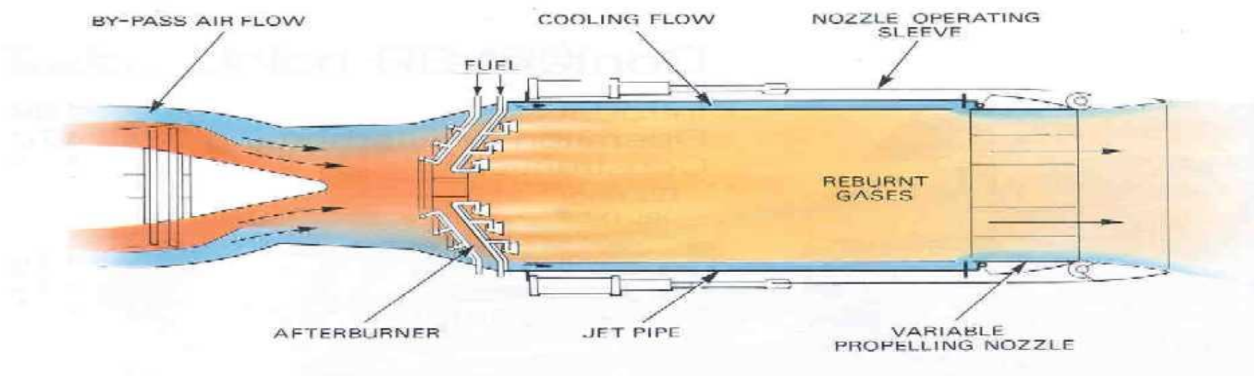

FIGURE 1. Schematic diagram for after burner [24]

Water Injection: One of the oldest methods to increase thrust is by injecting a water and alcohol mixture into the inlet. The mixture helps avoid freezing, as it is mixed with alcohol. Double cooling improves engine performance, power and efficiency during take-off. The combustion chamber is where the fuel is ignited. When a jet of air coolant (usually air) is injected through the inlet, it increases the mass flow rate and pressure. This elevated pressure ratio is meditated at some stage in the engine and increwes each the mass fIow of gases via t-he engine and the exhaust-jet velocity; each elements growth the thrust produced through the engine[28].This helps create more energy in the turbine and exiting through the jet pipe.

If water injection were used without an increase in thrust, it would extend the lifespan of engine parts and also result in lower NOx emissions. There are two popular methods of cooling an aircraft engine's water.[29]

Injection Types are:

1. Direct injection into the combustor.
2. Sprayed with water before the engine's compressor.

As a promising way to reduce in-cylinder temperatures, mitigate combustion knock, improve combustion phasing and decrease NOx emissions, water injection applied on different types of engines has excited people all over the world. With this, they hope to lower fuel consumption and create less pollution according to the stricter emission regulations [30].

Considerations For water injection systems: [31]

1. The engine cannot have excess power into it unless water is flowing into it.
2. Upon exhaustion of water supplies, the power should return to its safe dry limit.

In water injection systems, about half of the solution is made from water and a combustible alcohol like methanol. The rest of the mixture also includes nano cooling agents to prevent corrosion from happening.[32]

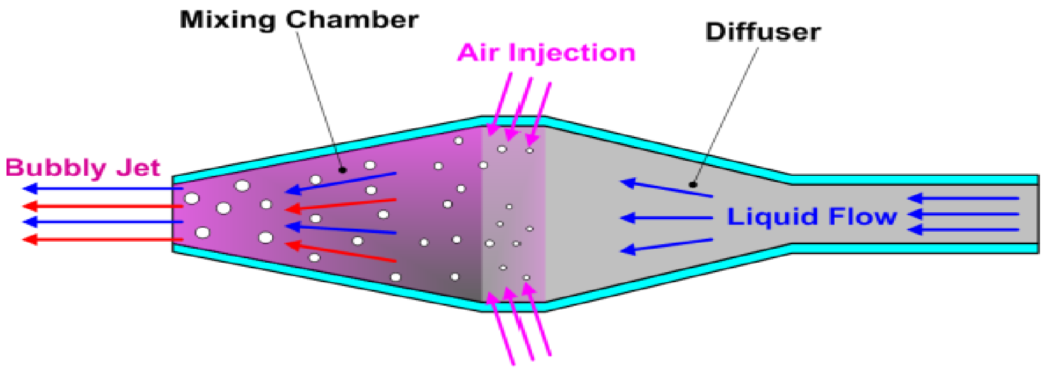

FIGURE 2. Schematic diagram of water injection method [39]

Airbleed Off: Air Bleed off is the greatest method among all to bestow the take-off thrust. Increasing the Thrust augmentation further in this method may be achieved by elevating improvement in the secondary combustion [33]. A turbojet engine with compressor air bleed and its provide downstream of the turbine is a new service, which is not yet run on flying airplane.[34].Bleed air is frequently extracted from jet engine's combustion for numerous programs all through plane operations. all the parameters have sturdy impact on plane performance[35].The 737 Engine Bleed Air System is designed to offer engine compressed air to aircon % with the reason of air pressurization all through flight; engine air from the compressor is used, from the 5° and the 9° level in a secure a cheap way, know-how of the precise characteristic of the additives will boom protection and notably lessen price of protection operations[36].Several bleed air device designs are presently in use, and every of them inflicting precise aerodynamic and thermal perturbations which could lessen the general performance of the compressor level or even result in thermal distortions with inside the casing of the compressor and for that reason lowering the predicted life time of the engine component[37].Airbus alternatively is greater careful and remains with a greater traditional ECS furnished through bleed air from the engines.[38]

5. Conclusion

On account of increasing the thrust of an aircraft during take-off, landing and climbing, Augmentation will be used. The advantage of using the afterburning gas turbine is that augmented engines are much lighter than the turbojet engines. Power output by a turbine engine is largely determined by the density or weight of the gases flowing through it. It follows that when atmospheric pressure decreases or ambient air temperature increases, thrust is lost. By cooling the airflow with water or coolant, power output can be increased or restored. Jet engine thrust may be enlarged by bleed off a number of this excess high pressure air because it leaves compressor thus it may be burned individually individual basis} in an auxiliary nozzle. it had been necessary to inject water into the water to switch the removed air.

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