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RESEARCH ARTICLE

INCREASE IN EFFICIENCY OF AN AIRCRAFT.

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Abstract

Efficiency is the ability to avoid wasting materials, energy, efforts, money, and time in doing something or during production of a desired result. In a more broader sense, it is the ability to do things successfully, and with minimum waste. In scientific terms, it is the measure of the extent to which input is well used for an output. It often comprises the capability of a specific application of effort to produce a specific outcome with a minimum amount or quantity of waste, expense, or unnecessary effort. Recent developments in all engineering fields have led to an increase in efficiency which has helped to save millions for companies as well as reduced the global impact of pollution on the world drastically. There are many examples of huge manufacturing companies in the aviation sector such as Airbus and Boeing that have led an extensive research in this field. An increase in the efficiency of the aircraft is the primary topic of discussion in this paper

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Introduction:-

NASA and Boeing flight tested a 500 lbs (230 kg) blended wing body (BWB) X48B demonstrator from August 2012 to April 2013. The design provided greater fuel efficiency, since the whole aircraft produces lift, not just the wings. The BWB concept offers advantages in structural, aerodynamic and operating efficiencies over today's more conventional fuselage- and-wing designs. These features translate into greater range, fuel economy, reliability and life cycle savings, also lower manufacturing costs.

Research projects such as Boeing's Eco-Demonstrator program have sought to identify ways to improve the fuel economy of commercial aircraft operations. The U.S. government has encouraged such research through the FAA's Continuous Lower Energy, Emissions and Noise (CLEEN) program and NASA's Environmentally Responsible Aviation (ERA) Project. The IATA technology roadmap, has a vision of improvements in aircraft configuration and aerodynamics, by 2022: Natural Laminar Flow would reduce Fuel consumption by 5 to 10% and Hybrid Laminar Flow by 10 to 15%, by 2026: Hybrid Wing -Body by 10 to 25%, by 2027: A Morphing Airframe by 5 to 10%, by 2028: Truss / Strut Braced Wing by 10 to 15%, by 2032: Flying without landing gears by 10 to 20%; new engine architecture by 2016: A Geared Turbofan and an Advanced Turbofan would reduce Fuel consumption by 10 to 15%, by 2019: Unducted Fan by 15 to 20%, from 2023: Counter Rotating fan by 15 to 20%, and by 2026: second generation core concepts by 25 to 30%.

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One of the most recent developments in the modification of design to improve the efficiency has been done by the two major companies in aviation i.e.; Airbus and Boeing. Airbus recently launched an updated model of the largest passenger aircraft the A380 Plus.

The A380 Plus boasts a promise to airlines that a 13% cost reduction per seat will be achieved, versus the current A380 model, while enjoying the A380's unique comfort level. The new features of the A380 Plus include a prototype winglet, which promises the winglets will provide up to 4% fuel burn savings.



Fig 2:- The A380 plus

The design changes from the existing design of the A380 are as follows :

The new winglets measure approximately 4.7 metres in height (an uplet of 3.5m, and a downlet of 1.2m). It is designed to improve aerodynamics and reduce drag force .

- The A380 Plus will have an increased maximum take-off capacity of 578 tonnes providing the flexibility of carrying up to 80 more passengers over today's range (8,200 nautical miles), or flying a 300 nautical miles further.
- The A380 Plus features longer maintenance check intervals, a reduced six-year check downtime, and systems improvements, which will reduce maintenance costs and increase aircraft availability .

Boeing in competition to the Airbus A320 launched a new model of their 737 series known as 737 - Max 10

It boasts of its newly designed winglets produced by advanced design and manufacturing techniques that allow natural laminar flow . Thus it delivers improved fuel efficiency than any other winglet. Also it has incorporated the latest CFM International Leap 1B engines which promises to deliver a reduction in noise , carbon as well as NOX emissions.



Fig 3:- The 737 Max 10 - The newest of the Boeing series .

In aircraft design, overall propulsive efficiency η is the efficiency, in percent, with which the energy contained in a vehicle's propellant is converted into useful energy, to replace losses due to aerodynamic drag, gravity, and acceleration. It can also be stated as the proportion of the mechanical energy actually used to propel the aircraft. It is always less than 100% because of kinetic energy loss to the exhaust, and less than ideal efficiency of the propulsive mechanism, whether a propeller, a jet exhaust, or a fan. In addition, propulsive efficiency is greatly dependent on the density of air and air speed .

There are two types of efficiencies ; Cycle efficiency and Mechanical Efficiency .

The cycle efficiency, in percent, is the proportion of energy that can be derived from the energy source that is converted to mechanical energy by the engine .Most aerospace vehicles are propelled by heat engines of some kind, usually an internal combustion engine. The efficiency of a heat engine relates how much useful work is output for a given amount of heat energy input.

From momentum considerations, propulsion requires material to be pushed backwards to push the vehicle forwards. In general, energy efficiency is highest when the air or exhaust gas used to propel the vehicle end up travelling as slow as possible for the required thrust, in the frame of reference of the Earth. This is called Mechanical Efficiency- For jet engines dependence of the energy efficiency (η) from the exhaust speed/airplane speed ratio (c/v) for air-breathing jets . For all air-breathing engines the propulsive efficiency is highest when the engine emits an exhaust jet at a speed that is as close as possible to the aircraft velocity. The graph of Efficiency v/s speed ratio is given below :-

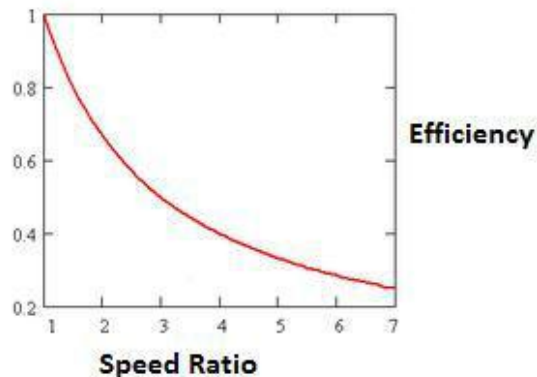


Fig 4:- Speed Ratio V/S Efficiency

An increase in efficiency not only guarantees a decrease in the running costs during the flight but also helps to preserve the environment as the amount of fuel burnt is decreased per nautical mile flown. Hence the carbon footprint of the aircraft decreases and vast results can be identified over a longer period of time. Today's world focuses mainly over the issue of pollution and saving the environment from its ill effects. Thus is a very important part of research which will help our world in one way or another.

Literature Review:-

(A) F. Liu and W. A. Sirignano -: [1]

A thermal analysis was carried out and the advantages of Continuous Turbine Burner (CTB) and Inter Turbine burner (ITB) engines for both the turbojet and turbofan configurations were noted. Burning in the turbine passages reduced the trade-off between Specific thrust (ST) and Thrust Specific Fuel Consumption rate (TSFC). It allowed significant increase in ST with only small increase in TSFC. A noticeable benefit for a CTB or ITB engine were, to be able to produce gases of high kinetic energy at high thermal efficiency, by providing a very desirable gas generator as the basis of high-performance engines which are applicable to both military and commercial applications.

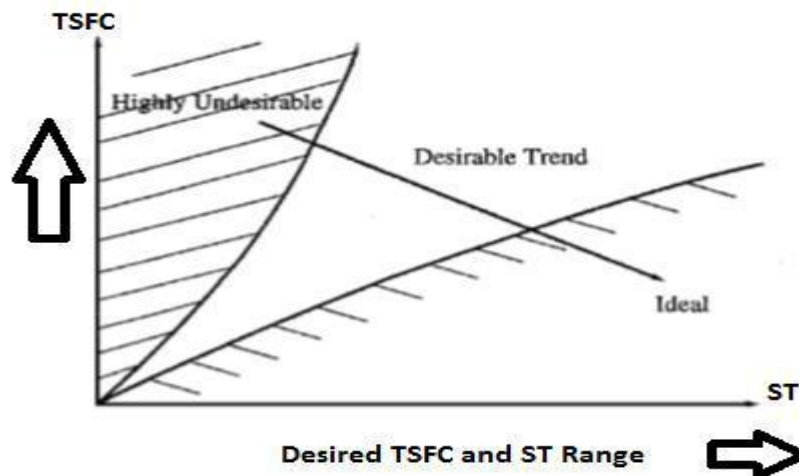
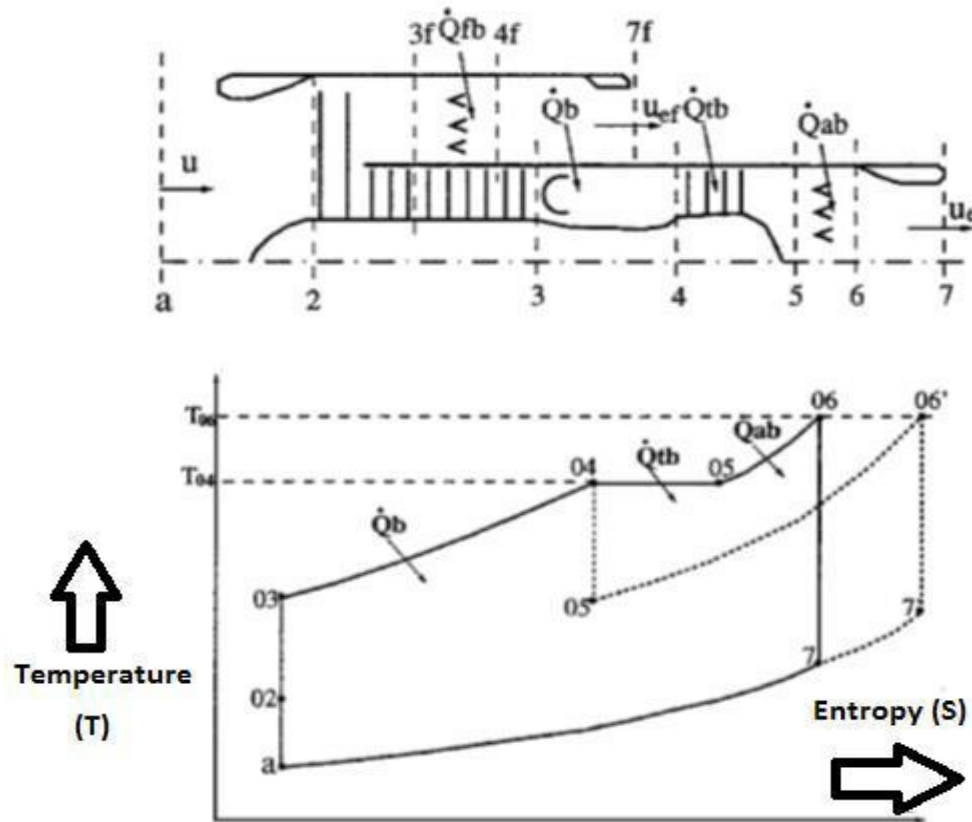


Fig 5:- The Graph between Thrust Specific Fuel Consumption (TSFC) V/S Specific Thrust (ST)[1]

The parametric studies in the paper enlightened the following:

- The turbine-burner engines were capable of operations at high compressor pressure ratios. Although conventional engines have an optimal compressor pressure ratio between 30–40 for supersonic flights, beyond which they have diminished thrust and very high TSFC, the turbine-burner engines were capable of operating at pressure ratios higher than 60. Increased compressor ratios generally increased ST and decrease TSFC of the turbine-burner engines.
- Because of the extended compressor pressure ratio range and also for the fact that the propulsion efficiency improves at high speed for jet propulsion, the performances of the turbine-burner engines were significantly superior at higher flight speed than conventional engines.
- The turbine-burner engines benefited more from efficient, large bypass fans than the conventional engines. The bypass pressure ratio can be optimised for a specific need.
- The turbine-burner engines benefit equally well as conventional engines do from high-turbine inlet temperatures that may result from development of new materials for turbine cooling technologies.



Comparison of the thermodynamic cycles with and without a burner

Fig 6:- The Thermodynamic Cycles [1]

Conclusion:-

The analysis concluded that the 1-ITB engine provides more than 50% increase in ST with equal or lower TSFC over the conventional base turbofan engine. Also the thermal analysis proved that A CTB or ITB engines for both turbojet and turbofan configurations yielded noticeable increase in ST with small increase in the TSFC. This can lead to an increase of efficiency of upto 5% [1].

(B) Dr. Jassim M. Abdulkarim Jaff [2]

(a) Experimental analysis:-

All types of jet engines were studied and their characteristics were noted. The types of jet engines studied were; Turbo prop, Turbojet, Turbofan. A vast thermodynamic analysis of each of the jet engines were taken.

The velocity of air entering the engine was also studied extensively. Also various parts which help in the efficient operation of the aircraft were studied such as; Turbocharger, Compressor, Turbine, Ignition system, Equivalent Ratio and Nozzle.

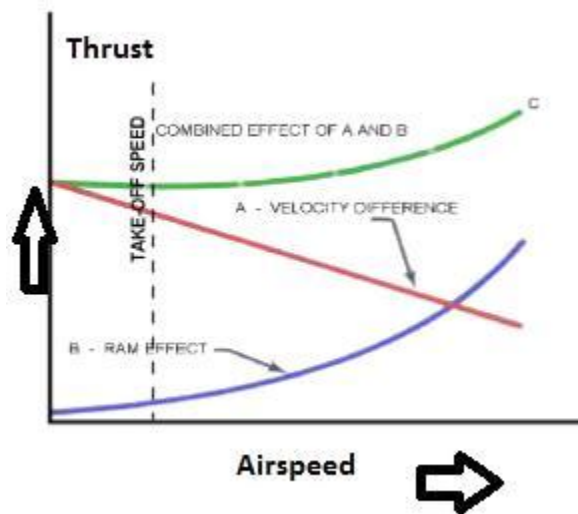


Fig 7:- Graph Of Thrust V/S Airspeed [2]

(b) Observations:-

From the experimental analysis it could be observed that ;

- (1) Most of the possible performance, programmatic, design, and technological parameters that effect of jet engine were analysed. The results indicated that rotor inlet, equivalence ratio, and combustion chamber design are a significant in almost all of the relationships.
- (2) Material technology continues to propel advancements in jet engine performance. There are multiple innovations that cannot be included in current designs because of the cost. Research in this would probably result in development of lighter and stronger materials.
- (3) The equivalent ratio is one of the most important parameters that effect of the speed jet engines, and to get the maximum speed equivalent ratio should be equal to one ($\phi=1$). [2]
- (4) When the flame length and impact force increases , equivalent ratio increases, this is due to increased fuel ratio in the mixture burning.
- (5) Design of combustion chamber and the method of entering the primary and secondary air have an essential role in the combustion process and the speed of the jet engine . -[2]
- (6) Increase in the jet engine speed with increase in the temperature of mixture burnt , because reactants in the combustion process participate in the combustion process to get the highest energy.

(c) Conclusion:-

Further analysis should continue on the speed of jet engine development. This will improve the quality of future cost estimating tools and lead to high performance of jet engines. Also Material Technology played an important role in defining the efficiency of the aircraft. [2]

(c) Derek Sitt -[3]

(a) Experimental Analysis -

The use of Gear boxes turbofans than traditional turbofans was studied . An experiment with Rolls Royce was conducted.

(b) Observations:-

A gearbox allowed the engine to run at optimal speeds while reducing the number of parts required to make the engine. Not only would it increase efficiency, but it also reduced fuel consumption which released fewer harmful chemicals into the atmosphere. The use of geared turbofans would replace conventional turbofans due to superior efficiency , increased sustainability and more prominent economic benefits The differences between the regular and geared turbofan are –

- a. Fan blade diameter,
- b. Reduced number of parts, and
- c. The addition of a planetary gearbox. [3]

It was found that though each difference was not that significant on its own, the combined effect of each of them would result in a much more efficient engine. Longer and wider fan blades would provide the geared turbofan and in increased intake of volumes of air. The larger quantities of air can be used to provide more thrust in the form of bypass air.

A downside to larger fans is the engine size. The larger engine is necessary to accommodate larger fans, also the increased volume of air passing through the turbofan. [3]

To the contrary, the geared turbofan weighs less than the conventional turbofan due to the less number of parts. The lesser number of components can be attributed to the planetary gearbox, which optimizes the speed of each part of the turbofan. The gearbox will be inserted directly between the fan and the compressor blades. By optimizing both the compressors and turbine, it would reduce the required number of blades.

(c) Conclusion:-

The conclusion can be analysed with an example - Boeing 787 Dreamliner has a life of around 40,000 cycles. 1 cycle is considered the time take-off to the time when it lands. With a price of 200 million dollars, this Boeing aircraft costs around 5,000 dollars per flight. In addition, the cost of fuel for a transatlantic flight costs upwards of 15,000 dollars. Using these estimates, the cost of fuelling is about three times as expensive as the plane itself. In the future, and engine like Rolls-Royce's Ultra Fan could drastically reduce fuelling costs thanks to its projected 25% increase in fuel efficiency.

Thus the use geared turbofans on aircrafts lead to a reduction of fuel burnt by 16 percent, emissions reduced by 50 percent and the engine noise reduction by 75 percent .[3]

Conclusion:-

From the three papers it can be concluded that ;

- (A) Optimum calculations of Continuous Turbine Burner (CTB) , Inter Turbine Burner (ITB), Specific thrust (ST) and Thrust Specific Fuel Consumption rate (TSFC) can result in effective improvement in the efficiency . An in-crease in efficiency of 5 percent could be computed
- (B) Characteristics of various jet engines were studied . The material properties of the engine played an important role in determining the efficiency.
- (C) Geared turbofans were preferable than normal turbofans . It was concluded that a reduction of fuel burnt was by 16 percent, emissions were cut by 50 percent and engine noise was reduced by 75 percent.

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