STRENGTHENING THE EFFICIENCY OF AIRCRAFT BY HARVESTING THE AIR

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Abstract

This system strengthens the efficiency of aircraft by harvesting the slow moving air which is moving around the fuselage of the aircraft.

In this concept the slow moving air is being collected and harvested by making it to run through boundary layer fan which reduces the overall drag, if the drag is reduced ultimately the consumption of fuel will be reduced. Adding generators to the turboelectric fans can help to generate the power to drive the boundary layer fan. But, in the case of conventional aircraft the boundary layer is just a covering or a cocoon of the slow moving air around the fuselage of the aircraft. Though this does help to reduce friction, as it flows off the rear of the aircraft, the boundary layer breaks up into turbulence.

Thermal efficiency of the aircraft can be further improved by the method of regeneration.

The temperature of the exhaust gases from the turbine is usually higher than the temperature of the air leaving the compressor. The heat of the exhaust gases can thus be utilized to heat the air coming out from the compressor counter flow of heat exchanger, also known as heat regenerator or recuperator. This arrangement helps to reduce the heat supplied in the combustion chamber resulting in improving the thermal efficiency of the cycle.

Keywords: Boundary layer ingesting(BLI), recuperator, infinitesimal fluid volume, thermal efficiency, turboelectric engine.

I. INTRODUCTION

An aircraft is a machine that is able to fly by gaining support from the air. It counters the force of gravity by using either static lift or by using the dynamic lift of an air foil, or in a few cases the downward thrust from jet engines.

Propulsion is a means of creating force leading to movement. The term is derived from two Latin words: pro, meaning before or forward; and pellere, meaning to drive. A propulsion system consists of a source of mechanical power, and a propulsor (means of converting this power into propulsive force).

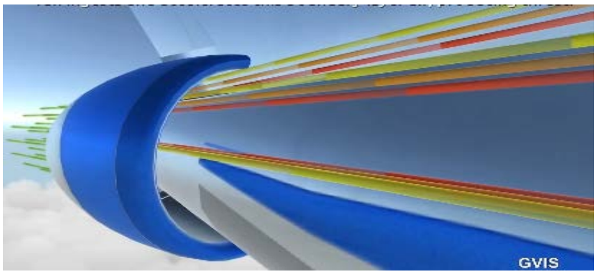
The main aim of this system is to improve the aircraft efficiency by making use of the slow moving air near the aircraft fuselage with the use of some special instalments.

The turbofan engine is an air breathing jet engine, usually used in aircraft. It consists of a gas turbine with a propelling nozzle. The gas turbine has an air inlet, a compressor, a combustion chamber, and a turbine (that drives the compressor). The compressed air from the compressor is heated by the fuel in the combustion chamber and then allowed to expand through the turbine. The turbine exhaust is then expanded in the propelling nozzle where it is accelerated to high speed to provide thrust. These turbofans engines which is mounted on the bottom of the wings, pulls the air and accelerates it to produce thrust.

The slow moving air near the aircraft fuselage is called the boundary layer. The fan ingests and accelerates the boundary layer air, producing thrust. The slow moving air is sent to the boundary layer fan, BLI works because the slower moving boundary layer air near the fuselage is accelerated by the aft fan.

These aft fan needs power to be driven, these are accomplished by adding generators to the turbofan engines on the wings, and hence we can produce electricity to power the rear motor.

One technique that has been the subject of



several investigations is the use of pneumatic blowing outward from the wing tip. The active nature of such a technique offers the advantage that it can be utilized during the phases of fight at which it is best suited. Past efforts of analyzing the effect of blowing in the wing tip region have concentrated on flow visualization and flow field measurements. Some progress has been made toward identifying several aspects of the complex flow mechanisms, but more measurements of the global effects on the lift and drag of the wing are required [1]

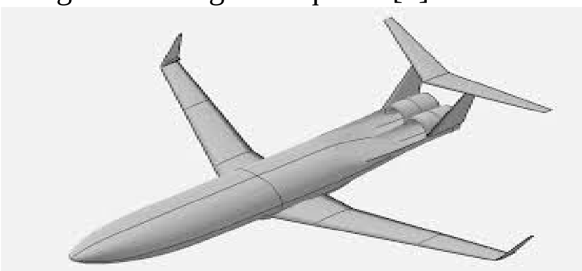


Fig. 1. Aircraft system

II. IMPLEMENTATION

The concept is very simple and the system consists of the parts which are same as of present in the conventional aircraft including an extra part called boundary layer fan which is mounted on the tail of the aircraft. In addition to these the stabilizer which is usually mounted on the rear end of the aircraft is placed on the fin of the aircraft.

The turbofan engine is an air breathing jet engine, usually used in aircraft. It consists of a gas turbine with a propelling nozzle. The gas turbine has an air inlet, a compressor, a combustion chamber, and a turbine (that drives the compressor). The compressed air from the compressor is heated by the fuel in the combustion chamber and then allowed to expand through the turbine. The turbine exhaust is then expanded in the propelling nozzle where it is accelerated to high speed to provide thrust. These turbofans engines which is mounted on the bottom of the wings, pulls the air and accelerates it to produce thrust. As the plane and the engine fly through the air, the air resists-causing drag on the aircrafts.

The STARC-ALB has an innovative boundary layer ingesting (BLI) fan on its tail, which reduces the overall drag and the fuel usage of the aircraft.

The slow moving air near the aircraft fuselage is called the boundary layer. The fan ingests and accelerates the boundary layer air, producing thrust. The slow moving air is sent to the boundary layer fan, BLI works because the slower moving boundary layer air near the fuselage is accelerated by the aft fan.

Fig 2- Slow moving air near the aircraft fuselage

The design mission for both the N3CC and the aircraft which is used in this concepts was 3,500 nm at a fixed-cruise Mach of 0.70 operating at an optimal altitude to maximize specific range. While 3,500 nautical miles was the required design mission range, the configurations were sized to minimize the economic mission (900 nm) block fuel. The takeoff field length requirement was less than 8,190 feet, a distance calculated as the greater of the balanced field length or 115% of the field length to clear a 35 foot obstacle with all engines operating. The propulsion system was required to have sufficient thrust to meet the second segment climb and missed approach gradients in the event of a single engine failure, and have adequate thrust to meet the initial cruise altitude capability (ICAC) requirement, meaning that the vehicle was capable of climbing higher than the optimal starting cruise altitude subject to a 300 foot per minute minimum rate of climb requirement.[2]

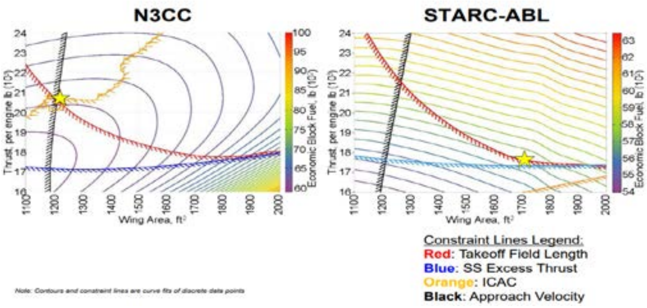


Fig 3- Graph of comparision between N3CC and STARC-ABL

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	N3CC Baseline Turbofans*		STARC-ABL Generator Turbofans*		+ BLI Tailcone Propulsor		= Total Propulsion System	
	TOC	RTO	TOC	RTO	TOC	RTO	TOC	RTO
Thrust**	6800	34 920	4060	22 780	3210	5560	7260	28 350
TSFC	0.441	0.2922					0.3875	0.3032
Thrust/hp	0.64	0.99	0.60	0.86	0.92	1.6	0.72	0.96
OPR	58	51	58	49.6	1.25	1.08		
BPR	11.3	11.9	6.4	6.9			14.4	13.3
Fan PR/%Nc	1.45/ 100%	1.39/ 93.2%	1.45/ 100%	1.49/ 100%	1.25/ 100%	1.08/ 62.1%		
LPT Power (hp)	5960	19 490	4940	14 840				
Fan Power (hp)	5320	17 705	3005	12 900	3500	3500		
Gen/Motor (hp)			3870	3870	3500	3500		

* The thrust and horsepower values for the baseline and generator turbofans are the total of both turbofans.
** The aircraft thrust requirements are TOC Fn = 6800 lb, RTO Fn = 28,340 lb

Fig 4- Table of Readings of different parameters

In order to interface with the propulsion model the power being used by the BLI fan needs to be computed via an volume integral over body-force zone:

$$Pwrflow = \iiint (V\ local \cdot f\ local)\, dv,$$

where V local is the local velocity vector and f local is the local body-force contribution for the infinitesimal fluid volume. Note that Equation computes only the power imparted to the flow by the fan, which does not equal the total shaft power needed to drive the fan. The shaft power and the flow power differ because of the fan adiabatic efficiency, ηfan. Thermodynamically, ηfan causes a slight increase in temperature of the flow, relative to what you would expect for ideal case. The implementation of the body-force zone used in this work assumes an isentropic pressure rise, based on the formulation of Hall et. al. Since the pressure ratio of the fan is so small, the lack of the temperature rise in the flow does not introduce major aerodynamic error. However the effect is significant to the propulsion system, which must ultimately provide the necessary shaft power, so ηfan is accounted for in the propulsion model.[3]

BLI increases propulsive efficiency by ingesting lower velocity flow near the airframe into the propulsors, reenergizing the wake and thereby reducing drag. BLI can be implemented on both conventional tube-and-wing as well as HWB aircraft. The propulsor is mounted such that the slow moving flow near the aircraft is ingested, reenergized, and exhausted where the aircraft wake would have been. Plas et al. provided a review of many fuselage BLI studies; early estimates of aerodynamic efficiencies ranged from no improvements to 16% improvement and further refinement through the years resulted in estimations between 3% and 7%.

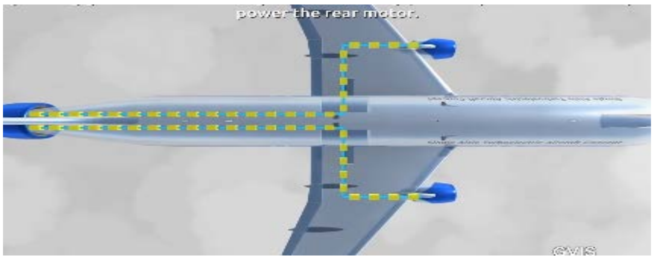
Distributed propulsion is expected to improve both lift and L/D ratio through wing flow circulation control. The propulsors can be distributed above, below, or imbedded in the traditional tube and wing configuration. Likewise, HWB configurations can employ fans distributed across the upper surface or imbedded. Improvements in L/D ratio may result in smaller wing area, and reduced drag and weight. The benefits of lift augmentation can be taken in reduced wing area for a given load capacity or shorter takeoff distances. Reduction in wing area reduces wing weight, lowers drag, and thereby imparts fuel savings.[4]

These aft fan needs power to be driven, these are accomplished by adding generators to the turbofan engines on the wings, and hence we can produce electricity to power the rear motor.

With the addition of rear motors, the wing mounted engine can be made smaller as they don't need to produce as much as thrust. Smaller engines weigh less and produce less drag hence producing less fuel required to drive the aircraft.

The stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The horizontal stabilizer prevents up-and-down, or pitching motion of the aircraft nose.

Fig 5 – generators to drive the aft fan



III. FUTURE SCOPE

A. Regeneration of Gas Turbine

Thermal efficiency of the aircraft can be further improved by the method of regeneration.

The temperature of the exhaust gases from the turbine is usually higher than the temperature of the air leaving the compressor. The heat of the exhaust gases can thus be utilized to heat the air coming out from the compressor counter flow of heat exchanger, also known as heat regenerator or recuperator. This arrangement helps to reduce the heat supplied in the combustion chamber resulting in improving the thermal efficiency of the cycle.

While the aircraft moves in the atmosphere the turbofan pulls the air too it and combustion takes place and leaves the remaining gases back to the atmosphere. These left gases will be at higher temperature these high temperatures can be collected and utilized to heat the air coming from the compressor. On comparing the efficiency of the aircraft with regenerator and without regenerator it was found that using regenerator we get an increase of 70% of efficiency hence using the addition of regenerator the efficiency of the aircraft can further be increased. The figure shown below is the line diagram of a gas turbine with regenerator.

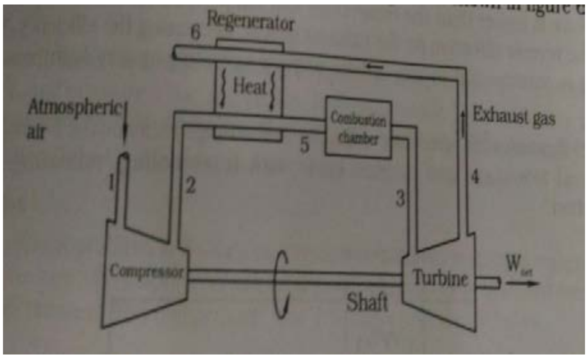


Fig 6- line diagram of gas turbine with regenerator

IV. ADVANTAGE

i. Uses generators motors to run the aft fan instead of electric batteries.
ii. Smaller sized turboelectric engines help in reduction of fuel required.
iii. Lesser drag.
iv. Stabilizers on the fins gives more stability.
v. Better power to weight ratio compared to conventional aircrafts.
vi. Regeneration method provides additional efficiency.
vii. More thrust using less power.
viii. 70% of increase in efficiency by using regenerator.

V. CONCLUSION

In a conventional aircraft, the boundary layer is a cocoon of slow-moving air that clings to and flows along the fuselage. Though this does help to reduce friction, as it flows off the rear of the aircraft, the boundary layer breaks up into turbulence. In this concept, the BLI engine is a giant ducted fan that encircles the stern of the fuselage while the aft control surfaces are moved to a top of the T-shaped empennage. As the boundary layer flows backward, the fan collects it, accelerates the air, and turns it into thrust. To power the fan, the 737-like aircraft has two slightly smaller underwing engines that not only provide thrust, but also about 3 megawatts of electricity for the BLI engine as well as the other flight subsystems. This system provides lesser drag and reduces the amount of fuel required. The BLI provides 20 percent of take-off power and 45 percent of cruising power. Keeping the future scope in concern the addition of regeneration method helps to improve the efficiency of the aircraft by 70%. As the take-off power and the cruising power are comparatively better than the conventional aircrafts hence, it is advisable to go for a Single-aisle Turboelectric Air Craft with an Aft Boundary-Layer concept rather than going for the concepts what is generally used in the conventional aircraft systems.

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